THE CONSERVATION OF ANCIENT MARBLE

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Conservator of Antiquities

The J. Paul Getty Museum

PREFACE

Beginning with this treatise on the conservation of ancient marble, the J. Paul Getty Museum is pleased to initiate a series of publications dealing with the care of fine artworks. Subsequent volumes will discuss the problems and treatment of other materials, such as bronze, wood, plaster, and terra-cotta.

This publication deals with the conservation of artworks made of marble. A definition of the material will be followed by descriptions of common problems and their treatment, beginning with those which occur above the surface of the stone and proceeding inward. The last section will be concerned with elements of treatment, such as disassembly, reconstruction, and the final appearance of the sculpture.

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THE MATERIAL

Cherished by countless civilizations throughout history for its beauty and sculptural qualities, marble is actually a product of seashells and other calcium-bearing minerals deposited in limestone during prehistoric changes in the earth's crust and metamorphosized by tremendous heat and pressure. The main component of marble is calcite, or calcium carbonate, joined with other constituents such as dolomite, or magnesium calcium carbonate, and argonite. Marble also contains many of the so-called "earth" elements—such as sodium, potassium, barium, and aluminum—as well as many of the "metallic" elements—such as iron, copper, manganese, and chromium, which cause the tremendous variations of colors and sedimentary patterns so often seen in Roman sculptures and buildings. With the development of new techniques, such as neutron activation, elements of a rarer sort are now being found as well and may become an important internal standard in the identification of the original quarries. Marble can be found in wide veins stretching through the mountain ranges of almost every continent. We are concerned mainly with the marble sources near the Mediterranean. Well-known areas in Greece such as Mount Pentelicus, Mount Paros, the island of Naxos, and Mount Hemetian were important sources of marble for the classical world and were mined by both Greeks and Romans. The major quarry on the Italian peninsula was and still is Carrara; renowned marbles found there are composed of dolomite or calcite mixed with magnesium calcium carbonite.

Alabaster, which is actually calcium sulphate, is often confused with marble. However, it has a hardness of 2 on the diamond scale—a system of measurement which uses ten minerals as constants, with diamond, at 10, the hardest—while calcite and dolomite, the components of true marble, have hardnesses of 3 and 4, respectively, resulting in greater resistance to wear. Alabaster is more susceptible than marble to damage from water. For all intents and purposes, marble is insoluble in pure water; however, the smallest trace of carbon dioxide in the water will cause rapid degeneration of the surface. Other gases such as sulphate—greatly increased in the atmosphere by pollution—and atomic sulphur will cause alteration of the calcite into calcium sulphate, a substance which, bearing a different expansion coefficient than the marble surface, will easily crumble away. Chlorides, either carried by the air or wicked from the ground by capillary action, also interact with the calcite and are carried to the surface of the stone, appearing as an efflorescence of crystals. Thus, while it appears to be an exceptionally strong material, marble is not impervious to damage by burial, atmospheric attack, and incompetent restoration. The ramifications of its susceptibility become complex with regard to works of art.

SURFACE CLEANING OF MARBLE

Most people do not realize that marble is chemically reactive and fairly porous, conditions that allow alteration of its character by surface contaminants. The types of stains possible fall into several groups: dirt and grit, oils, inherent discoloration from oxidized metallic ions, and external contact with metals or glues and other adhesives. Usually, stains are a combination of these factors.

Dirt and grime may adhere merely by electro-static force due to their finely divided state, or become caught in tiny cracks and crevices. They can also be attracted by binding media such as oil and wax which can come from the atmosphere or be applied by repeated handling, a situation which coalesces the dirt into a kind of paint. Often the stains become mixed with other materials which are transported to the surface by fluids traveling through the marble by capillarity and effloresced by evaporation. It has been discovered that the condition known as patination is always accomplished in the presence of this finely divided material existing in a layered structure.[1]

Oils present a special problem because they tend to "crosslink" or polymerize—turning darker and becoming more difficult to remove, until only an extremely strong base like sodium hydroxide can effectively hydrolyse them. Very polar organic solvents such as acetone or even methylene chloride will often remove the major portion of oils, especially when used in combination with a poltice, the nature of which will be discussed later.

Metallic stains can sometimes take a period of years to emerge because of existing veins of siderite, a grey iron carbonite which gradually turns brown or orange as it slowly changes to ferric oxide or hydroxide.[2] More often, iron stains are caused by the inclusion of iron pins, rods, and clips placed in the statue for support by past restorers any time from antiquity to the present day. These stains can be reduced by a number of chemical procedures, such as the use of citric or oxalic acid or the application of E.D.T.A. (ethylene-diamidetetracetic acid dibasic). Stambolov, in his article "Notes on the Removal of Iron Stains from Calcareous Stone," describes all of the various methods.[3] Of course, much of the effectiveness of these methods depends on the age of the stains.

