Appendix P: Curatorial Care of Ceramic, Glass, and Stone Objects

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APPENDIX P: CURATORIAL CARE OF CERAMIC, GLASS, AND STONE OBJECTS

A. Overview

This chapter is an overview of three common materials found in many museums:

- ***ceramics***
- ***glass***
- ***stone***

These are all hard, yet brittle and fragile materials that have been used since ancient times. Objects made of ceramic, glass, or stone can be both decorative and practical. They can be as tiny as a bead or as large as an outdoor sculpture, but all these objects share some basic properties in common. To properly care for the ceramic, glass, and stone objects in your collection you need to understand their properties and how they can deteriorate. This appendix will address:

- how ceramic, glass, and stone objects are made
- common deterioration problems
- preventive conservation in caring for these objects
- storage
- basic treatment issues
- specialized procedures for packing and shipping
- basic procedures to limit damage after a disaster

For information on the particular needs of glass plate negatives and transparencies see *Conserve O Gram* 14/5, Caring for Photographs: Special Formats.

B. The Nature of Ceramic Objects

1. *How are ceramic objects made?*

Ceramic objects are made up of a mixture of natural materials that are combined, formed into shape by a variety of processes, and transformed by heat to create a solid, brittle substance not found in nature. Different firing temperatures produce objects with a vast range of hardness and porosity.

Most clay objects are a mixture of materials:

- Clay is a fine-grained mineral--the smallest particles produced by the weathering of certain rocks. Because of the shape and size of the small plate-like clay crystals, bulk clay is plastic when mixed with water. When heated to a high temperature it chemically and physically changes to a hard, brittle material.

- Adding fluxes such as soda, mica, potash, magnesia, or lime lowers the firing temperature of clay. These fluxes may also be found in natural clay deposits.

- Non-plastic additives (temper) are added to clay to reduce shrinkage and cracking during firing and drying. Temper also increases porosity in the finished object.

These basic materials are mixed together by the potter to produce a heterogeneous plastic mass that is then formed into the ceramic object.

2. *How are ceramics fired?*

A kiln is used to fire ceramics to change the physical and chemical structure and fuse it into a rock-like material. Kilns can vary from simple piles of fuel to complex multi-storied structures. However, all kilns work using the same basic principle. Each kiln is designed to:

- house the objects

- control the amount and duration of oxygen and heat

- hold the level of heat surrounding the object

The process of drying and firing is a series of controlled steps. After the object is formed it must be slowly air-dried. Much of the water (up to 25% of prepared clay) evaporates as the object dries. If the air-drying process is not done carefully, you may see shrinkage cracks in the object. After a day or two of drying objects to a "leather-hard" state, ceramics will maintain their shape, but the surface can still be easily worked. Often the potter will do final finishing, smoothing, polishing, and painting at this point. By the time air-drying has finished, most of the free water between the clay particles has evaporated.

Objects may undergo a single firing or multiple firings. Many archeological ceramics are fired a single time at temperatures ranging from 800-1400ºC. Potters may apply glazes to an air-dried object so that glaze and body vitrify together in a single firing. This process is known as "through firing." However, most glazed objects undergo multiple firings. First, the potter does a "bisque" firing by heating the object to about 600ºC to strengthen the object. The glaze is then applied to the cooled bisqueware. It is then returned to the kiln and fired again, this time to a higher temperature (above 800ºC) so that vitrification of the glaze and ceramic occur.

If overglaze decoration, gilding, decals, or enamels are used to decorate the surface, an additional low-temperature (600-900ºC) firing may take place.

3. *What does firing do?*

After clay objects are formed, they are heated to high temperatures or "fired." This action causes chemical changes to the clay. After firing, objects take on hard, brittle characteristics and don't lose these properties when wet. Different processes occur at different temperatures in the firing process. The firing process proceeds through a number of steps:

(1) Added vegetal matter burns off (200-600°C).

(2) Clay decomposition begins as water is lost from the structure (400-700°C).

(3) Carbon and sulfur are burned out (700-900°C).

(4) Sintering occurs as the heat is raised and particles in the ceramic object begin to join together at points of contact. Sintering gives cohesive strength to low-fired ceramics.

(5) Vitrification takes place at higher temperatures (depending on the mixture of clay and fluxes). During vitrification, melted particles flow together and the object as a whole will shrink. Vitrified ceramics are non-porous; not all ceramics are completely vitrified.

Ceramics are loosely divided into four groups. These groups are based on their firing temperature, clay type, and physical characteristics:

- ***Adobe or mudbrick*** is an unfired clay mixture. This material is often used for building, but mudbrick objects, such as cuneiform tablets and sculpture, are often found in museum collections.

- ***Earthenware*** is a low-fired clay mixture. These objects are fired between about 950-1100ºC. At this low temperature sintering occurs but not vitrification. Earthenware is generally soft and scratches easily. It is often red in color from naturally occurring iron in the clay; brown, black, and yellow are also common colors. Earthenware has the following characteristics:

  – It is porous and will readily absorb water unless glazed.

  – The structure is often granular in appearance with numerous coarse particles.

  – There is a clear distinction between the ceramic body and any glaze layer.

- ***Stoneware*** is fired between 1100-1350ºC. Stoneware objects are partially vitrified. Common colors for stoneware are buff, brown, and gray. Stoneware has the following characteristics:

  – It is partially vitrified and less porous than earthenware.

  – It is harder and denser than earthenware and does not scratch easily.

  – If tapped lightly, the body will give a distinctive ring.

  – The glaze and body are tightly adhered.

- ***Porcelain*** is fired at very high temperatures, usually above 1300ºC. Porcelain is made of a special clay called kaolin. This clay is difficult to work and must be fired under precise conditions. Porcelain can be formed into objects with thin, complex structures. Porcelain has the following characteristics:

  – The body is completely vitrified and impervious to water (non-porous).

  – The clay body is white and translucent and extremely hard and brittle.

  – When tapped lightly, the object rings with a higher tone than stoneware.

  – In cross-section, glaze and body are nearly indistinguishable.

4. *What surface treatments are used for ceramics?*

Potters frequently add materials to the surface of the ceramic body both to decorate it and to make it less porous. These materials are either fired on or applied after firing. Fired-on materials are usually more stable. These materials include:

- ***Glazes:*** These are vitrified surface coatings that vary widely in appearance and can be divided into three categories:

  – ***Lead glazes*** are made of the mineral lead oxide, mixed with other materials. Lead oxide melts at a low temperature. Lead glazes characteristically produce smooth, glassy surfaces, but can be easily scratched. Lead glazes can be a health hazard. Weak acids found in foods such as tomatoes, vinegar, and fruit juice can dissolve the glaze, releasing lead that can be ingested. However, if glass powder (frit) is added to the glaze using proper techniques, these glazes are non-toxic.

