

CHAPTER 2

Methods in Conservation

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1 INTRODUCTION

Conservation is an interdisciplinary field that needs to take into account such disciplines as the humanities, the arts, the sciences and technology, and crafts. Although the actual conservation intervention is, or should be, carried out by trained conservators, the degree of that intervention cannot be decided by the conservator alone. The reason for this is that conservation is not merely a technical operation on a cultural object. Rather, it is a cultural operation carried out by technical means.

Thus, when a conservation intervention is being planned on an object, it is important that as much information as possible about that object be available to the conservator. For example, this includes the anamnesis of the object, *i.e.* its history, starting with its provenance, its historical context, including the available technology and materials available at the time the particular object was created, its subsequent use, and the conditions under which it was kept there.

It is clear, therefore, that the contribution of historians and art historians is critical for conservation. Furthermore, the study of the object, its constituent materials and any deterioration process that may be affecting it, requires the contribution of the sciences to effectively identify any changes and decay it may have suffered. Based upon the scientific information acquired, an appropriate conservation method can then be devised.

2 PRELIMINARY EXAMINATION

Any conservation intervention needs to follow a logical procedure. This starts with the visual assessment and the compilation of all the relevant historical

data available, including its recent history and information on any previous conservation intervention. Then a diagnosis as to the state of conservation of the object is required. Is the object sound? Does it suffer from any deterioration? If so, what are the causes? These questions, as well as the identification of the constituent materials require the support from various analytical techniques that are detailed below.

The results from these analyses serve various purposes. In the first place, they have to correlate with the historic information available. For example, was the pigment identified on a ceramic or on a painting available at the time and place the object was supposed to have been manufactured? Was the technology used in its manufacture consistent with the available information regarding the culture that supposedly manufactured the object? Second, is the object in question in a sound condition or does it show some deterioration? If so, is that deterioration active or is it the remnant of a previous decay process that has now ceased?

These are fundamental questions that need to be addressed so as to determine if a conservation treatment is required or not; and should a treatment be necessary, the most appropriate method and material need to be determined. Finally, and as a result of this preliminary examination and study, a condition report needs to be prepared including any recommendations regarding subsequent treatment(s) or the condition(s) under which the object should be stored or displayed.

3 ANALYTICAL METHODS

The examination of an object starts first of all with a visual examination aided by the use of loupes and microscopes. Then, if necessary, other analytical techniques may be employed to study particular aspects of the object. There is no single analytical method that will provide all the answers needed. Depending on the object and the problem to be studied, different techniques need to be used. In many cases, two or more techniques have to be used to confirm the data obtained.

It is also important to remember that analytical techniques have varying degrees of sensitivity when it comes to detecting the presence of an element or compound. Thus, not finding a particular element may not necessarily mean that this element is not present in the sample, rather it may be that the technique used does not have the required sensitivity to detect it at a low concentration. The sensitivity of a method depends both on the method and element or compound to be detected. In many cases, it will also depend on the “matrix”, *i.e.* the other compounds with which it is associated within the object.

The most useful techniques for conservation purposes are those that will identify the presence of a specific element, compound, or class of compounds, thus providing a qualitative analysis of the sample. In many cases, this analysis could give an idea of the relative concentrations of the elements or compounds found. However, as mentioned above, this is only an approximation and unless certain standards are used, the result can only be considered as semi-quantitative.

With the widespread computerisation of analytical instruments, results are often expressed as percentages, and, since a computer processes them, they are in most cases accepted as valid results by operators who do not have a thorough training in analytical techniques. It is therefore important to highlight that the interpretation of analytical results requires training and experience to be performed reliably. In particular, when dealing with archaeological and/or museum objects, which in general are unique, extensive experience is extremely important as the results obtained have to be interpreted in view of the historical information available about the object.

Most analytical techniques are based on the following principles: interaction of radiation with matter (such as Radiography, X-ray Diffraction (XRD), X-ray Fluorescence (XRF) and Fourier transform infrared spectrometers (FTIR)), or, interaction of elemental particles with matter (such as scanning electron microscope (SEM), energy dispersive X-ray spectroscopy (EDS), Thermoluminescent dating (TL) and Radiocarbon dating). More detailed information on some of the techniques described below and other special methods (such as UV and IR photography, gas chromatography and mass spectrometry) can be found elsewhere (Ferretti, 1993; Parrini, 1986; Sinclair *et al.*, 1997; Ainsworth, 1982).

3.1 Interaction of Radiation with Matter

Electromagnetic radiation has a broad spectrum, ranging from X-rays at high energies (short wavelength) to low-energy infrared light (long wavelength). The high-energy X-rays are capable of penetrating through solid bodies (hence, the need to be extremely cautious when using this radiation and the importance of having a good shielding system to protect operators). Since different materials have different densities, they will allow more or less radiation to go through. This is the principle used in radiography.

The high-energy X-rays when passing through matter are able to excite the electrons of the inner shells of an atom. When the excited electrons fall back to their original position they release the energy absorbed. This can be measured and is the principle used in X-ray fluorescence.

