

Conservation technologies for archaeological sites and artifacts

1 . Conservation of archaeological sites

Excavation and conservation technology Archaeological sites which have been excavated are usually backfilled for preservation. Structural components which are difficult to conserve in their original, unearthed state when using the backfilling method, such as pillar bases and platform exteriors made of tuff, are subjected to preservation treatment after removal from the site. However, the ideal situation would be to preserve the excavation site as is, with the entire site exposed, without backfilling or removing site components.

When an excavation is carried out with a view to preserve and organize the site post-excavation, conservation technology becomes involved in a variety of forms. Investigating the material and structure of unearthed artifacts and remains yields important information in determining the archaeological nature of the site. An environmental investigation is also needed to find out the geographical conditions of the site as well as the state of preservation of the remains. Ultimately, it becomes necessary to formulate a conservation plan which takes all of this information into account in a comprehensive manner.

Conservation on site Remains situated in dry soil can be impregnated with a material such as synthetic resin to strengthen and stabilize the structures. However, in light of the weather resistance of synthetic resins and the structure of the remains, it is not an easy matter to carry out conservation in conditions exposed to direct sunlight and precipitation. Generally, a protective structure such as a cover or roof is installed over such sites for display and conservation, even when they are hardened with synthetic resin. In cases such as kiln sites, where the structure is three-dimensional and the ceiling portion has collapsed, a partial restoration may be performed which also serves to support and bolster the overhanging walls of the kiln. The ceiling portions are restored with hard urethane foam, which is lightweight and can be shaped freely. By partially restoring the ceiling, the structure of the kiln body can be more concretely presented for effective display and conservation.

The conservation of remains made of rock, such as foundations and platform exteriors, is also important. On the earth's surface, rocks are vulnerable to accelerated weathering from physical, chemical, and biological forces due to direct exposure to sunlight (temperature etc.), wind, rain, weather damage (moisture, wind, sand, acid rain, etc.), and salts. Of course, it is often the case that rocks which were underground for long periods have also deteriorated due to such effects as moisture.

There are several types of weathering depending on the type of rock. Plutonic rocks such as granite have large grain sizes and break up into fine gravel, granules, and sand due to the loss of cohesion among crystals with the disintegration of feldspars, micas, and, in some cases,

hornblendes. Volcanic rocks such as andesites are relatively likely to retain their shape, but even so the substrate (glass) of the surface layers has often undergone degeneration from hydrolysis and the feldspars which are present as phenocrysts have dissolved and disappeared. In general, black colored andesites have become whitened. Moisture-logged portions may have turned into clay. Pyroclastic rock, such as tuff, have weak consolidation to begin with (welded tuff has strong consolidation) and is prone to weathering. Porous by nature, tuff develops more cavities and spaces when weathered and becomes more absorbent of water. Needless to say, when severely weathered it becomes argillaceous, or clay-like. Tuff with high moisture content when unearthed must be kept from rapid drying, as it will begin to crack when allowed to dry quickly. The same thing can be said for sedimentary rocks such as sandstone. Generally speaking, rock which has deteriorated and developed many spaces will absorb more moisture, and will undergo more damage from freezing and thawing. Therefore, when excavation is performed during the winter, there is a need to protect the structures from freezing by applying a sheet over a thick layer of protective material such as unwoven fabric.

In performing conservation treatment, there is a need to strengthen the deteriorated rock and apply a water repellent finish to decrease moisture absorption. However, when strengthening the rock, care must be taken not to apply a coating which suffocates the rock. Impregnation is carried out with synthetic resins or strengthening/water repellent impregnants such as alkyl silicate. There is a need to devise ways to ensure sufficiently effective impregnation of the entire structure, as insufficient impregnation of the agent into the interior of the structure results in unevenness of strength, cracking, and separation of strata, and possible peeling of the surface in future. The dipping method, in which the structural component is immersed directly into the impregnant, and the continuous spray method, in which the impregnant solution is sprayed onto the rock, are some of the methods used to impregnate the rock effectively with the preservative.