A major cause of stains are adhesives, especially shellac—a sticky orange material prepared from the lac insect and composed of dihydroxyfico-cerylic acid, some waxes, and coloring, with a melting point of 77 to 82 degrees centigrade.[4] Its staining character and acidity are the primary concerns for the conservator. Since the end of World War II, many acrylic and plastic glues have been developed which are more powerful than shellac. Of these, P.V.A.—or polyvinyl acetate—is especially problematic; not only is it readily available, but it is such a strong adhesive that it tends to be harder than most of the substances on which it is applied. When a substance like P.V.A. gets into the pores of a material such as marble, it tends to shrink or otherwise act as a substance of different density than the body of the artwork. In turn, differential shrinkage causes cleavage, often pulling away portions of the original material and making eventual registration even more difficult. Removing all remnants of this adhesive is a time-consuming ordeal: although the glue is soluble in boiling alcohol, large amounts remain deeply buried in the stone and necessitate the use of a microscope. Cements and grouts of various kinds can leave a grey cast on or in the stone because they can chemically interact with the material and penetrate its structure; in most cases, they are also harder than the marble.

A thorough cleaning of the surface should precede the application of any adhesive. Before discussing the actual cleaning procedure, it is best to point out several precautions. Often sculpture has remnants of pigment present on its surface

Marble cupids in the process of being cleaned

which act as a valuable record of the work's original appearance. Careful examination of the sculpture by ultraviolet, infrared, and day light and the use of optical devices such as a dissecting microscope can indicate the areas of pigment, fills, breaks, and calcarious deposits such as root marks. If pigments are detected, a system of thixotopic paste can be used.[5] As important as it is to preserve pigments which are on the sculpture, care should be given at the same time to the structural integrity of the piece, since unjudicious cleaning can cause it to come apart, damaging the artwork and possibly the conservator as well. Most structural fills are either soluble in water or will otherwise separate from the surface on which they were placed. Often these fills or adhesives are the only things which still hold a piece together. Inventory numbers, signatures, or other marks which give historical information about the provenance of an artwork are often overlooked on the bottom or underside of a statue. Such information should be protected and recorded before cleaning, and a photograph should always be taken to document the condition before beginning treatment.

During the cleaning process, several general principles should be followed:

1. The entire surface of the sculpture should always be treated uniformly by each step of the procedure.
2. Before beginning the actual cleaning process, sculptures should be thoroughly dusted so that surface details can be seen during examination and so that loosely adhered particles will not be washed into the surface.
3. Because marble is a porous substance, cleaning can proceed more easily if the statue is prepared by gently heating its surface with warm, then progressively hotter, water. Any wetting of the stone should of course be done evenly.
4. The order of application of solvents, soaps, and reagents should always proceed from the weakest to the strongest.
5. Chipping, flaking, or sugary marble can alter the cleaning sequence; often these areas must be protected, infused, or can only be treated with organic solvents.
6. Often, combinations of aqueous and organic reagents used successively will loosen stains which either, when used alone, will not.
7. Poltices can be an especially good way to ensure that stains are carried above the surface of the stone and are not washed into its surface. They also act to keep rapid-evaporating solvents in place, so that they can be used to maximum effectiveness.
8. The application of wet heat via the use of steam can enhance the chemical action of various steps of the cleaning process.
9. The reagents should always be thoroughly rinsed away and the pH of the surface measured to check its acidity or alkalinity.
10. Mechanical devices should be non-abrasive to the surface of the marble and should be small enough to get into tiny crevices and between design elements.
11. Brushing motions should follow cracks and design features; pressure should be applied toward the surface to remove grime from pitted areas.
12. Surface cleaning should be done from several angles as one can easily miss dirt which is not seen from the bottom or side. Cleaning should always be done in good light.
13. To determine the best cleaning pattern, use the design elements as an index. Move from bottom to top so that any dripping will not leave streaks.

14 The drying process should be such that solvents do not remain in pools, thereby concentrating their effects .too selectively.

During actual cleaning, the use of detergents should proceed from the non-ionized to the harsher types. Orvis paste by Procter & Gamble is an excellent starting point, after which Orvis paste mixed with a few drops of ammonia could be used. The medical-surgical soap Haemosol is very good for the removal of dried blood and other protein-like materials. If only organic solvents can be used, Igypal is an excellent agent. It was developed for use in ultrasonic cleaners which employ the fluorocarbons as a cleaning medium. The use of detergents for cleaning textiles is discussed by Judith Hofenk-De Graff,[6] but many of its basic premises also apply to the cleaning of stone. After applying cleaning agents, one should allow sufficient time for the solvents to act. The procedure should be repeated until the rinse water is clear. Cleaning can often be impeded by the presence of wax that was added to the sculpture as a fill or as a protective coating. Wax is easily removed by the use of naphtha or petroleum ether.

Oils and discolored biological products can often be removed with xylenes, while more difficult stains may require the use of acetone, alcohol, or the chlorinated hydrocarbons such as methylene chloride. Because it is extremely dangerous if inhaled over a period of time, the use of methylene chloride should be restricted to a well ventilated area. Sparks and any open flame are of course to be avoided, as fire hazards.

The Vermont Marble Company produces several excellent cleaning products, organic solvent systems, and rust removers, but these should only be used after experimentation and should always be carefully watched because harsh chemicals may etch a marble surface. The author has found the Purple Cleaner to be especially good as it contains an internal indication system allowing the acid and basic phases to be easily seen.