Radiation, when passing through an object that has “openings”, that is, in the same order of magnitude as its wavelength(s), is subject to the physical phenomenon of diffraction. This is the result of interference, *i.e.* that some wavelengths will be enhanced and other cancelled. When dealing with visible light, this phenomenon is the one that gives rise to the different colours visible, for example, when a thin oil film forms above water, the colour of an opal or some butterfly wings. Since X-rays have much smaller wavelengths, the spacing required to produce diffraction are found in the crystal lattice of materials. This principle is used for the characterization of materials in X-ray diffraction.

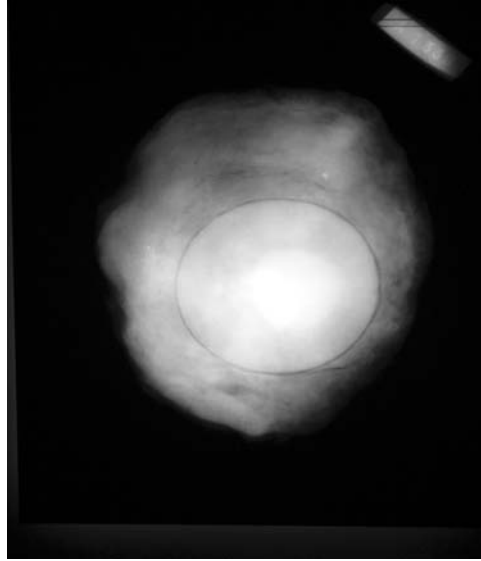


Figure 1 X-ray radiograph of sixteenth century iron shot

When dealing with low-energy infrared radiation, the interaction with matter is limited to the absorption of light by the outer shell electrons, *i.e.* those used in forming compounds. Hence, particular bonds will absorb particular wavelengths. This is the principle used for infrared spectroscopy. There are equivalent techniques for ultraviolet radiation and visible radiation, but they are mostly used to provide information about concentration of a given compound, rather than for identification purposes such as XRF or IR techniques.

Radiography. Radiography of the object is based on the capacity of X-rays to pass through most solid objects and to blacken a photographic film. The amount of X-rays of a given energy passing through an object will be dependent on the thickness and density of the material of the object. In general, the X-ray source is placed above the object and this, in turn over a photographic film. Usually, an X-ray tube serves as the radiation source whose energy can be controlled by the voltage applied to the tube, to produce the radiation. This will vary from 5 to 30 kV for drawings and paintings on wood, to between 250 and 1000 kV for large bronze and stone statues. The other variable that can be controlled is exposure time. Optimizing the conditions to obtain a clear radiograph of an object is essentially an empirical operation (see Figure 1). Radiography will allow one to understand much of an objects manufacturing technology as well as allowing one to see any previous structural interventions.

X-Ray Fluorescence. XRF will only provide information about the elemental composition of a sample (see Figure 2). This will be mostly limited to the

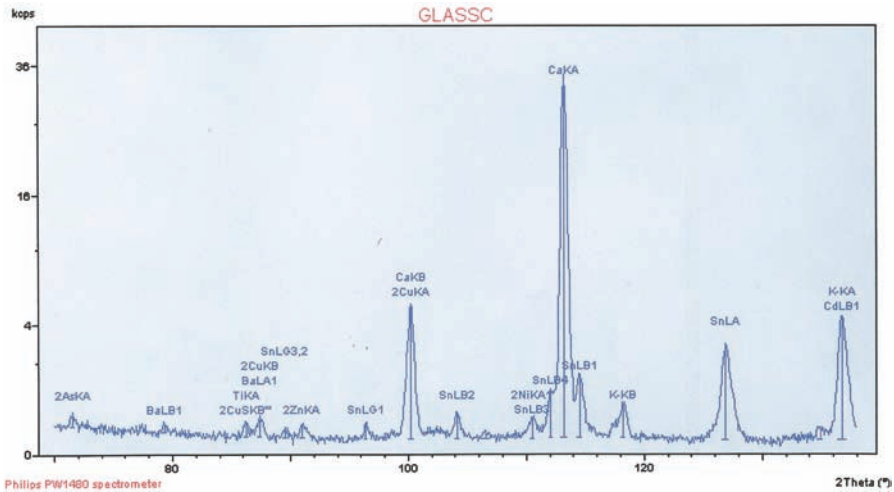


Figure 2 XRF spectrum of heavy metal coating of glass

surface of the object. The analysis is carried out in an air-path, or sometimes in a helium-flushed environment. One of the advantages of this technique is that it can be performed on large objects without sampling. However, the weaknesses are that, in an air-path, elemental detection is limited to the elements silicon and those with higher atomic numbers. Given that several layers can be present on the object, the depth of penetration of the X-ray beam may cause elemental information to be collected from different layers. In particular, this hampers quantitative analysis, the results being at best semi-quantitative if standard materials of similar composition are available for comparison. The detection limit for this method can be in the order of tens of ppm ($\mu\text{g/g}$).

X-Ray Diffraction. When monochromatic X-rays impinge on a crystalline material in which the crystal lattice dimensions are in the order of the wavelength of the X-rays, diffraction of the beam occurs. This is the result of the physical phenomenon of constructive (or destructive) interference. As a result, a diffraction pattern emerges where some beams are reinforced and other cancelled (see Figure 3).