  – ***Alkaline glazes*** contain alkali fluxes such as sodium, lithium, or potassium. They are also fired at low temperatures. Alkaline glazes usually have brilliant colors and may craze or crawl. They are not very durable and scratch easily. If not adequately fritted, they can remain slightly soluble after firing.

  – ***High-fire glazes*** are primarily feldspar and are used on stoneware and porcelain. These glazes are glass-like and form a hard, smooth, and durable surface. The colors produced are generally more subdued than in low-fire alkaline and lead glazes.

- ***Slip or engobe***: A slip or engobe is a thin layer of colored clay that the potter applies on the surface before the first firing. It generally appears matte (not shiny like most glazes), but may be burnished to get a smooth lustrous look. A potter may also use a brush to apply decorative elements over the slip.

- ***Underglaze***: Underglaze painting is generally used to add fine detail. The potter paints these decorative touches onto the surface of ceramics after the first firing (bisqueware) (see Section B.5) and then applies a protective transparent glaze.

- ***Overglaze***: Overglaze is used to provide additional decoration to the surface. The potter can apply overglaze decoration in two ways. In one technique, the artist will brush details onto a background of unfired clay and fire the glaze and overglaze at the same time. In the other, two-step technique, the artist applies the overglaze after the glaze has been fired and fires the piece again at a low temperature. Objects produced with the second technique are not as durable as higher-fired glazes.

- ***Other materials***: Potters may apply other coatings or materials to ceramics, such as gesso, resins and waxes, or powdered minerals. These coatings are applied for a variety of decorative and functional reasons.

5. *How are ceramics formed?*

Potters will use one or more of these techniques to produce ceramic objects.

- ***Hand-built ceramics:*** These are crafted using the oldest methods of producing ceramics. Potters roll out flat slabs of clay and assemble a form by pressing the slabs together or they may pinch and manipulate a ball of clay into a small object. They can form coil-built vessels by first shaping long ropes of clay, coiling them into a basic shape and then pinching and shaping the coils into the final form.

- ***Wheel-thrown ceramics:*** The potter shapes the vessel on a rotating wheel. You can often identify these pieces by looking for a flat base with concentric striations on the surface. Vessels are sometimes coil-built and then finished on a wheel.

- ***Mold-pressed ceramics:*** These are made by pressing a slab of clay into an open mold. This technique is often used for shallow shapes (like plates) that are difficult to throw on a wheel.

- ***Slip-cast ceramics:*** This method is often used for delicate porcelain objects. The potter pours a slurry of clay into an absorbant plaster or ceramic mold. The water is drawn from the slurry leaving thickened clay behind. Delicate and complex objects can be made with this method.

6. *What flaws might I find in ceramic objects?*

It is important to recognize the flaws that may occur during the manufacturing process so you can separate flaws from damage or active deterioration.

- ***Ceramic body flaws:***

  – *Warping* may result from uneven heating or cooling during firing.

  – *Spalling* or *delamination* of parts of the clay body can result if the firing temperature is not high enough.

  – *Sagging* is caused by firing at a temperature that is too high for the clay body.

  – *Cracking* will occur if the object is cooled too quickly.

- *Bloating* occurs when heating is too rapid. The gases that are formed during firing don't have enough time to be released and are trapped in the body.

- ***Glaze flaws:***

  - *Crazing* is a fine network of cracks on the surface of the glaze. Crazing results when the glaze is under tension because it has contracted more than the clay body during cooling. It may develop immediately or sometime after firing. Overtiring or rapid cooling can also cause crazing. It is sometimes used as a decorative technique.

  - *Shivering* results when the glaze shrinks less than the clay body. The glaze may peel or flake off the surface.

  - *Crawling* describes the shrinking of the glaze into islands, revealing bare areas of clay. The defect occurs when glaze is applied over a dirty or greasy clay surface and does not adhere properly during firing. Potters may purposely leave areas unglazed.

  - *Pitting* in the glaze can vary in size from pinholes to larger spots. Pits occur when firing temperature is raised and lowered too quickly and volatile materials don't fully escape before the glaze solidifies. Pits may also occur if a vessel is fired at too high a temperature causing the glaze to boil.

  - *Blistering* results when air is trapped between the glaze and the clay body. These surface bumps are easily crushed. This problem often occurs when glaze is applied too thickly.

C. The Nature of Glass Objects

Glass has been used for personal adornment, containers, construction materials, and a host of other purposes throughout the last four millennia. In order to understand how to preserve glass objects, you must understand how they are produced.

1. *What materials make up the structure of glass objects?*

The basic materials of glass are silica and alkaline oxide (also known as flux). Silica generally comes from sand or crushed flint. The flux interacts with the silica and lowers the melting temperature. Typical fluxes include lead, calcium, potassium, and sodium oxides. Other oxides (iron, copper, cobalt, manganese, chromium and nickel) are added as colorants. When melted, this mix of materials flows readily to form various shapes.

Glass is a unique material—a rigid liquid. A liquid is an amorphous material that does not have an organized, crystalline structure. Most materials, such as metals, form a crystalline lattice as they cool from a liquid to a solid state. Molten glass, however, cools too quickly for this structure to form. The structure is "frozen" into a random network of molecules. Glass is rigid and brittle at room temperature. Depending on the materials included in the mix, it can be transparent, translucent, or opaque.

Glazes and enamels are also glasses with small differences in composition from bulk glass. Glazes are applied to ceramics; enamels are usually applied to a metal support. Glazes and enamels are generally opaque and fired at lower temperatures than glass.

Both hot- and cold-working techniques are used to make glass objects. Generally, the artist forms the object using hot-working techniques. Cold working techniques are used to embellish the surface.

2. *What are the hot shaping processes?*

There are six hot-shaping processes:

- ***Mouth blowing*** begins by gathering a lump of molten glass at the end of a hollow pipe. The worker blows air into the pipe by mouth or with a bellows (which may be automated). Metal tools such as shears or rods are used to help shape the object. Glass can also be blown into a metal, stone, or wooden mold. A mold-blown object may be further hot-worked after it is removed from the mold.

- ***Glass pressing*** is a technique in which molten glass is pressed into a mold with a metal tool. The technology for this method developed in the 19^{th} century and made glassware widely available.

  You can sometimes identify pressed and molded glass by mold lines, though these lines are often ground and polished away.

- ***Core dipping or winding*** is the oldest technique used in making glass vessels. A core of organic material (for example, dung or straw) is mounded onto the end of a rod and coated with sand or clay. This core is dipped into molten glass or wrapped with coils of glass. To produce a consistent structure the glass is heated and rolled over a smooth surface. The core is removed after the glass has cooled.

- ***Pâte de verre*** means literally glass paste. Glass is ground to a powder and mixed with an organic adhesive so it can be molded or modeled much like pottery. After forming, the object is fired to burn away the organic adhesive and to fuse the glass paste. The resulting glass is usually opaque.