There are classes of stains which do not easily respond to any of the above treatments, and the use of chemicals such as sodium hypochlorocite—or its special form, Chloramin T, used by paper conservators—becomes the treatment of choice. This material can be applied by brush or held in place with a poltice. Hydrogen peroxide 3%, in water activated with a drop of ammonia, can be an effective agent for bleaching out certain classes of stains.

Cleaning can be one of the most important aspects of good conservation of marble. At the end of a discussion of cleaning methods, it should be stated that stains are often deliberately applied by unscrupulous dealers to the surfaces of sculpture in order to hide fills, damages, and the addition of new pieces or details which would increase the price of the work. Often, the reason for adding stains is to make the stone appear older than it is. To determine if such a procedure has been performed, the sculpture should be examined under an ultraviolet light of short wave length, or a sample of the surface should be taken and a cross section performed. The sample should first be cleaned in a Soxlet extractor—a device which allows a solvent of low boiling point to wash continuously over it, carrying the stain into a trap in the bottom of the device. The stone can then be judged to be old or new.

ACCRETIONS ON STONE

Most marble statuary that has been buried has on its surface a collection of sand, dirt, and various stains, all adhered by calcarious cementum. The calcarious deposits are either precipitated from ground waters or occur when calcium salts are washed out of the body of the marble. Often the calcium accretions absorb various iron salts which, when they precipitate out from the ground onto the surface of the sculpture, become almost as hard as the body of the marble itself. Unfortunately, silicates often accompany the calcium salts to further harden the mixture.

The removal of these deposits is always a difficult matter, because they are intimately bound to the statue and are of a nature similar to the material from which they are to be cleaned. In the case of loosely adhered accretions, rinsing with distilled water will often remove soluble components and free the crust with a minimum of mechanical teasing. Tightly packed or well-crystallized calcium carbonite—which could be the product of both exterior and interior deposits—may have to be removed in a slow mechanical way under magnification

The laser being used as a cleaning device

and with a scalpel, brass brush, or tiny pick. Mineral acids, carefully applied to selected areas after the stone has been prepared by the application of mild bases, ensure a minimum of risk. Areas treated in this way should be neutralized periodically during treatment and thoroughly rinsed afterward so that the products of the treatment will not appear on the surface as an efflorescence of tiny crystals. It is wise to check the surface being treated with mineral acids from time to time with pH paper to keep the process under control. This step is especially important after the entire job has been completed.

The air abrasive system is a new and efficient way to remove accretions. The device can be carefully controlled by using combinations of air pressure settings and abrasives which are available commercially and include sodium bicarbonate, dolomite, crushed glass, glass beads, aluminum oxide, and carborundum. The effect of the abrasive is diminished rapidly by removal of the nozzle from the surface being treated, and the aperture of the nozzle is only about one-half millimeter in diameter. Bethune Gibson describes its use in her article, "The Use of the Air-Abrasive Process for Cleaning Ethnological Materials."[7] Accurate cleaning with the air abrasive unit can be done under a microscope in a dust-free chamber.

Air abrasive methods seem to remove only surface accretions when properly employed, but there are a growing number of conservators who argue that a great amount of the surface characteristics of the sculpture is altered as well. The latest advance to come from the laboratory is the use of the laser as a cleaning device. The laser can be used in bursts of from 10^{-3} to 10^{-10} seconds, a time period so short and intense that it seems to vaporize only substances which are vastly different in color from the material being cleaned. A report by Asmus, Seracini, and Zetler titled *Surface Morphology of Laser-cleaned Stone*[8] gives the physics involved and provides scanning electron micrographs of cleaned stone. Another device now being used for deposits which are nearly the same color as the stone is the flash lamp, which uses powerful florescent bulbs in combination.

SURFACE PATINATION OR ALTERATION

The surface of any object can have what conservators call either a vile or a noble patina. The term "patina" refers to an alteration of the basic material of which the artwork is constructed. Marble is altered by several mechanisms involving conversion of calcite to other products. Water can carry chlorides to the surface and then evaporate, leaving them to effloresce and bloom just under the surface. When combined with the effects of other patination, this phenomenom can cause tons of pressure which will strip the surface to several millimeters deep from any stone. Calcium and magnesium carbonate can be converted to their sulphates by the action of rainwater and dissolved gases. Although prevalent in statuary from rural locations, this condition is particularly dangerous in the city, where by-products of burning hydrocarbons are