Conservation through relocation etc. In not a few cases, important archaeological structures found through excavation cannot be preserved on site. Or, in many cases a portion of the cultural layer or shell midden must be cut out and transported indoors for close inspection. Archaeological structures thus removed can be utilized as effective displays in museums and resource centers. In such cases, hard urethane foam can be used to package the structure for removal and transportation. There are a variety of types of urethane foam. The type used for the removal of archaeological artifacts and structures is the kind where two liquids are combined and mixed together to create foam. It is capable of filling narrow, confined, irregular spaces completely with foam, allowing for complete on-site wrapping of intricately configured archaeological structures.

Recording the horizon of the geologic strata is also important in the disciplines of geology, prehistory, archaeology, and soil science. In Europe, methods of taking thin film cross-sections of sedimentary strata for the purpose of preserving profiles of geologic strata have been studied and

developed over a long period of time. There are two types of resin which have been developed for the purpose of collecting thin layers of soil strata in archaeological excavations: epoxy resin and polyurethane resin. Epoxy resin can be used for dry soil, and is characterized by its high strength and for having virtually no shrinkage during hardening. Polyurethane resin, on the other hand, is advantageous in that it can be used for damp soil strata, and has an extremely wide range of application. When used for soil stratum transcription, the resin is applied to the surface to be transcribed, to which gauze or other backing material is made to adhere to, and over which the resin is applied again. When the resin is completely hardened, it is rolled up and peeled off the soil strata. After the transcription is washed with water, it is subjected to surface treatment with resin, and affixed to a panel or similar backing for display and/or conservation.

2 . Conservation of archaeological artifacts

Investigation of the excavation environment Prior to subjecting an archaeological artifact to conservation treatment, it is important to investigate the kind of environment it was unearthed in, so as to consider what kind of conservation treatment to carry out, as well as the environment in which to conserve it prior to and following such treatment. That is, by investigating the underground environment of the artifact, we can explore the factors behind its deterioration and/or weathering, and use the information to identify the state of deterioration or to consider methods of conservation. Furthermore, this information is utilized when designing programs for the storage and display of cultural properties: conditions such as the appropriate temperature, humidity, and lighting, as well as the structural design of air conditioning equipment and storage facilities.

Specifically, measurements are taken of the temperature and humidity, and analyses are performed of the soil and water quality, to determine whether the artifact had always been kept in dry conditions, whether there were great fluctuations in temperature, the characteristics of the soil, etc. When handling metal artifacts, the chlorine concentration in the soil provides a wealth of information in regard to how to carry out the subsequent conservation treatment.

Removal of the artifact Archaeological artifacts which have remained relatively strong can be removed as is, without any special measures, as long as care is taken. However, in many cases the artifacts are in an advanced stage of corrosion and/or deterioration, and any attempts to remove them as they are may result in damage to the artifact's shape. Materials used for the removal of such fragile artifacts include hard urethane foam, mentioned above in the description of transporting archaeological structures, liquid nitrogen, or resin.

Dry artifacts are brushed with alcohol to remove the sand and soil on the surface to the degree to which it is possible. On-site cleaning should be kept to a minimum to avoid any loss of information that the artifact may hold. After drying, acrylic resin is applied to the artifact to strengthen it temporarily. When the use of acrylic resin alone is not sufficient, or when the artifact is broken into many fragments, several sheets of finely cut up gauze are pasted together and backed with resin

before removal of the artifact. After taking the artifact indoors, a solvent (acetone, toluene, xylene, etc.) can be used to take the gauze off, little by little.

