Amheida 2009 - Object conservation work

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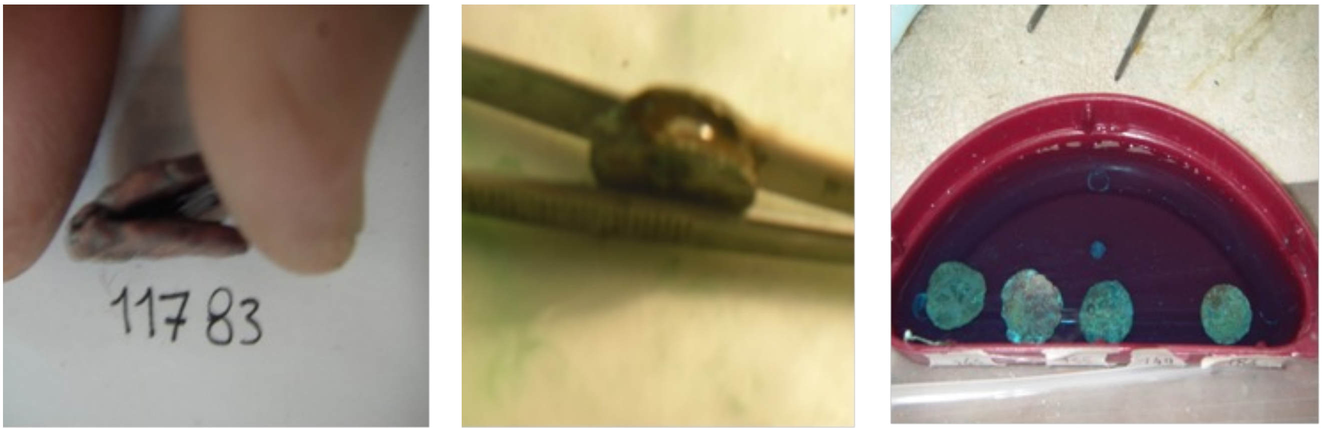
Work this year was concentrated on objects in the SCA's Dakhla antiquities magazine, which had been found in previous excavation seasons. These included coins, bronze rings, and some greenish objects of indeterminate shape. The shapeless fragments were under a big crust of green corrosion, with sand and soil; the rings were covered with a heavy green corrosion as usual at Amheida, thanks to the desert environment. The coins were of Roman date and covered with a crust of green corrosion, including sand and soil particles. Some coins were broken and separated into two fragments and then held together by corrosion; others had lost fragments. Sometimes the deterioration factors led to corrosion between the layers, with corrosion creating a separation between the two halves, especially toward the edges.

The treatments:
Each piece of coin was checked to decide on a system of suitable conservation treatment to be undertaken; generally, the steps taken were the following:
(1) Mechanical cleaning by scalpel, dremel, and metal tools under the microscope.
(2) Chemical cleaning, by immersion in formic acid or citric acid (5-10%) with heating, or by covering with cotton soaked in solution, or covering just the corroded areas with solution in gel to prevent the effusion and allow the use of the solution in localized cleaning, especially as most of the coins are of very small size, with fine details and inscriptions.
(3) Connecting and joining between the fragments by araldite, and filling the gap between the two sides by araldite with ground oxide in a similar color (fig, 2). After the coin is completely dry, the excess of araldite is carefully removed by dremel and metal tools.
(4) Immersion in distilled water repeatedly over a period of many hours, to neutralize the acidity (PH).
(5) Drying by silica gel a day or more to remove the humidity.
(6) In the final stage, covering the coin with 3% Paraloid (B72 on acetone) to avoid re-corrosion.

One of the shapeless objects during the cleaning process revealed the right side of the crown of a large statuette. At left, the corrosion crust; note the amount of the green layers of corrosion. At right, a small film of gold.

A bronze object shaped like a leaf, the two sides before and after cleaning. At left the back side. At right, the front side, showing relief like a tree. Note that the four holes may be for supporting by nails.



Left, state of coin damage separating the two sides. Center, after removing the corrosion between the two sides and using araldite with oxide as filler. Right, immersing in a solution as a step of cleaning.

Some of the coins after restoration.

Note the different sizes of coins.

I put these two coins into one frame, not only because the same figure appears (the female wolf standing, suckling the twins Remus and Romulus), but also to show the difference of corrosion. Note the left coin Inv. 11900 with the metal turned completely into cuprite (Cu_2O copper dioxide) on the two sides, with a reddish brown color. The right coin (Inv. 11777) had surface corrosion. The patina was sacrificed to recover the inscription and the figure.