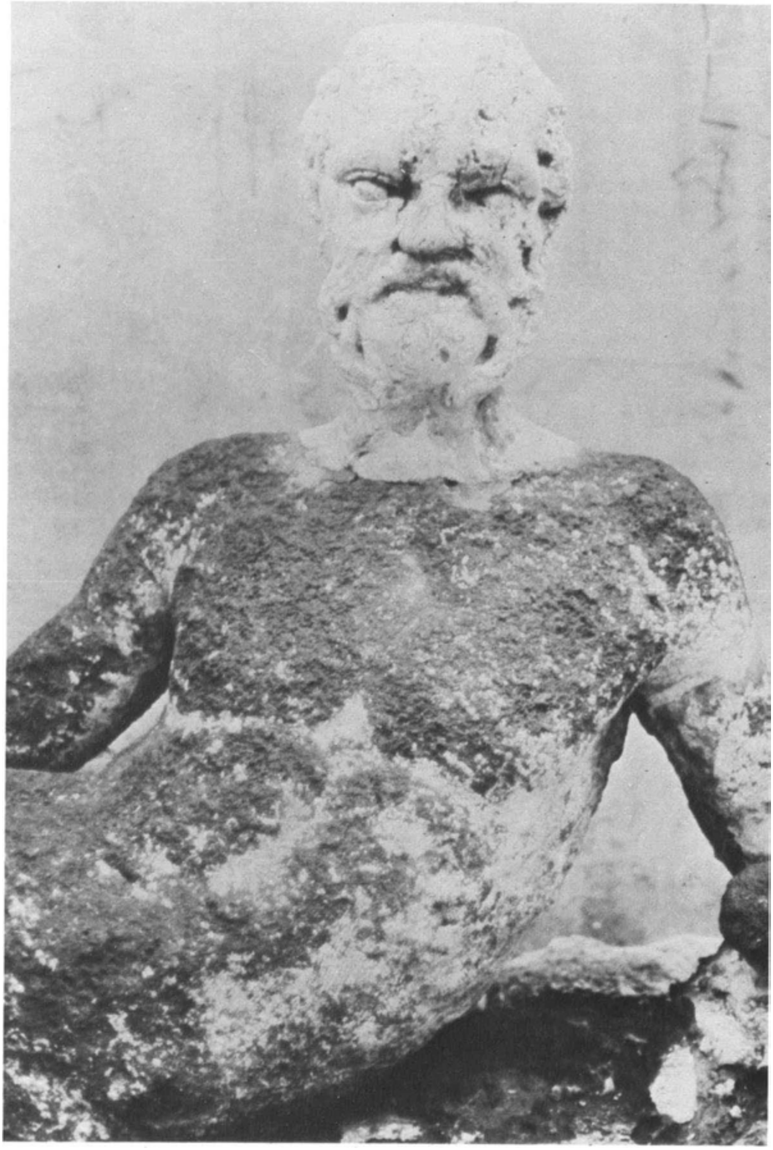
An example of sulfation and the result after cleaning

many times more destructive (Winkler 1970).[9] It is interesting that conversion of the calcite seems to occur only after soot and other particles have formed a layer on the surface of the stone.[10] Soot and the free sulphur interact to convert the carbonates into a dark brown to black layer on the surface of calcium bearing stone, a process called sulfation. Where water constantly rinses over the surfaces of buildings, this phenomenom will not occur. The dark skin interacts with the converted calcium sulphate to form thick eruptions which destroy sculptural detail on the surfaces attacked. A more subtle but equally dangerous effect occurs with sculpture kept indoors where there is no air conditioning or filtration. After repeated expansions and contractions due to temperature fluctuations, the difference in density between the altered outer layer and the body material of a sculpture causes them to cleave and separate.

Removing such a layer from a sculpture is a difficult problem because in doing so one must ultimately lose some of the surface as well. Applications of distilled water will remove small amounts of the black crust, but the author has found the use of an air abrasive device with glass beads to be the most efficient and easily controlled technique. Laser cleaning is currently being done with great success by Dr. Asmus in Venice. Dr. Lazzarini and his colleagues at the San Gregoria lab in Venice have successfully impregnated several pieces of stone against the effect of sulphur, but the technique remains impractical as yet for larger architectural projects. The removal of sulfation is of vast importance to the appearance and future preservation of a sculpture.

A problem often encountered by conservator when treating sculpture which has been kept outdoors for long periods of time is the attack of the porous stone by biological organisms such as fungi, lichens, and bacteria. Fungi of the calcicolous types prefer carbonate rocks, while the silcolous variety affects only igneous rocks. Of the organisms, lichens seem to do the greatest damage, because they apparently live between and within the actual crystals of the rock. This affects not only the appearance of the sculpture, but its structure as well. Both fungi and lichens seem to attack stone which either has been covered with plaster or was converted to calcium sulphate by exposure to atmospheric sulphates.[11]

An outdoor sculpture which had been partially covered by plants over a period of time



The effect of attack by biological organisms (the head had been removed and cleaned during the Renaissance)

Damage resulting from burial in sea water

Biological organisms will decompose stone when two sets of circumstances are present: retention of water on the surface, and a complex physical chemical reaction. In the former situation, these organisms—because of their very mass and the fact that they finely etch the marble—increase the amount of surface area, thereby multiplying its capacity for contact with water. In addition, the organisms themselves retain water in their bodies. The latter phenomenom takes two separate forms. Firstly, an ion exchange will occur when hydrogen atoms released by rhizomes—root-like projections on various species of lichen—are exchanged for metallic ions which are used as nutrients for the organisms in the stone. Certain forms of lichen and fungus, such as aspergillim niger and spicaria, release oxalic and citric acid during their metabolism in exchange for aluminum, magnesium, and silicon dioxide.[12] The use of 3% to 5% solutions of silico organiciqueries—such as methsiliconate of sodium, sodium ethsiliconate, and aluminum methi-siliconate—are a good way to stop microflora and the growth of higher plants.[13] Bacteria seem unable to survive on cleaned surfaces, but, once they get a foothold, their growth is exponential. Marble which has been buried in the sea has also been known to be attacked by various mussels and worms of the polychete family.