Particularly special care must be taken when performing on-site cleaning of artifacts which are moist, as there is a possibility that the soil around it also contains textiles or other organic artifacts. If alcohol dehydration or air drying is possible, the aforementioned treatment can be carried out. When drying is not possible, water soluble acrylic resin may be used for treatment, or hard urethane foam may be utilized to cut out the artifact complete with the surrounding soil, and wrap it for removal. Plaster of Paris was often used in the past for the removal of fragile artifacts. However, because it is laborious and time-consuming to remove the plaster afterward, and in order to avoid inadvertent shaking etc. of the artifact, it is advisable to avoid the use of plaster. Also, when the artifact has a high moisture content making the above-mentioned work difficult, it may be possible to use liquid nitrogen to freeze the entire artifact with the soil around it for removal. However, it will thaw in a short time and there must be steps taken to ensure the shape can be maintained, by the use of urethane foam for example.

Materials analysis The conservation science of cultural properties begins with the analysis of its material. Materials analysis is performed first through observation with the naked eye and the microscope, with instrumental analysis carried out as necessary. However, when analyzing valuable cultural properties, it is preferable to do so without taking samples, that is, non-destructively. Even in the rare case when sampling is allowed, it is needless to say that the samples must be in very minute quantities.

Furthermore, the conservation science of archaeological artifacts demands an accurate grasp of the interior of the article, which cannot be seen. This is essential to elucidate the method of manufacture, and also provides information that is important for cleaning, restoration, and other processes of conservation. The most widely used method for investigating the interior structure of artifacts has been x-ray radiography. In recent years, researchers have been using technologies where data is directly digitized from images taken using imaging plates with a wide dynamic range. With this method, it is easy to perform computerized image analysis which is difficult with film photography. Furthermore, it is possible to extract the microstructure. At the same time, the technology of x-ray computer tomography, wherein the interior structure can be shown three-dimensionally, has also been introduced into the field of cultural properties, making it possible to obtain more detailed information. Neutron radiography is also being studied and put to practical use as a method for obtaining information that is different from that obtained through x-ray imaging.

Another method of analysis, which is most important and has become widely used, is the deciphering of characters written in ink on wooden strips and lacquered paper. This is performed through the combined use of infrared TV camera and image enhancement devices to decipher writing which is beyond the visible range of the naked eye. These devices are used to decipher

writing and drawings done in ink on pottery and metal articles in addition to those made of wood and paper.

Conservation treatment Traditional methods and techniques have always been valued for the conservation and repair of cultural properties, and the materials and technologies for conservation have been selected with care. In particular, the conservation of artwork, handicrafts, and architecture has relied heavily on traditional materials and methods.

However, most artifacts unearthed in archaeological excavations do not even have known methods of manufacture, not to mention traditional methods of restoration. These artifacts have already undergone physical and chemical changes and are in varying degrees of degeneration, necessitating a program of conservation treatment which makes full use of modern science.

Conservation treatment for organic artifacts Organic artifacts include those made of wood, fiber, and paper, out of which wooden articles are unearthed in the highest quantities. Wooden articles range from structural components such as pillars to containers, tools, and ornaments including bowls and pedestal tables, not much different from the modern day. In some cases the wooden articles have been lacquered with urushi or bear writing done in ink (such as in the case of wooden strips). The wooden articles unearthed in Japan are usually very fragile, with the cellulose component largely reduced and displaced with large quantities of water. Some broadleaf materials in severe stages of deterioration have a moisture content of 1500%. This means one kilogram of the wood contains 15 kilograms of water. Such a piece of wood, when allowed to air dry, will undergo such pronounced shrinkage and deformation it will no longer be possible to restore it to its original shape.

The most important thing in the conservation treatment of unearthed organic artifacts is to bring them to a dry state which can withstand display and storage, without causing shrinkage or deformation. Many methods of conservation treatment have been devised and implemented to date, and they all have one thing in common. That is that the treatment is done in two processes: “impregnation with a chemical agent,” and “drying/hardening with a chemical agent.”