XRD is generally carried out on finely powdered materials that are spread uniformly on an amorphous silica petrographic slide that is inserted into an isolated unit and then irradiated by monochromatic X-rays (in general the $\text{CuK}\alpha$ radiation). The detector is rotated with regards to the impinging X-ray beam, at a given speed. The diffractogram obtained is a plot of the intensity of the diffracted X-rays as a function of the angle (2θ) formed by the detector and the impinging X-ray beam. The finely powdered material, randomly oriented on the slide ensures statistical probability of obtaining a correct diffraction pattern of the material. The pattern obtained is compared with those of standard

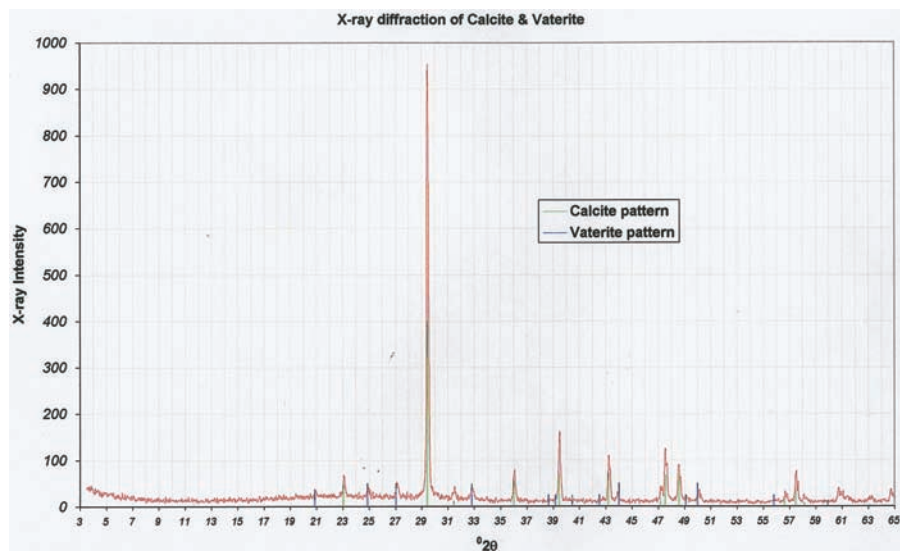


Figure 3 XRD Diffraction pattern of forms of calcium carbonate

materials. Sensitivity of the method depends on the nature of the material and ranges between 1 and 25% by weight, an average value being around 5%.

XRD is used for the identification of crystalline materials such as pigments, metal powders, organic materials and salts. Non-crystalline materials lacking a regular crystal lattice, such as glass, do not produce a clear pattern.

Infrared Spectroscopy. Infrared radiation is found between the higher energy (and shorter wavelength) visible light and the lower energy (and longer wavelength) of radio waves. When infrared light falls upon a compound it will interact with the outer shell electrons of a molecule, the ones that bond the atoms together to form that molecule. Thus, the technique can identify different types of bonding arrangements between atoms. Since bonds are not fixed in space but vibrate by stretching (distance between the atoms changes) or bending (the angle formed by the bond between the atoms varies), each type of movement will absorb a specific energy. The infrared absorption spectra produced can be divided into two regions, the group frequency region and the fingerprint region.

The group frequency region falls approximately between 4000 to 1400 cm^{-1} , and the absorption bands in it may be assigned to vibration of pairs of two (or sometimes three) atoms. The frequency is characteristic of the masses of the atoms involved and the nature of their bond, ignoring the rest of the molecule. Therefore, IR spectra are useful for determining the presence of functional groups in organic compounds: alcohols ($-\text{OH}$), ketones ($=\text{CO}$), amines

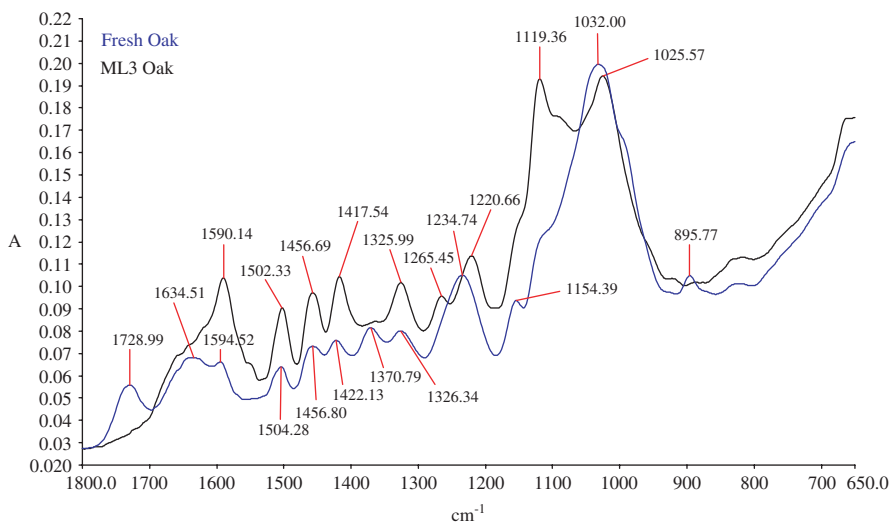


Figure 4 FTIR spectrum of fresh oak and ancient oak (ML3)

(—NH₂), etc. As a result, correlation charts tabulating the vibrational frequencies or absorption bands of the various functional groups are used.