SURFACE WEATHERING AND GENERAL DECOMPOSITION

When water is allowed to penetrate stone because of either burial or constant inundation by rain, one can expect the transport of various ions to the surface. When deposits have collected on the surface, they are carried away by further washings, thereby weakening the structural constitution of the entire mass. Chlorides carried by the wind are another major cause of instability, and changes in temperature will accelerate stone decomposition. Cold air allows a greater accumulation of carbon dioxide from water, while heat speeds up chemical reactions. Rainwater also promotes the alteration of carbonates to sulphates, and this condition, added to the pressure created by chlorides pushing outward, causes widespread damage. Marble in this state is often "sugary" to the touch and simply falls away of its own accord.

The light area shows erosion from internal weakness caused by water (the pile of marble dust by the foot has fallen away from the statue).

Fractures caused by the inclusion of iron pins

The two photographs on the cover are graphic examples of the effect of capillarity. The church of Santa Maria dei Miracoli in Venice has a partial foundation: half of the building rests on stone and wood pilings, and the remainder stands in water. The two roundels illustrated are details of door frames on opposite sides of the church. While the door from the side built on the foundation is in relatively good condition, the one from the unprotected side shows marked erosion and internal destruction. The design elements on the surface have been lost, cleaved from the stone as a result of water drawn upward into the marble by capillary action over the past four centuries.

Iron pins used to strengthen joints are actually a source of countless fractures. The iron discolors, permeates the structure of the intercrystalline matrix, weakens it, and, upon oxidation, expands to act as a wedge splitting the stone.

Before a strengthening agent is added during treatment, marble which has suffered loss of its structural integrity must be cleared of contaminating salts. Chlorides, in particular, are very reactive and may actually stop polymerization of the added resin. The salts can usually be removed by immersing the object in distilled water or otherwise inundating the surface thoroughly. The pores of the marble must be opened to allow complete entry of the strengthening agent.

Some researchers have experimented with various plastics such as silicone esters which, upon polymerization into silica gel, act as a good consolidant.[14] The difficulty in using this system is in getting the agents which cause the reaction into proximity of the silica. This reaction requires either strong acids—like phosphoric, nitric, or sulphuric—or any of the comparably strong bases. It has been discovered that triethanolamine can also be effective.[15] Other silicones such as methyl-trieth-oxysilane have been tried, but they apparently will not penetrate nor form good coatings.

Epoxy resins have been suggested as possible alternatives, but they, like the pure silicones, are difficult to get into the stone. Monomers, being of much smaller size, would seem to be a logical choice and could be taken into the stone by using large quantities of solvent until the solute reached 15% by weight. It was thought that putting the entire sculpture into a vapor of the solvent would ultimately drive the plastic to its limit. Unfortunately, it has been discovered that monomers often make marble more susceptible to sulphate attack.[16] The most virulent attack on the stone occurs when the plastic contains many aliphatic groups. Gauri reports that partial success in using polyacrylics and polyurethanes as coating agents has been documented.

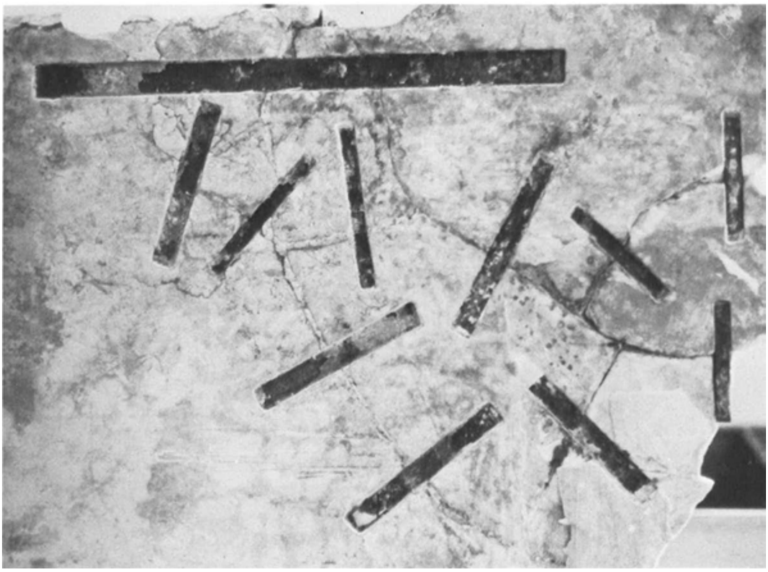
A traditional agent for strengthening stone is barium hydroxide. Again, there is some difficulty with getting the treatment into the area where it will be effective. It has been discovered that the addition of urea causes the formation of barium carbonate crystals which seem to bind the calcite remaining in the strong part of the stone. Excellent examples of this process and the documentation of the penetration achieved are shown in the article "Rational of the Barium Hydroxide-Urea Treatment of Decayed Stone."[17]

The treatment outlined above has two major drawbacks: it is not easy to get the materials for the treatment into the right place, and, once they are there, it is difficult to coax them into reacting properly. In the long run, it is hard to know whether it is beneficial to close the pores in marble, thereby setting up a different layer near the surface which may react adversely with expansion and contraction.

