OBJECT INTERRED, OBJECT DISINTERRED

Gaël de Guichen
ICCROM, Rome, Italy

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Introduction: object interred, object disinterred

When any object, whatever it may be, is put in the ground, it generally finds itself in a different environment to that for which it was made. The essential characteristics of this new environment are:

- absence of light
- frequent presence of mineral salts carried in water
- contact with more or less corrosive soils
- an extremely stable temperature
- an extremely stable relative humidity (RH)
- limited access of air (particularly oxygen)

When in contact with this new environment, the object will undergo a transformation regardless of whether it is of an organic material (wood, textile, skin, paper) or an inorganic material (stone, ceramic, glass, metal). This transformation can affect its colour, weight, material, or size. In most cases transformation will lead to the total destruction of the object. In certain cases, unfortunately very rare, the object will not be destroyed because transformation will have brought the object to a new stable state. One says the object has reached an equilibrium with its environment.

The discovery of the object will generally involve transferring it to a new environment, again different, characterized by:

- variable RH with values considerably higher or lower than those of the soil;
- air, containing O_2 (plus CO_2 , SO_2 and other acid gases); and
- light, which can activate oxidation processes.

This abrupt change can be quite traumatic for the object, setting in motion processes that can result in its complete disappearance, sometimes within a few hours of discovery.

To avoid this destruction it is essential to understand the condition of the object at the moment of its discovery and the changes that it has undergone while it has been in the ground.

1. Some physical characteristics of materials that affect their conservation

(a) *Organic.* These materials come from the animal and vegetable world:

- They usually burn if ignited.
- They are sensitive to light.
- When the RH is above 65% and there is poor ventilation and no light, micro-organisms can grow on organic materials at their expense and will disfigure and weaken them in the long run.
- Most of them are hygroscopic and absorb water readily, undergoing a change in dimension.
- They tend always to keep their water content in equilibrium with the ambient RH.
  Consequently, *if the air is drier than they are*, they will give up water vapour and dry out. They lose weight and shrink, and are in danger of cracking.
  If the air is more humid than they are, they will absorb water vapour and become damp until they again reach an equilibrium with the ambient RH. In the process they will increase in weight and volume.

(b) *Inorganic.* These materials come from the mineral world:

- They usually do not burn when heated.
- They are not usually sensitive to light.
- Micro-organisms do not generally grow on these materials, or, if they do, it is not at their expense.
- Stone and ceramics are porous. They transport water in liquid form by capillarity. When put into contact with water containing soluble salts (as can happen underground), they will take them up. Once the object is excavated, these salts, being often hygroscopic, will take up water vapour from damp air, or crystallize in dry air. Metal and glass are not porous but can undergo chemical change (corrosion) which will transform these materials into mineral salts (either soluble or insoluble, but always sensitive to humidity in the air).

2. The underground environment

Anyone who has been in the cellar of a house will recognize the characteristics of the underground environment:

- lack of light;
- frequent presence of soluble salts (commonly, but often mistakenly, called saltpetre);
- contact with a soil containing water, salts, acids (or bases), etc. (a metallic object on the ground will corrode very quickly);
- a stable temperature (required for keeping wine in temperate climates); and
- stable humidity in general.

Conditions underground can vary considerably depending on the local situation:

(a) In desert areas, humidity in an enclosed space underground will vary according to the soil and the depth of the water table. By way of example, the tomb of Queen Nefertari in the Valley of the Queens in Egypt has a stable RH of 30%, whereas the tomb of Nefer at Saqqara has an RH of 66% (Nasri Iskander, personal communication). Of course, over the centuries, exceptional cloudbursts have resulted in considerable quantities of water entering these tombs and temporarily raising the RH.

(b) In cavities of an unusual nature, such as the salt mines of Wieliczka near Cracow in Poland, the RH is perfectly stable at 76% (the RH of a saturated salt solution).

(c) In general, in non-desert areas, the RH reaches 100% at a certain depth in cavities in the ground – i.e., the air is saturated and no evaporation is possible. An example is the prehistoric site of Lascaux in France.

Moreover, temperature in the ground is the result of heat's being transmitted by the soil. Seasonal variations that can be found at the surface will be reduced and eliminated the deeper one digs into the ground. At a depth of 5-6 m, the air temperature becomes extremely stable and can vary annually by only 1°C.

3. Modification, transformation, reaction of an organic object during burial and exposure

3.1 Burial

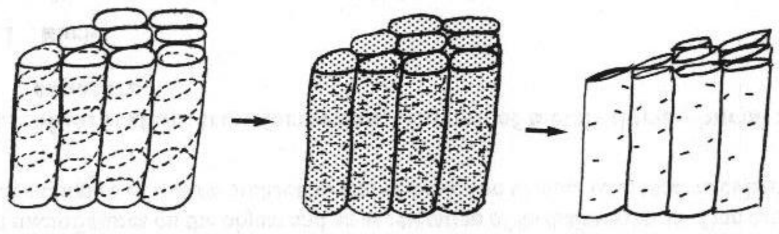
The absence of light and contact with more or less corrosive soils and with soluble salts are lesser factors in the deterioration of organic objects. A major factor is the level of the air's RH. It is this which will bring about deterioration.