Impregnation with a chemical agent can be done in one of two ways. One is to take a water-steeped article and impregnate it directly with a water soluble chemical agent. The other is to replace the water in the artifact with an organic solvent before impregnating the artifact with a water soluble chemical agent. When using water insoluble chemical agent for impregnation, the procedure of replacing the water within the artifact with an organic solvent becomes necessary as a preprocessing step. The primary objective of impregnation with a chemical agent is to strengthen the artifact and give it dimensional stability. When replacing the water in the artifact with the impregnating chemical agent, the impregnation step itself becomes the dehydrating process. In this process, the important point is the osmosis and diffusion of the chemical into the artifact. Generally speaking, when a high density solution is added to a low density solution, there is movement of

solute and solvent in an effort to make the overall density uniform. For instance, in the case of impregnation with polyethylene glycol, the solute is polyethylene glycol and the solvent is water. That is, the water within the artifact gradually works its way out while the polyethylene glycol or other impregnating agent seeps and diffuses its way in as the solute and solvent attempt to equalize the density inside and outside the artifact, and the water is progressively replaced with the chemical agent. The troublesome thing about the process of impregnation with a chemical agent is that the osmosis and diffusion of the chemical agent is not only dependent on the nature of the chemical but also greatly influenced by the properties of the archaeological artifact, such as the type of artifact, the species of wood, and the state of deterioration.

Once the impregnating step is complete, the artifact proceeds to the “drying/hardening with a chemical agent” step. When replacing the entire water content of the artifact with a water-soluble chemical agent, the final step is heating the artifact to melt the chemical impregnant and make it a liquid of 100% concentration. Nonsoluble agents which when heated become liquids of 100% concentration can also be used to ultimately replace all of the organic solvent within the artifact. When an artifact which has thus had all of its solvent (water or organic solvent) replaced with chemical impregnant is taken out of the processing tank and cooled, the impregnant becomes a solid and the artifact has been strengthened in a dry state. Or, in some cases the artifact is taken out of the tank at an impregnant concentration of 70-80% instead of bringing it to 100%. In such cases the 20-30% water or organic solvent remaining within the solution composition of the artifact is removed through air drying or by using part of the water as water of hydration for the crystallization of the chemical agent and allowing the rest to evaporate. In another method, freeze drying, the impregnation process is completed with the artifact still containing a significant amount of water or organic solvent, and the artifact undergoes drying under special conditions. The pronounced shrinkage and deformation of an organic archaeological artifact is largely due to the surface tension of water. When liquid water is heated, it boils at 100°C and turns to steam. However, when water is placed in a cup and allowed to stand, the amount gradually decreases until the cup is finally empty. As can be seen from this phenomenon, water molecules are always escaping from the surface of liquid water in an effort to maintain constant vapor pressure, even when the water is not heated to 100°C. When this liquid water becomes water vapor, significant pull strength is generated.

As can be seen in the everyday phenomenon of cut-up vegetables drying out when left in the freezer, water molecules are also escaping from the surface of solids as well. The phenomenon of solid ice turning into water vapor without first becoming liquid water is called sublimation. In sublimation, surface tension is negligible. Freeze drying makes use of this phenomenon. In reality, the water in the artifact is sometimes replaced with tertiary butyl alcohol for the purpose of enhancing drying efficiency and to minimize shrinkage and deformation.

Conservation of inorganic artifacts Inorganic artifacts are made of a wide range of materials:

earthenware, tile, stone, glass, ceramic, porcelain, metal, etc. Out of these, metal articles are especially prone to corrosion while buried and pose problems for conservation.

Ancient metal articles are made of various materials. Some are made from a single material such as iron, copper, silver, tin, or lead, while others are made of a combination of materials, such as copper-tin alloys or copper-plated iron, where iron was covered with copper plating. In any case, all metals except gold undergo some degree of corrosion while buried. The causes of corrosion are oxygen, moisture, and dissolved ions, with chloride ions believed to play a particularly major role. Such unearthened metal archaeological artifacts are subjected to scientific investigations relating to their structure and material, and are made to undergo conservation treatment before being displayed in public or put in storage.