DISASSEMBLY OF MARBLE SCULPTURE

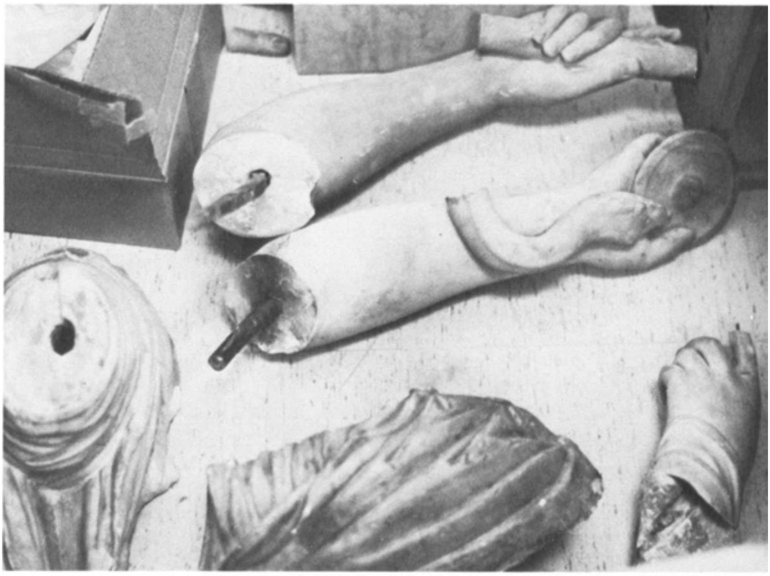
One of the major tasks of the objects conservator is the disassembly of sculpture of all types and sizes. The majority of past restorations was done using shellac and iron pins, and most of the shellac repairs are hidden by fill material and paint of some sort. After it has been cleaned, a piece should be examined using the various techniques described earlier in order to ensure a proper approach to the work. At this point, mention should be made of laser inferometry, a new mode of x ray-like information which is becoming a standard tool. This practice relies on the difference between two holograms of an object—one made after it has been quickly heated and the second made after it has been allowed to cool for less than a second. The resulting image, when the two holograms are superimposed, has the form of the object but is covered by a moiré pattern. The tiny wave-like perturbations that can be seen in the image are indications of structural discontinuity or weak spots.

Once the material hiding an old mend is removed, attention can be given to dissolving the adhesive. Shellac is soluble in acetone or alcohol, and a tiny sample of the adhesive should be tested to find the best solvent for it. Most plastics will dissolve in acetone, while epoxies are usually soluble in chlorinated hydrocarbons. Polyvinyl acetate emulsion will swell in repeated soakings of water and alcohol, making it easier to remove. Gentle tapping will often facilitate the loosening of a joint, and patience will allow the pieces to be separated without damage to the delicate edges of the mend. It is particularly important to proceed slowly when one suspects the inclusion of pins, as they are often placed in the joint at divergent angles.



Iron clips used in an old restoration

There is an advantage to being familiar with the way in which shellac was applied in the past to broken stone. The orange resin was heated to about 80 degrees centigrade and smeared over the surfaces while hot. The two broken faces were then placed together and allowed to harden. Once a separation has been made of an old repair, the excess shellac can be removed by dissolving it in alcohol or by applying gentle heat and brushing away the bulk of the glue. Pins and clips can be freed by lightly heating the metal until the resin can be seen to melt and then simply pulling them away. Some pins have been added as press fits; that is, they were wedged into the marble. If corrosion has taken place, they will have to be drilled or ground out with as little damage to the marble as possible. Iron clips shaped like giant staples have been used since ancient times to make joints of a mechanical sort. The worst aspect of their removal is the fact that often the clips have been leaded in place as well. The removal of the lead is an arduous task which can be accomplished either by drilling the soft metal out or by carefully controlled heating until the lead melts. It is difficult to accomplish the latter method without doing some damage to the stone, the degree of heat being hard