If the RH is low, organic materials are in general well preserved. At worst, if the air in a cavity is too dry, cracks can appear. On the other hand, in a moist environment, organic materials have a very high probability of being attacked by micro-organisms (bacteria, fungus, mould). These will usually lead to the slow destruction of the object.

However, it is important to note the particular case of partial destruction when wood is immersed in water. Wood is composed of lignin and cellulose. Lignin (solid line in the drawing) forms kinds of empty tubes. Cellulose (dotted line in the drawing) forms spiral springs in the interiors of the tubes, preventing the tubes from collapsing inwards (fig. 1a).

During a long stay underwater, cellulose will gradually dissolve and disappear. The tubes of lignin do not collapse, however, because the water that has entered them plays the role formerly played by the cellulose. In this way, although it retains its appearance, the wood is transformed and is called 'waterlogged wood.' So long as it remains underwater, it will retain its shape and appearance perfectly well for hundreds of years (fig. 1b). The same is true of leather.

Figure 1.



a) Normal wood: lignin + cellulose

b) Waterlogged wood: lignin + deteriorated cellulose + water

c) Waterlogged wood exposed to the air: deteriorated lignin + cellulose

It is essential to understand that, whatever the humidity underground, certain organic objects are going to disappear and others will adapt to the prevailing humidity.

It will not be an object in wood that is going to be discovered but an object in wood that has been transformed into a new material which is stable only under certain humidity conditions. Therefore, any abrupt change of RH caused by its exposure can be fatal.

3.2 Exposure

Only by chance does the same humidity prevail below ground as above ground. Most of the time the air is drier above ground. Therefore, at the moment that a tomb is opened, drier air (not to be confused with warmer air) will penetrate the tomb and dry out the organic materials. The result will be a rapid transfer of water vapour from the object towards the air, causing a contraction of the surface of the material and pressure on its interior. From that moment on, there is a danger of surface splitting.

The same will happen when an organic object is excavated from the soil. In the case of waterlogged wood, this phenomenon is all the more impressive in that, with the evaporation of water from the object, the lignin no longer has interior support and collapses. The object can also irreversibly lose up to 90% of its weight and 80% of its volume within a few hours (fig. 1c).

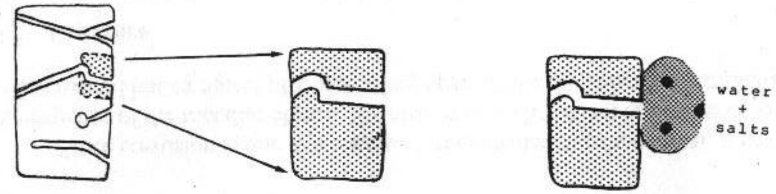
4. Modification, transformation, reaction of a porous inorganic object during burial and exposure

4.1 Burial

The absence of light and changing RH do not usually affect stone and ceramics, but the pH of the soil may do so. Moreover, the soluble salts and liquid water present in the soil, while not changing the external appearance of stone and ceramics, will penetrate into them, sometimes to the very core of the material.[1]

The process is simple. Stone and ceramics, being porous, contain an infinite number of minute pores. Through capillarity, these can absorb water and any salts previously dissolved in it right into the core of the material (fig. 2a-2c).

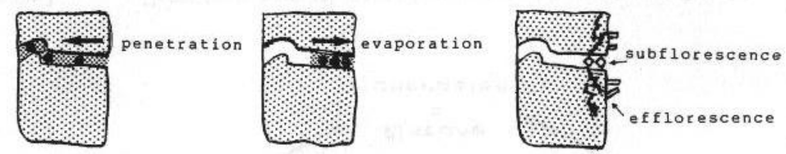
Figure 2.



2a) Section of a porous material

2b) Enlarged pore

2c) Put into contact with a drop of salty water



2d) The water has penetrated by capillarity, carrying the salt inside

2e) If the stone or brick dries out, the salts will concentrate towards the exit of the pore

and will crystallize with a mechanical effect that can cause fractures

1 All soils contain soluble salts in greater or lesser quantity. If the soil is near the sea, or is part of a former marine deposit, the quantity of sodium chloride is particularly high. Salts can also be introduced artificially through fertilizers and salt stores or through the de-icing of roads in cold countries, etc., by spreading mixtures of chlorides.

So for most of the time they are not merely stones or ceramics or mosaics that are discovered, but stone-with-salts, ceramics-with-salts or mosaics-with-salts.