- ***Lost wax casting*** is a technique in which a wax model is created, covered with clay, and fired to melt out the wax. Molten glass is poured into the void left behind.

- ***Millefiore*** glass is produced when different colored rods of glass are wrapped with layers of colored glass and heated. The package of glass is rolled on a textured surface to work together and shape the layers. Each thick rod is then cut into short lengths that show a floral design in cross section. These lengths are then used to form objects.

Decorative details can be added to molten glass by fusing colored glass onto the surface of the object or by integrating glass threads or shapes into the body and then reheating.

3. *What cold-working techniques are used to decorate glass?*

Commonly used cold-working techniques used to decorate a glass object after it has cooled include:

- cutting or engraving the glass with a sharp point or cutting wheel
- chipping away the glass inside an engraved design outline
- acid etching a design in the glass (The glass surface is coated with wax and a design is cut through the wax. The piece is then dipped into hydrofluoric acid to etch the exposed glass. This technique has been used since the 19^{th} century to decorate glassware.)

The final step with all these techniques is to polish away surface roughness and imperfections.

4. *What flaws might I find in glass objects?*

Flaws can be introduced during the manufacturing process. Learn to distinguish these flaws from active deterioration problems. Look for:

- ***Bubbles:*** They may also be added intentionally for decorative effect. A few isolated bubbles will not weaken a glass object, however, a cluster of bubbles might. The shape of the bubbles gives clues to the direction that the object was worked in the molten state.
- ***Inclusions or foreign bodies:*** These are more noticeable in translucent glass. Often these flecks come from contamination in the crucible or impurities in the raw materials. Small inclusions may disrupt the surface and look of an object, but they will not affect its strength.
- ***Compositional flaws:*** Sometimes these are not apparent for many years. The symptoms of deterioration from compositional problems are covered in Section E, Agents of Deterioration.

D. The Nature of Stone Objects

Stone in museum collections is often perceived as a material with few problems, but stone is brittle and can break or shatter. While generally, harder and tougher than many other materials found in collections, the agents of deterioration also can affect the preservation of these materials. It reacts with the environment in a variety of ways. Understanding the origin and production of stone objects in your collection will help you identify problems.

1. *What materials make up the structure of stone objects?*

Geologists divide rock into three broad categories:

- ***Igneous rocks*** are formed when magma cools and solidifies. They are generally hard and very stable because of their interlocking crystalline structure. Types of igneous rocks are granite, basalt, obsidian, and porphyry.
- ***Sedimentary rocks*** are formed by the solidification or cementing together of layers of organic and mineral sediments. They are usually more permeable and deteriorate more easily than igneous rock. Examples include sandstone, limestone, alabaster, and travertine.

- ***Metamorphic rocks*** are formed by transformation of igneous or sedimentary rocks with pressure and heat. The structure depends on the parent rocks. For example, marble is metamorphosed from limestone.

The durability of stone depends on its porosity, permeability, hardness, mineral content, and number and type of inclusions. Porosity is the amount of free space in a rock; permeability is the capacity of a rock to allow fluids to pass through it.

2. *How are stone objects formed?*

Stone-working tools and techniques have changed little through time. Although metal tools have replaced stone and, more recently, electric power has speeded up some processes, modern artists use the same basic tools to carve stone. Workers use heavier and thicker tools for carving hard, igneous stones (for example, granite), than for softer limestone and marble. They must also temper steel tools used on hard stones, hardening them by heating, cooling, and slow warming.

The carver holds a carving tool in one hand and uses a hammer or mallet to strike the tool. Stone surfaces are often polished to remove tool marks, but sometimes you can find traces on back surfaces or inaccessible undercuts that can be used to identify techniques. Sculptors use six basic tools:

- ***Point (punch):*** After selecting a stone, the sculptor uses a point for roughing-out the shape from the block. The sculptor holds the point at an oblique angle to the stone surface and hits it with a hammer. Larger masses of stone are removed, progressing from larger to smaller diameter points.

- ***Tooth chisel (claw chisel):*** Following the initial roughing-out, the sculptor uses the tooth chisel to remove more layers of stone and further define the form. The tooth chisel is used primarily on limestone, sandstone, and marble. The sculptor will start with a coarse chisel with well-spaced teeth and progress to a fine chisel with closely spaced teeth. You can identify the tooth marks angled in different directions. Using this tool gives the stone a raked or combed appearance.

- ***Bushhammer:*** Sculptors use a bushhammer on hard stone such as granite. The bushhammer is a series of points or teeth in one head (multi-pick) used to wear down or pulverize a hard stone surface. As when working with a tooth chisel, the sculptor progresses from coarser to finer toothed bushhammers. The bushhammer gives the stone a pitted, granular appearance.

- ***Flat chisel:*** To remove the marks of the tooth chisel and bushhammer, the sculptor often uses a flat chisel. The sculptor holds the flat chisel almost parallel to the surface of the stone and cuts across to remove the rough surface material. On concave surfaces, a rounded chisel edge may be used. Sculptors sometimes use only a flat chisel when carving soft stones or producing low-relief carvings.

- ***Abrasives:*** Rasps, rifflers, and files are abrasive tools. They are used to do rough finishing. Mineral and stone abrasives such as sandstone, pumice, and carborundum (silicon carbide) are used for shaping and smoothing. Sculptors used emery cloth, solid tin oxide, and sandpaper for finishing the surface. Whiting (calcium carbonate) is used for final polishing. A sculptor may stop at any point in the surface finishing process depending on the desired look.

- ***Drills:*** To split stone the worker drills a series of holes along a stone face and then hammers wedges into the holes. You may see evidence of this technique as a line of parallel vertical marks left by the drill on the face of the stone.

3. *Will I see different techniques used on archeological stone objects?*

Flaking methods were used to produce the stone tools found in many archeological sites. Flint or chert and obsidian were used for tools because they flake easily and give a sharp edge when fractured. You can identify the fracture face by the conchoidal fracture, a series of concentric arcs radiating from the point of impact. You can identify the point of impact by the bulb of percussion, a swelling caused by the compression of the blow.

There are two basic methods for detaching a flake:

- ***percussion flaking***, where the core or parent block is struck with another stone

- ***pressure flaking***, where heavy pressure is applied with a stone, bone or wooden tool

Early stone tools were also drilled and abraded with sand, just like wood, bone, stone or early metal tools.

4. *What different tools and techniques are used on contemporary sculpture?*

Though the basic tools used for modern stone sculpture are the same as those used in the past, the addition of pneumatic equipment speeds the process and makes working stone less physically difficult. Wire saws, diamond saws, and flame cutters are now available to cut and roughly shape stone.

Pointing is a contemporary mechanical process used to duplicate an original model. A pointing machine, a movable instrument with adjustable rods, mechanically measures a number of points on the original and transfers these to the stone block. Holes are drilled into the stone to the point and depth measure with the pointing machine. The stone between the drilled holes is chiseled away. Finer pointing is employed as the reproduction progresses.