In the fingerprint region (approximately 400–1400 cm⁻¹) the absorption bands correspond to the vibrations of the molecule as a whole, and are therefore characteristic for each molecule, and can serve as unambiguous identification by comparison with a standard. However, long polymers of a given family, such as long chains of fatty acids can give almost identical spectra.

The technology in infrared analysis has been improved significantly by the use of FTIR, which has increased the sensitivity of this method significantly (see Figure 4).

3.2 Interaction of Elemental Particles with Matter

Materials are made up of chemical compounds that in turn are formed by atoms. Atoms have essentially a dense nucleus around which a cloud of electrons balances the electrical charge of the nucleus. If high-energy electrons are shot at matter, some will bounce off the surface, some will penetrate into it producing X-rays, while others will interact with the higher energy electrons (inner shell electrons) of the atoms. These are the principles used for SEM, EDS and wavelength dispersive X-ray spectroscopy (WDS).

Scanning Electron Microscopy. A useful tool for investigation of the surface appearance of materials and any changes after treatment is the SEM. This tool is widely available in universities and some art museums. The principle of

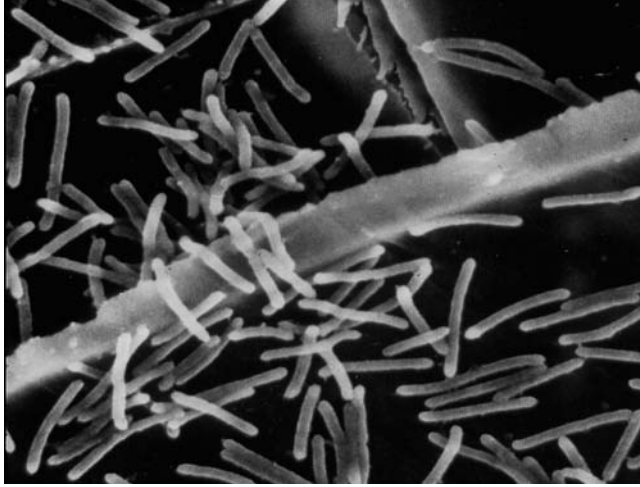


Figure 5 SEM photomicrograph of wood surface colonised by bacteria

operation is to generate an electron beam, with a range of 1–30 kV, at the top of a high-vacuum column. An electro-magnetic lens focuses the beam into a fine-spot size that then impinges onto the surface of the object to be examined. The unique feature of the SEM is that it has a set of scanning coils that drives the beam across the surface of the object, left to right, in a repeating fashion, similar to reading a book. As the beam interacts with the surface of the object different signals are generated from the sample surface. These surface interactions are collected by appropriate detectors, as the beam scans the surface, and are amplified and displayed on monitors (for a very readable introduction to SEM, see Postek *et al.*, 1980).

The main image generated by SEM is a surface image, generated from low-energy electrons (called secondary electrons), that are knocked out of the surface by the primary, high energy, beam. A black and white, 3-dimensional image of the surface is generated and presented on a cathode ray tube or computer monitor. Analysis of the surface morphology can produce much useful information (see Figure 5).

Another useful method that the SEM provides is that of viewing the surface of the sample with backscattered electrons. These are higher energy electrons from the primary beam that have been “bounced back” or scattered from the surface of the sample. The amount of back-scattered electrons depends on the atomic or molecular weight of the sample. The higher the atomic weight the higher the quantity of back-scattered electrons and the greater the contrast in image generated among elements of different atomic weight. Information collected in this mode can generate elemental distribution maps of the sample surface. Figure 6 compares two SEM photomicrographs of a corroded

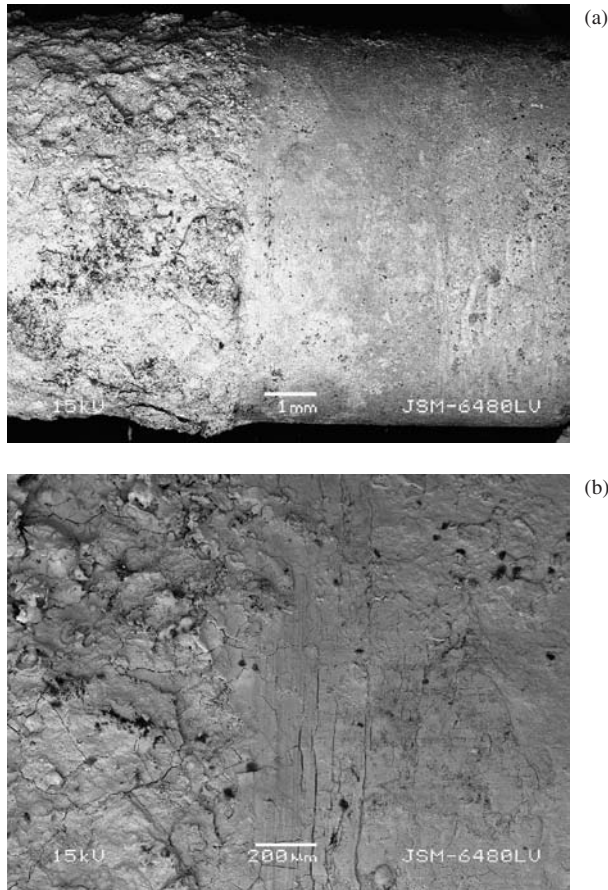


Figure 6 Scanning electron micrograph of a corroded iron bolt (a) SEI and (b) back-scattered electron image

iron bolt; one image produced by secondary electrons (SEI) and the other by back-scattered electrons.