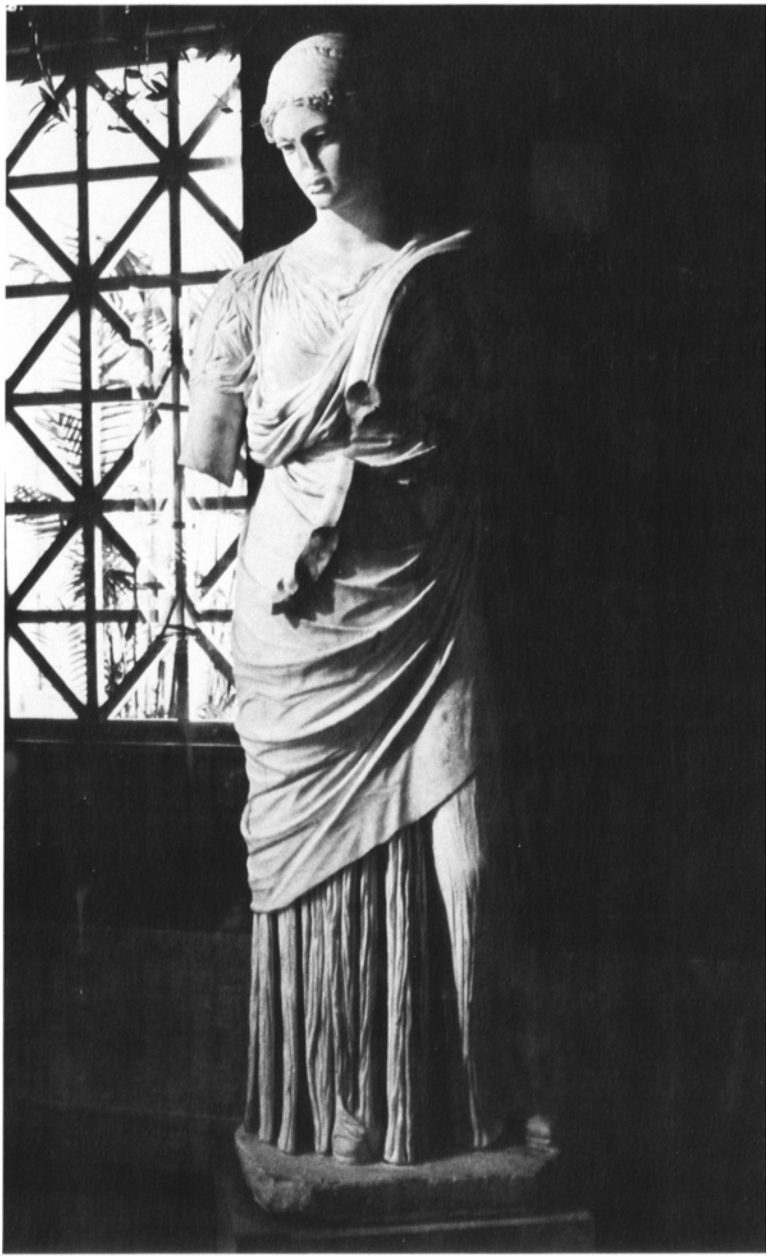


Modern additions removed from a statue and stored

to control. Once the cement or lead has been removed, the clip can be drilled or sawed in half and wedged out. If iron stains remain, they can be reduced by the use of sequestering agents which anchor the metallic oxide so that its detrimental effects cannot spread. Any pieces which are later restorations or additions should be labelled and stored after they are separated from the statue. In many cases, they are the only record of the artistic taste of a past era, or they themselves may have been done by a well-known sculptor.

It should always be the policy of the conservator to work closely with the curator during all stages of treatment. By doing so, the extent and order of the process can be decided. Also, valuable information can be gained should a detail long hidden under a past restoration be uncovered. Often, the method of fabrication can be determined or a clue to the provenance found. It was the practice in previous centuries to desire that artworks be "complete" above other considerations, while modern conservation will at all times respect the integrity of the work and the intention of the artist.

Hope Hygeia, from the J. Paul Getty Museum collection, before treatment



Hope Hygeia after conservation, with modern restorations removed

Venus Mazarin, with later restorations deliberately retained

There are a few instances when later restorations are deliberately left because they indicate the taste of the particular period in a highly unique and informative way. Such was the case with the Venus Mazarin in the J. Paul Getty Museum collection. It has also become an acceptable technique to leave unjoined pieces of a statue separate, especially when the original design of the connecting marble is uncertain.

RECONSTRUCTION OF FRAGMENTS

Marble owes its special translucence to several factors: the purity of the calcite of which it is made, the size and shape of the crystals, and the inclusions which provide nuances of color. In the past, conservators and curators tried to categorize fragments by appearance. While the trained eye can be very successful at this exercise, new methods of analysis are far more exact. X-ray florescence can be used when the taking of a sample is not possible. Neutron activation, which requires several samples in a grid pattern, is a great deal more accurate. The latter is able to detect the vein structure not visible to the eye so that correspondences can be made.

In the reconstruction of stone, epoxy resins have taken the place of shellac. The new epoxies in combination with non-oxidizing pins form a tough solid joint which remains, however, reversable. The author uses brass when metal is to be included in a reconstruction because it is not susceptible to oxidation, especially when coated; at the same time, it is soft enough to be fashioned into useful shapes or drilled and tapped for the application of various threaded devices. Many conservators are turning to stainless steel when greater strength is required or the color is important for the appearance.