Other mechanical aids are also used to produce reduced or enlarged products from a model.

E. Deterioration of Ceramics, Glass, and Stone

You can find general information on the agents of deterioration that affect ceramics, glass, and stone in Chapter 3: Preservation: Getting Started, and Chapter 4: Museum Collections Environment.

The agents of deterioration that can have the most profound effect on ceramics, glass, and stone in museum collections are direct physical forces. If ceramic or glass objects are dropped, they usually break. Most stone will chip, crack, or break if dropped. Cumulative damage can occur with improper handling—pieces can be chipped off and residues left from handling. Some ceramic, glass, and stone objects also have flaws, either inherent or from their previous use, that make them vulnerable to heat or moisture.

1. *How do ceramics deteriorate?*

Besides the obvious problems of breakage, ceramics can be vulnerable to changes in temperature and relative humidity. In particular, archeological ceramics may contain "soluble salts" that can crystallize at or near the surface and destroy decoration or even the ceramic structure. See *Conserve O Gram* 6/5, Soluble Salts and Deterioration of Archeological Material. Other historical objects (for example, salt containers or pickling jars) that held contaminants can suffer similar damage.

Unstable glazes may become crizzled and crazed, deterioration problems common to glass and discussed in more detail below.

2. *How does glass deteriorate?*

Most damage to glass is mechanical. It is easily broken and chipped. Water is the major chemical agent of deterioration for glass and the susceptibility of glass to deterioration depends greatly on its original chemical structure. Some deterioration processes are caused by similar reactions, but have different visual characteristics. Be aware of the following deterioration types:

- ***Crizzling*** is a fine network of surface cracks that turn glass translucent. Moisture in the air reacts with unstable glass containing too little lime (calcium oxide). The moisture causes potassium and sodium in the glass structure to leach out. As the structure weakens, small cracks appear.

- ***Weeping*** is caused by leaching sodium or potassium absorbing water on the surface of deteriorating glass to form sodium or potassium hydroxide. These compounds accumulate on the surface of the glass and may give it a greasy feeling. The hydroxides may also react with carbon dioxide in the atmosphere to form carbonates, which can absorb even more water.

- ***Crusty or waxy deposits*** on the surface, which may have a white crystalline appearance, are typically seen on ethnographic beadwork and may be a reaction of the glass deterioration products to oils in adjacent leather.

- ***Iridescence*** is a rainbow-like effect on the glass surface and is an indication of deterioration. The colors are visible when light is diffracted between the air-filled layers of deteriorated glass.

- ***Devitrification*** is the production of small areas of crystal growth in the otherwise amorphous glass structure. These crystals may be intentionally produced during production as they give glass good thermal shock resistance. Unintentional devitrification is caused by unstable glass with too much alumina or too much calcium.

- ***Solarization***, a process that can cause some glass to turn purple or brown, is caused by exposure to sunlight over long periods of time. This deterioration can sometimes be seen in old window glass.

3. *How does stone deteriorate indoors?*

Stone is affected by agents of deterioration—especially when it is not well protected in storage or it is put on exhibit. You must be aware of how damage can occur and how you can protect stone.

- ***Dirt and dust*** accumulate on horizontal surfaces and in nooks and crannies in stone objects. It disfigures the object and over time the dirt can penetrate porous stone and cause staining. High traffic areas will have greater accumulation of dirt.

- ***Oils*** from repeated handling will also cause stains. This is typically seen on protrusions such as noses or knees on sculpture that are accessible to visitors.

- ***Old coatings of wax or oil and old adhesive repairs*** may also discolor over time. Staining will be most noticeable on light colored stones and may have a blotchy appearance.

- ***Relative humidity*** that is fluctuating or too high can also cause damage. Fluctuating humidity can bring salts to the surface and cause spalling. High humidity can react with pollutants and damage stone, just like in an outdoor environment**.**

- ***People*** can cause a lot of damage to stone objects indoors. Breakage and chipping from handling are obvious examples. Graffitti from vandals, paint drips and smears from careless maintenance, and damage from splashed cleaning fluids are other examples.

4. *How does stone deteriorate outdoors?*

Stone is often exhibited outdoors where it is not well protected from the agents of deterioration.

Water causes most of the damage to stone stored or exhibited outdoors. Water can penetrate between the layers in sedimentary rock and push them apart. Water carries salts, such as chlorides, into the stone and as these crystals dry they can damage the surface of the stone (see *Conserve O Gram* 6/5). During the winter, when water freezes, the expansion of the ice can cause cracking, splitting, and spalling. ***Corrosion*** of metal components that may be attached to the surface, mounted into the stone, or used as interior supports in some cases causes severe damage. Copper corrosion will produce green stains; rusting iron produces brown stains. As metal corrodes it expands. Expanding internal supports can crack apart the surrounding stone. Also be aware that some solutions used to clean mounted metals may stain the stone support.

Atmospheric pollutants can react with water and cause damage. Carbon dioxide and water form carbonic acid that can dissolve calcium carbonate, a major component in limestone and marble. Other sources of acid that attack stone come from the reaction of water with chlorides, nitrates, and sulfur. Other chemicals from car exhaust and industrial pollution react with carbonates to create disfiguring brown and black layers on the surface or simply adhere to stone and discolor the surface. Abrasive particles carried by the wind can wear away surface detail.

Biological agents such as bacteria, algae, fungi, and moss grow on stone surfaces and inside cracks pushing them further apart. These agents also retain water and contribute to the damage caused by water and atmospheric pollutants. Their organic waste products can dissolve calcium carbonate. Biological agents can also cause staining. Birds can disfigure and damage stone with their waste.

5. *Should I move stone objects indoors?*

The best way to protect stone objects stored outdoors is to move them inside. This action radically limits the agents of deterioration that will contact the objects. However, be aware that moving an object indoors is a major environmental change and you should carefully examine the object before moving it. Monitor the object after it is brought inside. Most objects will dry out when moved indoors. As water is lost from the interior, residues left by pollutants, biological matter, cleaning agents, and soluble salts may begin to crystallize on the surface. Where previously they were washed away by rain, they can now cause damage to the stone and may require treatment. Mold may grow on dirt and biological waste accumulated on the surface when it was outside.