Energy Dispersive X-ray Spectroscopy and Wavelength Dispersive Spectroscopy. Another useful signal collected from interactions of the primary beam with the sample surface are the X-rays generated within the sample. These can be analyzed both as a function of their energy (EDS) or their wavelength (WDS). EDS collects a range of energy signals, typically in the 0–10 KeV or 0–20 KeV range with a multi-channel SiLi detector. Each element in the sample produces a characteristic energy that can be collected and displayed on a monitor (see Figure 7).

EDS is a fast technique that can produce qualitative elemental information within a few minutes. Although the computer will process results in a

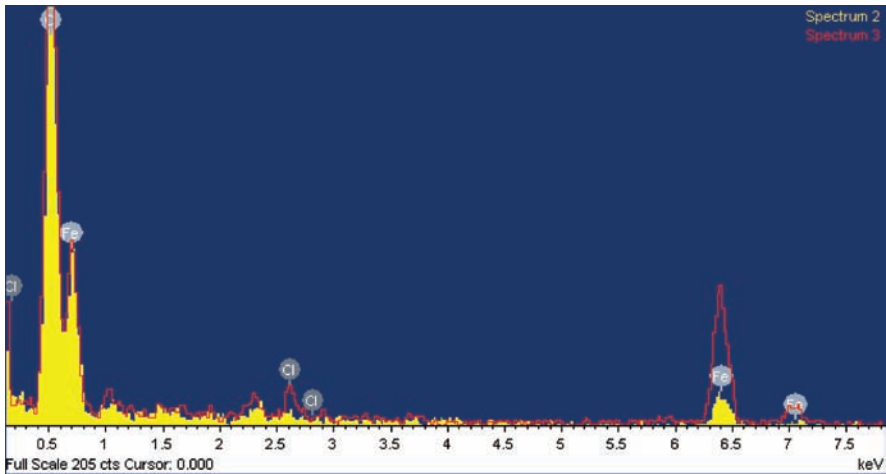
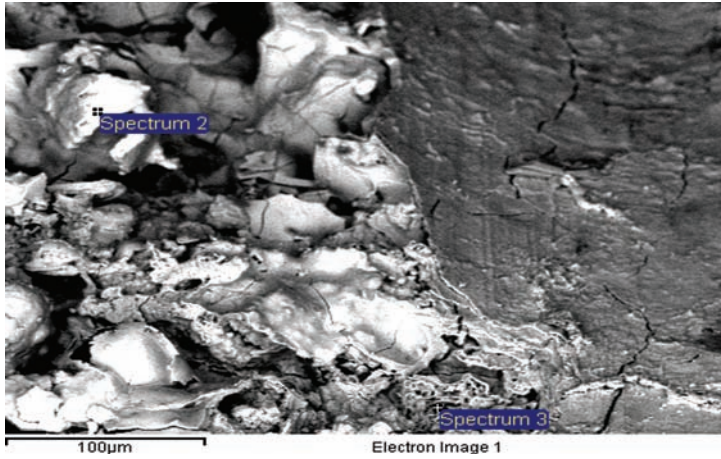


Figure 7 SEM and EDS of an iron bar

quantitative manner, care must be taken in its interpretation, as it may be indicative but not definitive. Some samples, *e.g.* polished metals, may yield quantitative results whilst powdery samples will be indicative of relative concentration at best. The sensitivity of this technique is typically in the 0.1–0.5% range, depending upon element and matrix.

WDS information is collected with a specific crystal detector that is rotated through the range where each specific element's diffraction wavelength is found. Different crystals are also used for different wavelength ranges and the geometry of the primary beam, sample and crystal are important for proper detection and collection of the information. WDS is much slower than EDS, but is generally one order of magnitude more sensitive than EDS. As a result, both techniques can nicely complement each other, as they have different