A basic premise in any reconstruction is the idea that every fragment, no matter how small, should be repositioned correctly. The importance of careful examination and prefitting cannot be over-emphasized. It is a great waste of time to discover at the end of a long gluing session that you have failed to include a chip or that the fit is improper. Often, pieces have been merely carved to fit into place by irresponsible restorers or amateurs who have simply not taken the time to properly register the fragments. With this in mind, it is often necessary to space or shim pieces so that the final construction will look correct. It may be necessary to split the difference between two joints where there is a large space with no original stone to guide the reconstruction. One can of course research the particular type from which the statue derives, and use the information as a model.

When it comes time for the application of adhesive, this should be done with great care so that none of the glue gets on the outside surface. Adequate amounts of adhesive must be used to ensure a strong mend, and both faces which are being joined should be covered; otherwise, surface tension may keep the glue from sticking to one half. Whenever possible, a mend should be done under pressure applied at right angles to the join and both sections held firmly in place as the adhesive hardens. When deciding the placement of a supporting pin, one should consider placing the pin in sound, or healthy, stone whenever possible and burying it in the thickest part of the statue accessible. Also, enough surface area must remain for the adhesive to be successful.

FILLING AND IN-PAINTING

The majority of reconstructions will require some type of fill. Broken edges, in particular, are susceptible to chipping. Fills are made of several materials, such as wax, plaster, spackling compound, and marble dust with a binding medium. When any volume is being considered, the author prefers plaster because it does not shrink as much as gesso, it is white—a good base from which to begin in-painting, and it is easily removed. If greater structural strength is required, a dental product such as hydrocal can be used. However, hydrocal also has several important drawbacks as a fill material. Its setting time is rather long, but once it begins to set, it does so too rapidly and does not allow much carving to be done before becoming rock hard. In addition, it is yellow-orange in color. The final smoothing of a fill is usually done with a product such as D.A.P. spackling compound which is translucent white, remains soluble with water for long periods of time, and can be easily worked. It often becomes necessary to imitate textures that are adjacent to the area of fill, or, in some cases, to deliberately leave a fill low. These decisions should be arrived at through consultation with the curator and are usually determined by the lighting conditions under which the piece will be seen.

A comment should be made about the use of wax and crushed marble dust as fill material. At one time, the former was used because it successfully imitated the translucent quality of marble. However, it is quite acidic and turns brown and crumbly with age. Marble dust fills, on the other hand, can be very successful when structural support is not required. Properly crushed marble can, in the proper matrix, give the same texture and some of the translucency of the original surface.

Coloring the fill is an important consideration. Unless it is done, the dull, overly-white, opaque qualities of plaster and spackle become distracting from the general design of the sculpture. Color could be added to the plaster before it is used for fill, but the color will change as the fill dries, and the result will be structurally weaker than untinted plaster. Before in-painting, the fill should be infused with a very dilute solution of varnish, such as P.V.A., in mixed solvents so that the paint can be easily removed if necessary at a later date without disturbing the water soluble spackle.

Each area can be in-painted separately, or a color can be selected that will blend with the various hues on the statue. The in-painted area should remain a shade lighter than its surroundings and the general hue should be maintained. If the restored area is to "disappear," surface streaks, mottling, and discolorations on the statue should be simulated so that the area appears continuous to the viewer at a distance. Some conservators use watercolors, which are then covered with an appropriate varnish. The author prefers Liquitex polyvinyl acrylic paints because they are waterproof but remain soluble in toluene for long periods of time.

ENHANCING OF SURFACES

There is a great distinction between enhancing the surface of a statue for aesthetic or preservative reasons and for unethical or dishonest purposes. For instance, after conservation work is completed, waxes and varnishes should be added to areas where pigment might be lost or damage occur from handling

An ultraviolet photograph of a relief. The light areas show normal patination of the original surface; the dark portions were recut or re-polished by past restorers. (The fragments at the bottom are modern additions.)

by the public. On the other hand, the undamaged original surface of a sculpture should never be covered with either fill or in-painting, a practice called "looting." By covering the entire surface of a statue with a coating of color, unscrupulous persons will attempt either to make the overall color appear more even or to hide mends. On occasion, pigments will be added to simulate design elements, flecks of gold leaf applied, or even dirt sprinkled in cracks and design elements to heighten their effect.

As a conservator, the author is generally against the repolishing of a surface. However, he will condone the reduction of a scratch done in excavation if it so mars the piece that the eye is distracted from the general design. Such a decision is always difficult and should be made by the conservator and the curator together.

MOUNTING THE SCULPTURE

Mounting is an important factor in the final appearance of a sculpture, its structural safety, and its security. The center of gravity should always be well within the confines of the base on which the sculpture stands. Mounts should never be placed in design areas and should be used as sparingly as possible within the limits of safety. Dissimilar metals should never be used together, as one tends to corrode the other in the presence of moisture. Often, it is necessary to use soft plastic protective devices over metal supports. Mountings must be painted a neutral color if they are to be unobtrusive to the spectator.

The unique and beautiful qualities of marble have been highly prized since the beginning of civilization. We are fortunate to be able to enjoy today the creations of numerous sculptors of the past. With proper conservation and care, these works of art will continue to inform and delight the generations that succeed us.

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