Restoration work on two bronze oil lamps

As usual, working on the bronze objects is very interesting because of the unexpected details and decoration. Before conservation, it was impossible to determine the form and circumstances of the lamps, particularly their attachment to one another, and whether the current situation was a result of corrosion or of fabrication.

Because the materials of the lamps are bronze, the treatment and restoration methods described here are the same for them. But the description differs somewhat, because the larger lamp has a more significant lead element in its composition than the smaller. To understand what kind of corrosion and problems faced us, we need to know what factors in the circumstances on the excavation site contribute to the condition of the lamps. Future excavation practices may be improved by such knowledge.

Causes of deterioration:

1. Soluble salts: These were present both in simple ions and in compounded ions like carbonate CO3, sulfates So4, chlorides CL, and nitrates NO3. These are soluble in water and make acidic solutions that penetrate easily through the porous, sandy soil and then reach the surface of the object and lead to chemical reactions.
2. Moisture: the humid environment interacts with the soluble salts, soluble gases, and suspended materials in the ground to the detriment of the metal.
3. Temperature: As a result of the temperature changes during the daily cycle and through the year, there is a tendency for the salts in solution to evaporate; as a result, the salts form crystals between the grains of metal, which in turn lead to cracks. These can create physical pressure against the lower surface of the object and lead to the separation of some parts as a result. These factors can in combination produce significant damage to the objects.

Description:

The smaller oil lamp is composed of bronze, with a handle in the form of the head of a lion. It had a heavy green corrosion layer mixed with soil particles, which disfigured all surfaces and hid the decorations and the details completely. Small pieces were enclosed in this green-colored layer, including a chain attached to the lamp (fig. a), as well as a ring in the mouth of the lion. The body of the lamp is decorated with a flute-like design.

The larger lamp, also composed of bronze, with a handle in the form of the head of a lion and with remains of a ring in the mouth of the lion and a chain, had these elements attached to one another, so that the oil hole was covered with a broken ring and a hook, all attached to the paw of the lion (fig. b).

(fig. a) The chain adhering to the body of the small lamp.
(fig. b) The hook and remaining pieces of the large lamp.

The bronze corrosion:
The presence of humid but unpolluted air (as is the case at Amheida) creates a reddish brown layer (cuprite, Cu2O) as a first step in the electrochemical corrosion of copper and copper alloys. This is the product of cuprous ions, and when exposed to oxygen it turns black (Tenorite, CuO). The cuprite layer (up to 20 angstroms in thickness) can protect the surface in dry air. That corrosion can described by the following electrochemical reactions:

1) 2Cu=2Cu++2e-
2) 2Cu++O-=Cu2O
3) Cu2o+1/2O2=CuO

Cupreous metals are relatively noble metals, which frequently survive adverse conditions. Cupreous metals react with the environment to form similar alteration products, especially in presence of Chloride Cl- in the soil to form cuprous chloride as a major component of the corrosion layer (ionic bonds between Formula 1 and Cl-).

4) Cu+ + Cl- = CuCl

Cuprous chlorides (attacamite) are very unstable mineral compounds because of the activity of the Cl-. When cupreous objects that contain cuprous chlorides are recovered and exposed to air, they inevitably continue to corrode chemically by a process in which cuprous chlorides in the presence of moisture and oxygen are hydrolyzed to form hydrochloric acid and basic cupric chloride:

5) 4CuCl + 4H2O + O2 = CuCl2 · 3Cu(OH)2 + 2HCl

The hydrochloric acid in turn attacks the uncorroded metal to form more cuprous chloride: 2Cu + 2HCl = 2CuCl + H2. The reactions continue until no metal remains. So we can understand just how dangerous the presence of chloride Cl can be. This chemical corrosion process is commonly referred to as “bronze disease.” To restore objects suffering from this problem, the corrosion should be removed completely. This was precisely the situation at the point where the handle and body of each lamp joined (fig. n & n'), and the damage was filled out by araldite in a similar color.

In the acidic environment which contains credible concentrate of CO3—(bond with formula 2 and formula 3) in the moisture, green- and blue-colored cupric carbonates, malachite [Cu2(OH)2CO3], and azurite [Cu3(OH)2(CO3)2] are formed.

In the presence of disulphide SO2- (bond with formula 2 and formula 3) in moisture, CuSO4.3Cu(OH)2 (Brochantite) is formed in an emerald-green color. In our excavation a sandy environment is present, and the two most commonly encountered copper corrosion products are cuprous chloride and cuprous sulfide. The mineral alterations in copper alloys, however, can be more complex than those of pure copper.