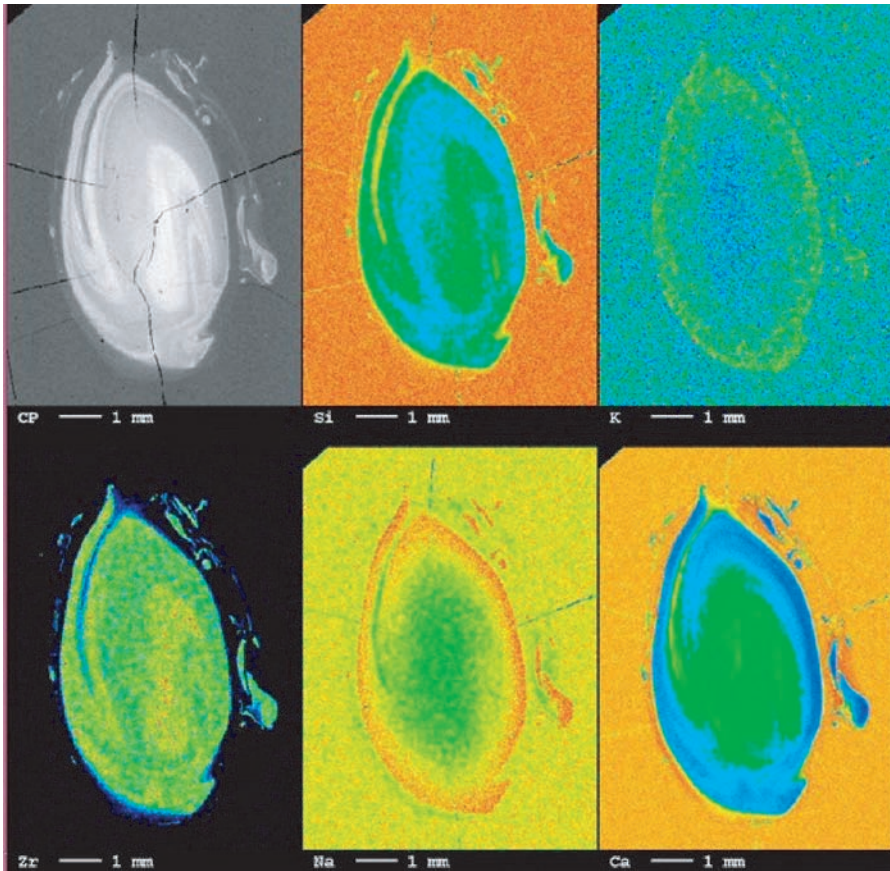


Figure 8 SEM and dot mapping of inclusions in glass

strengths and weaknesses, to produce a more accurate composition of the sample. Elemental maps may also be generated from EDS or WDS data. Figure 8 compares dot mapping with regular SEM images for inclusions in glass.

3.3 Dating Methods

The dating of an object is critical both from an archaeological point of view and from a museum point of view. In the first case, it will allow a date to be attributed to a settlement, or provide a chronological sequence in an excavation. In the second case, it may confirm or refute the assigned provenance of the object. Unfortunately, there is no single dating technique applicable to all materials. For example, obsidian objects can be dated by the thickness of the hydration layer that forms on this volcanic glass once an object has been fashioned out of it. Wood can often be dated by dendrochronology, which

counts the number of rings that trees develop with growth. Apart from the radiocarbon dating discussed below, there are several radioactive methods for dating other elements (see Dijkstra and Mosk, 1981). Each of the available dating techniques is limited to only some types of materials, and all of them are complex techniques that require much experience to be able to assess the data produced.

Radiocarbon 14 dating. Radiocarbon dating uses the physical and biological phenomenon of incorporation of the radioactive ^{14}C isotope into the biosphere (all living plants and animals; see Bowman, 1990). This isotope is continually formed in the upper atmosphere where it is rapidly converted into “marked” carbon dioxide $^{14}\text{CO}_2$. This in turn mixes within the atmosphere with the “normal” carbon dioxide (mostly $^{12}\text{CO}_2$) and in waters and is eventually utilized by living organisms and incorporated into their tissue. The ratio between these two isotopes is about 1:10¹². The activity associated with the ^{14}C in this equilibrium is about 15 disintegrations/minute.

Once an animal or plant dies, it ceases to accumulate CO_2 and the level of ^{14}C slowly decays as it disintegrates by β -emission. It takes approximately 5600 years for the number of ^{14}C atoms to decay by one half; this is called the half-life of the isotope. This rate of disintegration is directly proportional to the number of radioactive atoms present. Since the decay constant for ^{14}C is known, by measuring the decay rate of the object at the present time (and knowing the original decay rate) it is possible to calculate the age of the object.

Dateable materials are the organic matters that includes pollen, bone, charcoal, shell and many animal products and remains. There are a number of assumptions that go into dating and are best left to experts in the field to take into account when trying to determine a ^{14}C date for any material.

Thermoluminescent dating (TL). This technique is useful for dating pottery and ceramics (Wagner *et al.*, 1983). It is based on the cumulative effect of radiation from disintegrating radioactive isotopes present in minerals of most rocks, clays and soils. The ionizing radiation may cause electrons to detach from their parent atom and become trapped in lattice defects of the material. As the material ages, defects accumulate. When a ceramic object is fired, trapped electrons are freed and, since radioactive minerals are incorporated in the object, defects start to accumulate again.

TL uses this same principle to date the object. A small powdered sample of the object is heated and by measuring the emission of light in excess of the incandescent glow that is produced the date of the firing can be calculated. The technique requires calibration of each particular sample, since every clay particle will accumulate defects at a different rate. Although the operational principle of the method appears simple, it requires experience to interpret the data correctly.

4 DIAGNOSIS OF DETERIORATION PROCESSES

During the examination of the object it is important to assess its condition and determine whether it has deteriorated over time. If so, what were the causes that led to this change and is it still occurring?

For museum objects, in many cases the deterioration occurred prior to its acquisition by the collection; however, some deterioration agents may have entered into the body of the object, become dormant and continue to be a problem. Such is the case with archaeological ceramics that have been contaminated with soluble salts, or of wooden objects that bring with them insect infestation. Although in some cases it may appear that the deterioration is not progressing, this may re-appear at any moment prompted by a change in environmental conditions (temperature and relative humidity (RH)). The detection of these possible dormant deterioration factors is critical since it will allow a conservation treatment to be designed specifically to address them. For example, some potassium glasses are susceptible to changes in RH, around the 40% level. If the RH varies here, cracking and crizzling may occur. Some modern materials, *e.g.* Masonite[®], absorb moisture very rapidly, but release it slowly. This means that transient spikes in humidity may lead to moisture retention by a material, with subsequent fungal growth.