4.2 Exposure

The discovery of a porous object either in a tomb or in the ground will generally put it into contact with drier air. The water filling the pores will then slowly evaporate and the water in the middle of the object will slowly migrate towards the surface, carrying soluble salts along with it. These arrive at the surface of the object, obviously cannot evaporate, and so they crystallize. This crystallization can sometimes happen beneath the impermeable surface of an object. All salts exert a pressure inside the pores at the moment of crystallization which may burst them, resulting in a surface flaking of the object to a greater or lesser extent (fig. 2d-2f). Crystallization can also occur on the surface of an object, which will be covered with a whitish deposit.

It is also essential to recall that insofar as a porous object contains soluble salts, these will move into the object according to the variations in the RH of the air. The process of dissolution, crystallization, re-dissolution and re-crystallization will result in microfissures on the object and an acceleration of its disintegration. One can easily see examples of this on archaeological ceramics on display or in reserve collections.

5. Modification, transformation, reaction of metals during burial and exposure

5.1 Burial

Apart from gold, metals are an unstable form of material. Minerals (salts or metallic oxides from which the metals were extracted) are the stable compounds of metals. The natural tendency of a metal is to regain its stable form and so to corrode, since the corrosion product is the salt or metallic oxide.

In the absence of water, corrosion affects, in general, only the surface of the metal and is seldom able to penetrate in depth (dry corrosion). When a film or water is formed on the surface, electrochemical corrosion (wet corrosion) takes place and it may cause a transformation in depth.

Absence of light will not damage a metallic object. On the other hand, the presence of oxygen and soluble mineral salts, contact with a more or less corrosive soil and a high RH will accelerate the transformation of the metal into a corrosion product (fig. 3).

This corrosion, which is due to the formation by chemical reaction of new products (sulphates, carbonates, chlorides, oxides, sulphur, etc.), will bring about an increase in volume of the object, a change in weight, a change in colour and a weakening of mechanical properties.

Thus a bronze object which was yellow might exceptionally remain yellow, but in most cases it will become red, black, blue, pale or dark green or layers of these colours depending on the environment(s) in which it is found.

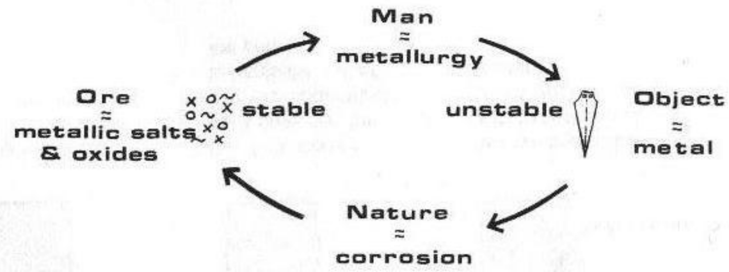


Figure 3. Corrosion is a natural destructive process which tends to re-form the salts and oxides from which the metal was extracted.

Since corrosion is due to a chemical transformation of the metal, it develops at the expense of the metallic object. So, also, it is not an object of bronze or silver that is discovered but an object of which a large part of the metal has been transformed.

5.2 Exposure

One might think that an excavated metallic object would not undergo further alteration because it has been removed from the corrosion stimulants; but there exist two types of corrosion:

- stable or passive corrosion which ceases its action the moment the object is removed from the soil in which it is found;
- unstable or active corrosion which continues its action at the expense of the remaining metal even if the object has been removed from the corrosive soil in which it was found. When the RH rises above 45%, the chlorides – or 'bronze disease' – are reactivated. This can happen within the space of an hour and can be very violent.

Active corrosion is frequently due to chlorides. It is especially common, therefore, on metallic objects found near the sea or in deserts. It appears in very bright green spots.

Consequently, if the bronze object has active corrosion, it will be essential to keep it in dry air, i.e., at 35% RH, if one does not want to run the risk of seeing it irreversibly transformed.

6. Modification of a glass object during burial and exposure

6.1 Burial

Glass is a composition of which the principal constituents are silica, lime and sodium oxides. It follows that, depending upon the proportions of the constituents, one will obtain not glass but various glasses. After burial in the ground, complex decomposition processes will transform the lime and sodium oxides into carbonates. This change often gives the object an iridescent appearance. If the alkali content of the glass is high, the corroded material is hygroscopic.

6.2 Exposure

At the moment of discovery, if the RH of the air is too high, the hygroscopic salts will absorb water vapour. At the other extreme, if the RH is low the hygroscopic salts will crystallize, with the risk that the glass will become even less transparent and may undergo mechanical damage. A suitable environment must be found for it, which is not an easy task.

7. Conclusion

Whatever the material of an object that has been buried in the ground – deliberately or accidentally – the burial will have brought about a profound physical, chemical or mechanical alteration:

- loss of weight, or sometimes a gain
- change of size
- change of colour
- change of chemical composition, etc.

This material was the material carrier of a message, either human, historical or technological, which the object brought to us. In order to let the object retain its message as intact as possible, it is essential from the moment of discovery to take a series of measures which will prevent the object, already mutilated by its stay underground, from being even more damaged by its being brought to light.