F. Preventive Conservation

1. *What special handling rules for ceramic and glass objects should I know?*

Follow these special rules when handling ceramic and glass objects:

- Handle glass and ceramic objects as little as possible.
- Before handling, examine the object carefully. Note any unstable repairs, loose parts, lifting glaze, hairline cracks, or vulnerable appendages.
- Don't wear cotton gloves to handle glass or ceramics because the surfaces are slippery. Use clean, bare hands or snug fitting latex or nitrile gloves. In particular, use latex gloves for lustreware, iridescent glasses, and gilded ceramics and glass. The moisture, oils, and acids left from bare hands will disrupt and eventually etch these delicate surfaces.
- Don't lift objects by handles, knobs, rims, or decorative motifs. ***Always use both hands to support the object uniformly.***
- Transport ceramic and glass objects in a padded container. Don't stack objects. Don't allow objects to knock together. If you are moving numerous objects, use a well-balanced and padded cart with a lip at the edge of the surface. Use plenty of soft tissue or cloth diapers to prevent objects from rolling and tipping.
- Transport detachable parts such as lids or bases separately. If there are loose (but not removable parts), slip tissue or polyethylene foam between the parts to prevent rubbing or bouncing.
- Carry thin, flat objects, such as mirrors or panes of glass, vertically. This position distributes the weight and minimizes the chance of cracking the object. If the object is heavy, you may need to use a dolly or hand truck and assistance from other people. Be sure the dolly has soft wheels and all surfaces are cushioned.
- Never apply tape or sticky labels to ceramic or glass objects. When they are removed, delicate overglazes, decals, and gilding may be removed as well. Tape and labels will also leave residues on the surface of the objects that may cause staining or attract dust.

Refer to Chapter 6: Handling, Packing and Shipping Museum Objects, for basic rules on handling museum objects.

2. *What special handling rules for stone objects should I know?*

Follow these rules:

- Wash hands and wear clean, white gloves.
- Always take care when placing your hands on a surface. Paint, gold leaf, and delicately carved areas can be damaged. Previously repaired areas may not be stable.
- Always carry one item at a time and never lift by projecting parts such as arms, legs, or wings.
- Use a cart when moving an object more than a few feet or when moving more than one object. Use padding, wedges, and blankets to stabilize objects and prevent them from touching and abrading each other.
- You may need to use a forklift to move large, heavy stone sculpture. Be sure you have enough help when moving large objects. Make sure straps or chains that secure the object are well padded and cannot slip and scratch the surface. Cover and pad protruding parts. Make sure the object is properly supported on the forklift before putting your hands underneath the object.
- Be sure that equipment used around large stone objects (ladders, scaffolding, other maintenance equipment) is used carefully.

3. *What environmental parameters should I use for ceramic, glass, and stone objects?*

See Chapter 4: Museum Environment, for a discussion of how to set temperature and humidity ranges for your objects. In general, objects should be maintained in a stable temperature and relative humidity with no more than +/-5% variation in a day.

A few types of ceramic, glass, and stone objects will need special consideration when developing their museum environment because of deterioration problems.

- ***Deteriorating glass objects:*** Unstable, weeping and crizzling glass and glass that appears cloudy or iridescent or is suspected of being unstable for some other reason should be stored in a stable microenvironment. The humidity must be tightly controlled: too high and deterioration will progress; too low and cracking may occur. Contact a conservator for advice on how to prepare a microenvironment to store unstable glass. See *Conserve O Gram* 1/8, Using Silica Gel in Microenvironments, for information on using silica gel to buffer the environment.
- ***Archeological ceramics and stone:*** Archeological ceramics and stone may have absorbed soluble salts from burial. (See *Conserve O Gram* 6/5.) These objects must be stored at a low and stable relative humidity. If fluctuations occur, the salts can move through the porous ceramic structure and crystallize near the surface to cause damage.
- ***Composite objects:*** If ceramic, glass, or stone objects are combined with other materials, particularly organic materials, use the environmental parameters recommended for the organic materials. For example, keep stone objects framed in wood in an environment that will preserve the wood. Store polychrome sculpture in a stable environment to protect the painted surface.

4. *What light levels should I set for ceramics, glass, and stone?*

Visible or UV light will not damage most ceramics, glass, and stone. Light will not deteriorate inorganic materials. Infrared (IR), however, can cause damage, by heating objects and by causing changes in relative humidity around the object. These RH fluctuations can cause salts to crystallize out or cause slight expansion and contraction of surfaces. Keep light fixtures outside of exhibit cases. Don't use spotlights directly on objects. See Chapter 4: Museum Collections Environment, for a discussion of light and light levels.

5. *How should I store stable ceramic and glass objects?*

Choose storage solutions that will minimize handling and thus the chance of breakage. Design the storage area so that access is safe, simple, and direct. See Chapter 7: Museum Collections Storage, for more complete information on storage design and choosing cabinetry.

- Cabinets should be in a low traffic area in the storage room to reduce the chance that people will bump into them.

- Store ceramics and glass on stationary shelves to avoid damage from vibration. Line shelves with closed-cell polyethylene foam (Volara®). Attach the foam with double-stick tape so it will not bulge or slide.

- If possible, choose museum cabinets with clear glass doors to allow visual access without handling. Don't store other light sensitive objects in these cabinets. All cabinets should have gaskets and close tightly to minimize dust accumulation. See *Tools of the Trade* for information about storage cabinets. See also, *Conserve O Gram* 4/3, Installing the Retrofit Gasket Kit.

- If possible, choose shelves that are only deep enough to accommodate a single object. This limits the need to move one object to retrieve another. Place small objects in rows with ample space to reach one object without touching another.

- Store the heaviest objects on the bottom shelves.

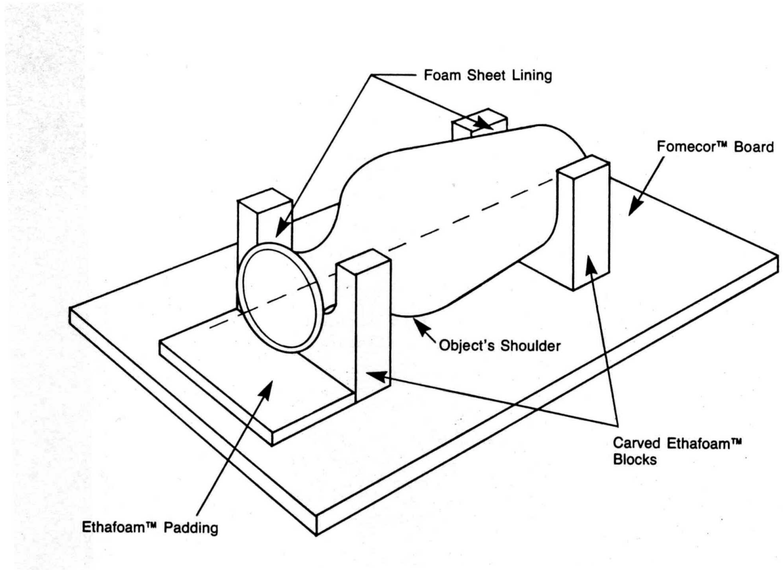
- Don't stack plates, cups, and bowls. If a critical lack of space requires stacking, place soft fabric, such as washed, white cotton flannel or polyethylene foam, between each object. Make sure the objects nest well and don't put pressure on each other.