5 CONSERVATION TREATMENTS

Conservation treatments can be divided broadly into four main categories: cleaning, desalination, consolidation and disinfestations. Within each of these categories there can be several sub-categories for the different cases and different materials that have to be addressed, such as the de-acidification of paper. The following is an attempt to give a broad picture of the aim of these treatments and the problems that need to be considered. Three principles should guide any conservation intervention:

- Reversibility or retreatability
- Compatibility
- Minimum intervention

The concept of a “reversible” treatment was suggested by the traditional periodic removal and re-application of varnishes to oil paintings. However, this cannot really be extended to all objects. For example, an archaeological object may have an incrustation resulting from its long burial. Removal of this incrustation will result in the loss of information about the type of incrustation and the mechanism by which it was formed; information that may be crucial from an archaeological or historical point of view. Furthermore, this process is not reversible. The decision to remove the incrustation is based upon

a judgment of values, *e.g.* the value of the object itself is more important than its history; hence, part of the historical value is sacrificed as a function of the aesthetic value of the object.

A further example is furnished by the case where a fragile object requires consolidation. How can one expect that this treatment will be “reversible”, *i.e.* that it can be completely removed without risk of stressing the object even more by this removal? These considerations have led to replacing the “reversibility” concept with that of “retreatability” (see Teutonico *et al.*, 1997). In this case, any treatment applied should not preclude or hinder any future treatment. An example of a totally irreversible treatment is the complete impregnation of stone statues with *in-situ* polymerized methyl methacrylate.

The concept of compatibility asserts that any material applied to an object should be compatible with it, *i.e.* its properties should be as close as possible to eliminate future stresses. The problems that appear when different materials are put together in an object are illustrated by many of the museum objects that present conservation problems today. Consider, for example, an object that has a metal inlay in wood, as compared to stone inlay in stone. The latter has far fewer problems than the former, precisely because their properties, such as expansion coefficients upon heating or during changes in relative humidity, are similar.

Finally, the minimum intervention concept is the most important. This is because, as discussed above, any action taken on an object is irreversible, as time is irreversible. Any treatment applied changes the object and will interfere or preclude other analyses that one might want to do in the future. This is particularly important given the fast development of more sophisticated analytical techniques that can provide data that had not even been envisaged only 50 years ago.

5.1 Cleaning

This is probably the most frequent treatment performed on museum objects. It can range from removal of loosely-deposited surface dust to that of hard, adherent concretions. In general, it is considered as a simple and self-evident task and consequently not much thought is given to it. However, it is not a simple task and, in many cases, difficult decisions have to be made about how it has to be performed. If a metal object has a heavy calcareous incrustation covering most of it, would removal of this incrustation, which may result in the removal of the original patina the object had, be acceptable? Loss of the original patina means that part of the information that patina carried (How was that patina formed? Was it natural? Was it the result of an intentional treatment?) would be lost, and with it, part of the authenticity of the object.

If the case presented by a metal object is difficult, it is even more difficult in the case of a stone object, because the concept of “patina” is yet to be generally accepted for this material. In some cases, for example some porous

limestones, a hardening of the surface will result from their exposure to an unpolluted environment, referred to as “calcin” by the French. Some ferruginous sandstones may develop a thin, black surface layer (not to be mistaken with a black gypsum crust) when exposed outdoors, through migration of iron and manganese oxides to the surface. These can be considered “natural” patinas equivalent to those formed by metals such as aluminum and copper. On the other hand, there are man-applied patinas, such as the “scialbature” applied to marble sculptures and, in some cases, corresponding with the formation of an oxalate surface deposit.

At heart of the matter is to what degree should the object be cleaned? Does it have to look new? Or should it show its age? The current school of thought is that it should show its age. But this was not always the case. A good example is provided by the Elgin marbles – the marble sculptures acquired by Lord Elgin from the Parthenon in 1801–1802. These sculptures still had traces of polychromy when they were acquired; however, at the time, the perceived “classical” marble sculpture was white. Hence, the sculptures were cleaned down to the bare marble (Oddy, 2002). This clearly emphasizes the point that conservation is a cultural operation carried out by technical means. The conservator has to use his judgment in assessing the degree of cleaning required and this needs to be confirmed in conjunction with the historians and art historians.

Cleaning techniques may range from a simple dusting with a soft brush, to careful removal of light deposits with aid of a scalpel, or in some instances using spit on a cotton swap to effectively remove the deposit, with the enzymes in the spit providing a cleaning action. For harder deposits, microabrasive techniques can be used, or, in some cases, poultices may be applied.

5.2 Desalination

If the object contains potentially damaging soluble salts, as is the case for most archaeological ceramics, the approach to their removal will depend on the amount of salt present in the object. If it contains only a relatively low amount of them, then brushing off (or vacuuming off) the efflorescence may be the most effective method. However, if the object contains a large amount of them, then either poulticing or successive baths in distilled or de-ionized water may have to be the procedure used. These approaches need extra care, since successive poulticing may affect the surface finish on the object and, in the case of desalination by water immersion, the thoroughly water-soaked material will be far more delicate to handle.