In general, unearthened metal artifacts are covered with some type of rust. The covering of rust may have inhibited corrosion in some cases, while it may have accelerated it in other cases. In order to control the progression of rust after unearthening a metal artifact, it is important to identify the cause of the rust and eliminate as many causative factors as possible. Generally speaking, the causative factors of rust in metals are oxygen and moisture as external factors and soluble salts contained in the rust as an internal factor. Through the analysis of secondary matter, including rust, it is possible to determine from the artifact's history as to whether the rust will continue to progress in that particular artifact.

Many iron artifacts are covered with iron oxyhydroxide. There are three types of iron oxyhydroxide known to be found on unearthened iron artifacts: alpha-, beta-, and gamma-FeOOH. Beta-FeOOH (mineral name: akaganeite) is produced in the presence of chloride ions and accelerates corrosion, thereby posing problems for conservation. At present, conservation treatment is preceded by x-ray diffractometry to identify the type of rust, and by ion chromatography to determine the quantities of anions such as sulfate ions, fluoride ions, and nitrate ions, to formulate a program for conservation. In Japan, with its climate of high relative humidity, chloride ions are a significant causative factor for corrosion. Desalination treatment is therefore performed to remove these ions as much as possible. Various types of desalination processes, dry and wet (solution method), have been devised for iron artifacts, out of which the solution method is generally used in Japan. In recent years, methods have been developed involving the use of high-temperature, high-pressure chambers for the extraction chloride and sulfate ions from unearthened artifacts. After completing these types of chemical desalination steps, the artifact ultimately undergoes impregnation with acrylic resin to strengthen it.

Chloride ions are similarly associated with the corrosion of copper and bronze artifacts. The presence of these ions exacerbates corrosion and destroys the artifacts. Bronze mirrors, which appeared stable at the time of unearthening, have been known to succumb to general disintegration after several to dozen years due to advanced pitting. This kind of phenomenon which occurs

especially in bronze artifacts is called “bronze disease.” Copper (I) chloride (mineral name: nantokite) or hydrous copper chloride (mineral name: atacamite) is detected in the diseased parts. In recent years, the development of the non-destructive parallel beam x-ray diffractometer has made it possible to gain diffractometry data of rust without causing any damage to valuable cultural properties, thereby contributing to the early detection of bronze disease.

Bronze disease is sometimes treated by removing the causative chloride ions, but because bronze is more prone to changes in color compared to iron, the method is difficult to employ for fear of damaging the artifact. Therefore, methods have been developed and put into practice whereby a protective film is generated on fresh metal parts to prevent corrosion from advancing, and to protect the artifact from the forces of chloride ions. This is called the benzotriazole method and the principle is a type of chemical conversion treatment. It is now used generally on unearthened copper and bronze artifacts.

3 . The storage environment

Conservation treatment does not ensure the prevention of further degradation of the archaeological artifact. Instead, it is an attempt to inhibit further degradation as much as possible. For example, even when a wooden artifact is successfully conserved with polyethylene glycol, placing that artifact in high temperature and high humidity will cause the polyethylene glycol to absorb water and elute, causing the deformation and shrinkage of the artifact as a result. Or, even when a metal artifact is treated exactly according to theory, the rust may progress in reaction with moisture. In either case, the problem is not about the treatment itself but is about the major influence of the storage environment.

In order to minimize these kinds of storage problems, there is a need to maintain the storage environment in an optimal state. Notwithstanding the need to upgrade storage facilities so that they can maintain a constant temperature and humidity, it is also important to deal with each artifact individually. Generally speaking, oxygen and moisture are the environmental factors which are most closely associated with the deterioration of artifacts during storage. Therefore, devising methods to shield the artifact from oxygen and moisture will help to create significantly favorable conditions. One method devised from this standpoint is the use of deoxidizer and desiccant in a bag made of special film with extremely low air permeability. Since this method can be applied to artifacts of different types and sizes, it can be described as an excellent method of storage. However, it is not a permanent method and must be checked on continuously. In any case, we must recognize that artifacts which have undergone treatment are not stable in every kind of environment and that storage must be undertaken by checking the status on a continuous, ongoing basis.