- If objects are unsteady due to their shape or to damage, store them in a stable position using padding or foam blocks. See Figure P.1 for an illustration.

- Pieces of broken glass and ceramic objects should be kept together. Pad pieces so they don't abrade each other and keep them together in a tray or box.

- Use dust covers on open shelving. See *Conserve O Gram* 4/2, Dust Covers for Open Steel Shelving. If oversized objects must be stored in the open, they should be covered with a polyethylene bag or dust cover.

- Stabilize shelves by bolting them to walls and ceiling. Open shelving should have earthquake bars.



A top heavy or damaged object can be stored in an Ethafoam™ cradle. To make a cradle.

(a) Lay the object on its side, supported so it is level.

(b) Measure the curve of the base and the neck with a flexible drafting curve.

(c) Cut each curve into a 1" - 2" thick Ethafoam™ block. Use a long knife (e.g., bread knife) with a fine serrated edge. Thickness depends on the size of the object. The placement of the curve on the block should allow the shoulder of the object to touch, not rest heavily, on the mat. The foam blocks can be free standing or fixed to a Fomecor™ board so that each cradle is portable.

(d) Place padding or a thickness of Ethafoam™ underneath any projecting part of the object (such as the rim) as a barrier against bumping.

(e) Cut thin foam sheet for lining the cradle surfaces.

Figure P.1. Method of Stabilizing Objects in Storage

See *Conserve O Gram* 14/5, Caring for Photographs: Special Formats, for information on the special housing and storage needs of glass plate negatives and transparencies.

6. *Are there special storage concerns for unstable glass and ceramics?*

You may need to store unstable glass or ceramics in a microenvironment that keeps the relative humidity at a lower level than the general storage environment. Low RH slows the deterioration of weeping glass and ceramics with soluble salts.

Before taking this step, carefully discuss the need for this option and the design of your storage system with a conservator. Creating a microenvironment generally requires long-term maintenance, and if it fails, more harm may come to the objects than if you had done nothing.

You may create a closed microenvironment in:

- an individual container, such as a polyethylene box with a tight fitting lid (Rubbermaid®, Tupperware®)

- a fishtank with a plate glass top
- a single museum cabinet

Use silica gel buffered to 40% RH to control the microenvironment. See *Conserve O Gram* 1/8 for an explanation of how to buffer silica gel and how to figure the quantity of silica gel needed in your container.

Your storage system must isolate the object from the silica gel. ***Don't let the silica gel touch the object.*** Work with a conservator to develop the best storage system for your particular objects. You need to consider the following:

- How many objects do I need to store?
- What size are the objects?
- What shapes are the objects?
- How fragile are the structures of the objects?
- How fragile are the surfaces of the objects?

7. *What are the storage requirements for stone objects?*

Keep in mind the following points when developing a storage system for stone objects:

- Keep dust from the surface of stone objects. Dirt and dust can accumulate in the pores and darken the surface. Use individual polyethylene bags or muslin dust covers (see *Conserve O Gram* 4/2) to keep dust from settling on objects in storage.
- Keep objects away from open windows, air conditioning vents, and heat sources.
- Small objects, such as arrowheads and beads, should be stored in individual bags or boxes so that they are not easily lost.
- Large stone objects present problems because of their weight. Be sure your shelving units can support the weight of the object. Use polyester felt as a shelf liner for heavy stone objects because it will not compress as much over time as polyethylene foam.
- Store heavier objects on bottom shelves. This lowers the center of gravity and minimizes the danger of a rack toppling over.
- Don't allow any part of an object to protrude beyond the edge of shelving where it might be bumped.
- Don't store large sculptures directly on the floor. Create a low deck or use pallets at least four inches off the floor. Raising objects protects them from floor cleaning chemicals and minor flooding.

- Allow sufficient space between objects so that they can be easily moved and periodically inspected. Large objects especially need enough space so they can be handled without knocking other nearby objects. If heavy pieces are regularly moved, store them on dollies with lockable wheels.

- In earthquake prone areas, use earthquake stabilization techniques. Securely bolt shelves and cabinets to walls and floors. Attach restraining bars to the edges of shelves. Be sure overhead lights, pipes, and ductwork are also reinforced.

8. *What special preventive conservation concerns should I have for ceramic, glass, and stone objects on exhibit?*

Exhibiting an object puts it into contact with many more agents of deterioration. See *MH-III*, Chapter 7: Exhibits, for an overview of preservation concerns when objects are put on exhibit. *Exhibit Conservation Guidelines* by Toby Raphael is also a useful guide to incorporating preservation in your exhibit.

Work with a conservator and experienced designers and mountmakers to ensure exhibit techniques will not damage objects. Heed the following when designing a new exhibit or evaluating ways to improve your current exhibit.

- Make sure all objects are securely mounted so that they cannot fall if the case or pedestal is bumped. Construct mounts from stable materials and attach them so they don't put undue physical stress on the objects. Use seismic stabilization mounts in earthquake-prone areas.

- Don't direct spotlights on individual objects. Spotlighting can cause thermal shock as well as raise the interior temperature of the case.

- If sculpture is exhibited outside a case, be sure to provide a physical barrier so it cannot be touched. Use a pedestal or a deck to raise the objects up off the floor. Make the pedestal large enough that it cannot be easily ignored by visitors trying to reach the work of art.

- Busts and small stone objects must be securely mounted to prevent them from toppling over. A variety of techniques can be used to mount the object. Work with an experienced mountmaker and a conservator to design a safe mount.

- Don't plaster or cement stone reliefs directly into the wall. They will be difficult to remove later and moisture and salts from rising dampness can infiltrate the object from the wall.

- When cleaning objects on display, brush the dust off into a vacuum; don't use a cloth. See *Conserve O Gram* 8/1, Removing Dust from Ceramic and Glass Objects.

- If stone sculptures are exhibited outdoors, you should develop an annual monitoring program to watch for deterioration. Conduct a careful condition survey and document the sculpture with detailed photographs. Consider having a conservator conduct a Collection Condition Survey to give you baseline information and train staff in evaluating deterioration. If objects are deteriorating rapidly, they should be brought indoors. Consider putting a replica in place of the original. Refer to *MH-III*, Chapter 5: Three Dimensional Reproductions.