5.3 Consolidation

When an object turns fragile because of its age and the consequent deterioration of the material, as is the case of textiles, papers and many objects from

natural history collections; or, because of the deterioration suffered by insect infestation or the presence of soluble salts, the object needs to be consolidated.

There are many products and procedures for carrying out a consolidation treatment, but they all involve introducing another material into the object. As discussed above, the ideal “reversible” treatment does not exist. Furthermore, once the treatment is introduced it may interfere with future objectives. For example, previously buried bones in natural history collections can be very friable and have been consolidated systematically to allow their presentation. This, however, precludes that they can be dated after treatment (especially if organic resins have been used), since more carbon has been introduced in the sample. It may also, preclude analysis of DNA, or other biological molecules.

5.4 Disinfestation

The problem of insect and microbial infestation of art is centuries old. Techniques to control it have included such things as herbal treatments, fire smoke and, most recently, chemicals. All have provided some degree of effectiveness if not complete control of the pests, but too often the treatment, whilst meant to save the art, has created damage of its own. A recent approach developed at the Metropolitan Museum of Art, and other institutions, is a non-chemical treatment using oxygen-free environments. The best choice for generating an oxygen-free environment is to use argon gas. This gas is heavier than oxygen so that it sinks to the bottom of the enclosure or bag forcing oxygen out of the object and pushing it to the top of the bag. This approach has proven very successful for insect control and also kills some species of fungi, if the residual oxygen level is low enough (but has no effect on spores).

The concept of anoxic treatment is simple, and is the same for any anoxic gas used. It consists, essentially, of the following three steps:

1. Isolate the object from the oxygen-rich environment;
2. Replace the oxygen-rich air with an anoxic (oxygen-less) air to the desired residual oxygen level; and
3. Wait until the insects die and then remove the object from its anoxic environment.

Whilst simple in concept, each step requires an understanding of environmental, physical and biological factors that may affect the procedure. Perhaps the most important of the three steps is isolation of the objects. Isolating an object requires construction of a suitable barrier around the object. This means any enclosure system must successfully maintain such a low level of oxygen for extended periods of time, ideally with a minimum of intervention and cost. The enclosure may be hard-walled or soft-walled. The soft-walled, *e.g.* heat-sealable oxygen barrier film, gives the flexibility to create any sized

enclosure specific to the need and is very portable – it permits an enclosure to be constructed on-site, reducing potential damage and costs of shipping.

How low an oxygen environment and for how long must it be held? To determine how long insect-infested objects must remain in a given argon environment has been determined by actual measurement of insect respiration before and after treatment by use of a gas cell FTIR system to measure the CO₂ produced by insects or fungi. Using this system it is possible to detect the presence of one insect in a 10-L bag within 4 h. A treatment length of 3–4 weeks, at less than 500 ppm (0.05%) oxygen in argon, is the recommended time (depending on insect species, life stage, size of object, and temperature and humidity conditions).

6 PREVENTIVE CONSERVATION

Following the considerations of the problems presented by conservation treatments, the ideal would be that these should not be necessary or are only required in a minimum of cases. From this consideration the idea of “preventive conservation”, that is, prevent the need of a conservation treatment, was born.

The concept of preventive conservation is to try and maintain, and monitor, the most appropriate environmental conditions around the art so as to reduce stresses on the objects and preserve them with no, or minimum treatment. For insect control, this is referred to as integrated pest management (IPM), but the principals of IPM can be extended to control of other problems in storage of art. IPM is basically good house-keeping: keep moisture away from materials – whether in the form of liquid water or high humidity; keep food, plant and animal products isolated from the art; keep an airflow around the objects to reduce the risk of moisture buildup; keep the environment clean. All objects are not the same and some may require special storage or display conditions, for example, a potassium-rich glass may “crizzle” if the humidity oscillates above and below 40% RH, whereas a soda-rich glass may not show any response to the change.

7 CONCLUSIONS

It is clear, from the brief discussion of but a few of the methods used in conservation that this is a large, interdisciplinary field. While the contribution of curators, art historians and scientists is fundamental, the conservator probably has the most difficult task: actually working on the object. This is an enormous responsibility and requires that the conservator acknowledges it as such. The key approach in conservation is respect for the object to be conserved. This requires that the conservator be a good observer, a talented craftsman and endowed with the clear discernment required to determine the exact point to which any procedure should be carried to.

What contributes to the complexity of the conservation field is the juxtaposition of the rigor needed in the methods used for analysis to the varying approaches that conservation requires, depending on time and location. Thus, while analytical methods rely on the use of standards against which measurements can be compared, conservation definitely does not have such standards. Furthermore, conservation relies heavily on the crafts component – a point that is being forgotten as the application of science has gained terrain in conservation. But science can never, nor should it, replace conservation. The contribution of science, with regard to conservation, is to help understand deterioration mechanisms that affect works of art and other cultural objects. This will certainly aid in diminishing their deterioration rate and assist in devising better preventive conservation approaches and better conservation methods, but the applications of these methods will still depend on the sense and sensibility of the conservator.

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