G. Care of Composite Ceramic and Glass Objects

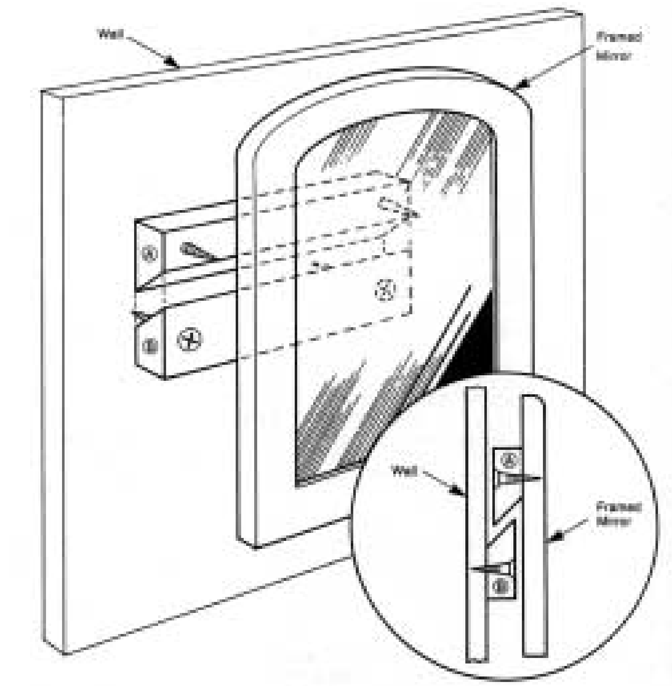
Composite objects are museum objects made of more than one material. These materials can react to the environment differently, setting up stresses that may cause the object to deteriorate more quickly than one made of a single material. Glass, in particular, was used in many types of composite objects and may be sewn or attached to a variety of materials. Be sure to take into account the preservation of all parts of the object. For example, never use water to clean glass beads sewn onto costumes. You may damage the attachment thread and the fabric or leather of the costume.

Two types of composite ceramic and glass objects that have special preservation concerns are:

- ***Mirrors:*** Look closely through the front of the glass to see if any silver-colored droplets or beads have formed on the back of the glass. Before the 19th century, mirrors were made reflective with a toxic mercury/tin amalgam. This coating can break down. Look for droplets collected at the bottom of the frame. Always wear disposable plastic gloves when handling mirrors you suspect may have a mercury coating. Contact a conservator to examine an unstable mirror.

  For all mirrors, examine the glass carefully. Do you see breaks or chips in the glass? Is the glass sticky (weeping glass), or does it have an overall network of very fine cracks (crizzling)? Is the coating on the back still reflective, or do you see black spots or streaks that indicate deterioration or peeling?

  Be sure the glass is securely attached to the frame and the frame is in good repair. Store heavy framed mirrors face up on well-padded shelves. Support the frame with padding. Make sure that all the weight is not resting on the mounting hardware or the glass.



To mount a heavy mirror:

(a) Place the mirror face down on a padded surface. Use additional padding in the flat and recessed areas to relieve any pressure on ornately carved areas.

(b) Measure the width across the back of the frame, approximately one-third down from the top.

(c) Locate a point on each side of the frame back into which the mounting board can be safely attached.

(d) Cut a rectangular clear pine board (e.g. 1" thick x 4" wide, though the actual dimensions depend upon the size and weight of the mirror) to the width of the frame back. Cut the board along the grain at a 45º angle to the edge. Paint all wood surfaces with one coat of two-component epoxy paint.

(e) Screw Part A into the back of the frame and Part B into the wall.

Figure P.2. Flush Mount for Hanging Heavy Mirrors

- ***Chandeliers:*** Look closely to identify parts that are fixed and parts that are free to move before cleaning or moving a chandelier. Ask the questions:

  – How secure are the hooks and joints?

  – Are there any missing prisms or other parts?

  Chandeliers on display in the open air, for example in historic houses, will need to be dusted occasionally. Use a scaffold or sturdy ladder to reach the chandelier so you can keep your hands free and safely move around the chandelier. Move furniture and other items on the floor away from the ladder. Dust prisms or moving parts individually so they don't knock into each other. Follow the instructions for dusting found in *Conserve O Gram* 8/1.

When a chandelier is not on view (for example, when a house is closed for the winter) or has been placed in storage, cover it with a muslin or polyethylene bag to keep it clean. Mark light switches or turn off the power at the fuse box so covered lights will not be turned on.

H. Treatment Issues for Ceramic, Glass and Stone Objects

The following section discusses particular considerations before any treatment is carried out either by park staff or a conservator. See Chapter 3: Preservation Getting Started, and Chapter 8: Conservation Treatment, for general information on working with a conservator. When you work with a conservator, you will need to make choices about the type of treatment that is appropriate for your objects.

If objects are not stored in closed cabinets, for example, on display in a historic house, trained museum staff should dust them. This basic maintenance will avoid the need for more difficult and more expensive cleaning in the future. Follow the instructions in *Conserve O Gram* 8/1, Removing Dust from Ceramic and Glass Objects.

1. *What should I consider before cleaning ceramic and glass objects?*

If objects are dirty enough to require washing, you should work with a conservator to develop a cleaning program. Before placing any ceramic or glass object in water, determine that:

- the ceramic is actually fired
- the glass or ceramic is intact
- there are no previous fills
- no surfaces are powdery, sticky, or crackled
- there are no stains that might migrate

If any of the above conditions is not met, don't wash the object.

2. *What should I consider before cleaning stone objects?*

Stone objects stored indoors should be regularly dusted. Don't wash stone objects. If stone objects are very dirty, get advice from a conservator. Don't use commercial cleaners without the advice of a conservator; many contain acids that can dissolve the stone. Problems that can occur with wet cleaning include:

- stains that move further into the stone, instead of washing out
- loss of polish on soluble stones such as alabaster
- movement of soluble salts that then crystallize and damage the surface of the stone as it dries

3. *How can I tell if an object has been repaired?*

You may be able to identify repaired areas using one of the following methods:

- Examine the surface with a magnifying glass in good light to identify breaks.
- Examine the surface with a hand-held ultraviolet light to identify cracked glaze, fills, adhesive lines, or painted surfaces. Different materials will fluoresce differently and some will not fluoresce at all, allowing you to identify damage and repairs that may not be visible to the naked eye.
- Test different colored areas on the surface in inconspicuous areas with a slightly damp cotton swab to confirm that they are truly glazed.

4. *Should old repairs be removed?*

Work with a conservator to decide whether or not to treat a previously repaired object. A conservator can give you a variety of options for any project. Old repairs should be removed only if they are unstable or obscuring or damaging surface detail, and if they are not an important part of the history of an object. If a heavily repaired object is stable, there is no reason to remove all the old repairs and redo them. You may want to consider doing cosmetic cleanup and restoration if an object is going on exhibit.

5. *What should I discuss with the conservators before losses are filled?*

If there are losses in an object, you will need to discuss with the conservator whether or not they should be filled or replaced. For example, a porcelain vase may have small chips along break lines or even small pieces missing. A stone sculpture may have lost a piece or had it stolen by vandals. Take into account the following before a fill is carried out:

- Is the object stable without the fill?
- Is the loss unsightly?
- Do you know what the loss area looked like previously?
- Do you want the fill to match exactly or only be of similar tone?
- Are available fill materials stable or will they discolor quickly?

Different choices will be made based on the stability of the object and aesthetic desires. In general, fine and decorative art objects are restored to a higher level than archeological objects.

6. *When are objects consolidated?*

Conservators consolidate objects when they have lost cohesiveness in their structure. Examples of objects that might require consolidation include:

- delaminating glass
- ceramics that have been seriously damaged by soluble salts
- stone with a flaking surface

Different consolidants are used for different materials and for different problems. A conservator will evaluate the problem and recommend a specific material and a specific technique for application that will stabilize your object.

I. Packing and Shipping Glass, Ceramic, and Stone Objects

See Chapter 6: Handling, Packing, and Shipping Museum Objects, for general guidance on packing and shipping objects. Since ceramic, glass, and stone objects are all brittle, sufficient padding must be provided to cushion the object from any shock. Always use double boxing when packing and shipping these objects.

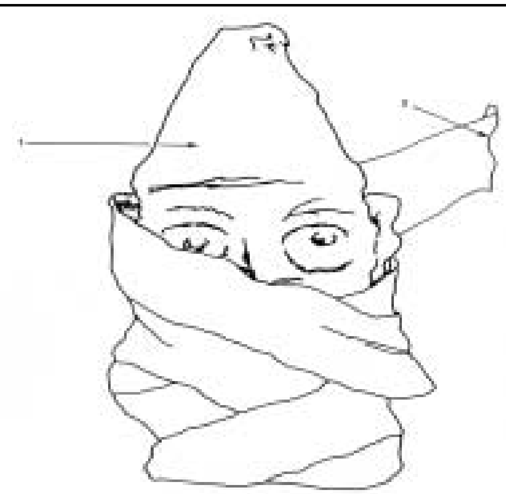
1. *How should I pack ceramic, glass and stone objects for shipping?*

In order to ensure that ceramic, glass, and stone objects are protected, they should be packed in individually contoured foam wells. Polyurethane is a good shock absorber, but it is an unstable material. Polyethylene foam is stable, but cut edges are very abrasive. When you use either foam for padding you must isolate the object from the foam with soft tissue or washed cotton flannel. Don't use buffered paper as it can be slightly abrasive to gilded or painted surfaces.

Objects with extremely delicate surfaces and appendages require special attention. Wrap long strips of soft tissue closely around the object to protect the surface. Fit unsupported areas (for example, handles and spouts) with soft tissue prior to overall wrapping. See Figure P.3 for an illustration of the technique to use for wrapping fragile objects. See Figure P.4 for an example of using layers of foam to completely surround, protect, and pad the object.

2. *How will I ship particularly heavy items?*

Heavy items like stone sculpture will require specially designed cases with interior supports at weight bearing and stabilizing locations. Pad all interior braces. Build in a pallet base so the object can be lifted with a forklift.

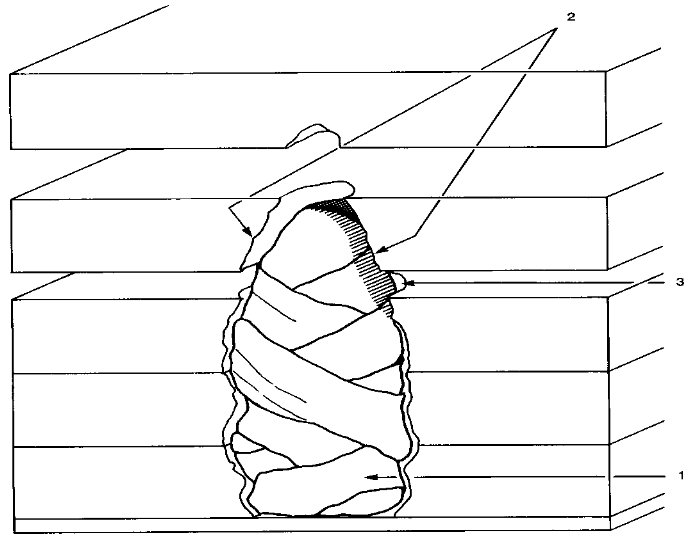


Object with a fragile or delicate surface (1)

Wrapping Technique (2)

- (a) Cut soft tissue (does not have to be acid free) into long strips.
- (b) Carefully wrap tissue strips around the object.
- (c) Tape ends to tissue only.
- (d) Repeat wrapping until object is completely covered with a few layers of tissue.

Figure P.3. Technique for Wrapping a Fragile Object



Fragile object that has been enclosed in mummy wrapping (1). The tissue wrapping protects the object's surface from abrasion that may be caused by the foam packing material. This technique works best when the top and front of the crate are removable. Follow these steps:

(a) Cut layers of Ethafoam™ (2) to completely fill the interior dimensions of the foam lined crate. Use a long knife (e.g., bread knife) with a fine serrated edge. The stack of foam is then cut in half vertically. Next, the contours of the object are cut in each half of the foam stack, one layer at a time. Nest the object in the center of the layers.

(b) Fill any gaps in the foam's center with tissue paper (3). *Caution:* Do not put pressure on the object.

Figure P.4. Layered Foam Packing for Fragile Objects

J. Emergency Procedures for Ceramic, Glass, and Stone Objects

See Chapter 10: Emergency Planning, for general information on planning for emergencies and responding to disasters.

1. *What special procedures should I follow for ceramic, glass, and stone objects after a disaster?*

The following procedures give some specific actions you can take to help preserve ceramic, glass, and stone objects immediately after a disaster.

- ***Water:*** If water is dripping onto objects, immediately cover them with plastic sheeting or bags. Water can cause stains and streaks. In particular, protect painted pieces, unfired clay, or deteriorated stone or glass. Don't seal the plastic completely as mold may grow.

- ***Severe weather:*** Move objects away from windows. Cover glass cases or tape the glass to prevent shattering and flying glass. Lay tall objects on their sides and pad so they cannot roll.

- ***Liquid attack*** (for example, acids, bases, or solvents): Vandals may throw or spill chemicals onto objects that are not protected by cases. Avoid contact with unknown liquids, but act quickly and try to identify the substance. Consult a conservator as quickly as possible to get advice and ensure that damage has been contained.

  Small, localized attacks should be rinsed well with water. Water will neutralize acids or bases and slow severe etching.

2. *How do I recover from a disaster with ceramic, glass, and stone objects?*

Air-dry wet ceramic glass and stone objects. If they don't have a damaged or rough surface, you can blot the surface gently with a soft cloth to remove excess water.

If an object is broken, keep people away from it. Photograph it *in situ* if possible. Keep all pieces together, carefully collecting them and placing them in a padded tray or box. Small pieces can be put in plastic bags. Collect even tiny chips. Don't try to fit broken pieces together as this will only abrade edges and prevent a good fit when the object is repaired. Don't allow pieces to rub together. Keep pieces clean; protect them from dust.

Contact a conservator to have the object repaired as soon as possible.

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