In combining with the chloride in the soil, cupreous objects will self-destruct over time. Copper objects in humid air are also converted to cuprous and cupric sulfide (Cu2S and CuS) by the action of sulfate-reducing bacteria. In anaerobic environments, the copper sulfide products are usually in the lowest oxidation state, as are the ferrous sulfides and silver sulfides. After recovery and exposure to oxygen, the cuprous sulfides undergo subsequent oxidation to a higher oxidation state, cupric sulfide CuS, which is green in color.

Occasionally, the corrosion process will pit the surface of the artifact, but this is more common on cupreous alloys where tin or zinc is corroded preferentially. The stable copper sulfide layer does not adversely affect the object after recovery from the site; copper sulfides only discolor the copper, imparting an unnatural appearance to the metal.

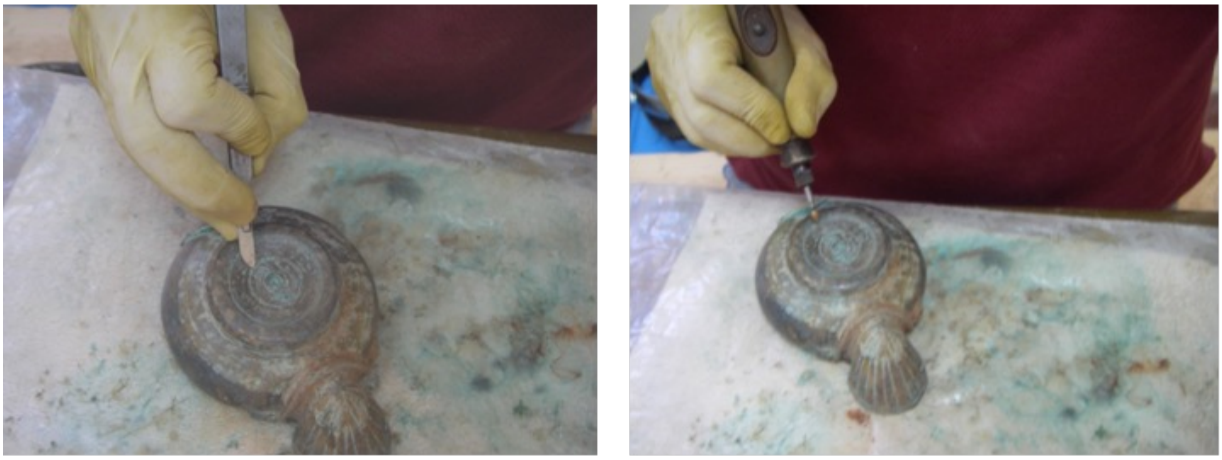
Conservation work:

The aim of cleaning was (1) discovering all possible information about each unit, (2) identifying each unit's relationships with other units, and (3) discovering the details and the decorations of the surface, which, fortunately, are in relatively good condition.

Mechanical Cleaning:

Depending on the physical effects of the layers of corrosion, mechanical cleaning was done by scalpel and by dremel, using different burrs and brushes. These and the speed of the dremel were varied according to the thickness of the corrosion layers, the particles of soil, sand, and sometimes quartzite that reached the surface, what condition the surface was in, and whether the surface was decorated (fig. c & d).

Mechanical cleaning with dremel (note the different burrs)
(fig. c) The hand of the big lamp; note the chain arrow
(fig. d) The base of the larger lamp; note the decoration.



Mechanical cleaning with scalpel and dremel.

Chemical cleaning was accomplished by immersion in formic acid (5-10%) in order to remove the green layers, and citric acid (5-10%) to remove the reddish brown. Sometimes soaked cotton was used instead of immersion, as shown.

Chemical cleaning by immersion in solution or by cotton soaked in solution.

The first step was consolidating the small pieces by (3-5%) paraloid. In a second phase, the units were separated from the body of the small lamp, covered with cotton soaked in formic acid 10%, and sometimes in citric acid 10%.
The cleaning of the handle in the form of a lion's head was undertaken carefully under microscope with mechanical cleaning by dremel and scalpel to remove the humid corrosion after immersing in citric acid 10% because of the decoration.
The main cleaning method to the body was by dremel and scalpel in a horizontal direction, removing corrosion layer by layer; at times, EDTA 10% or citric acid 10% was used as chemical cleaning.

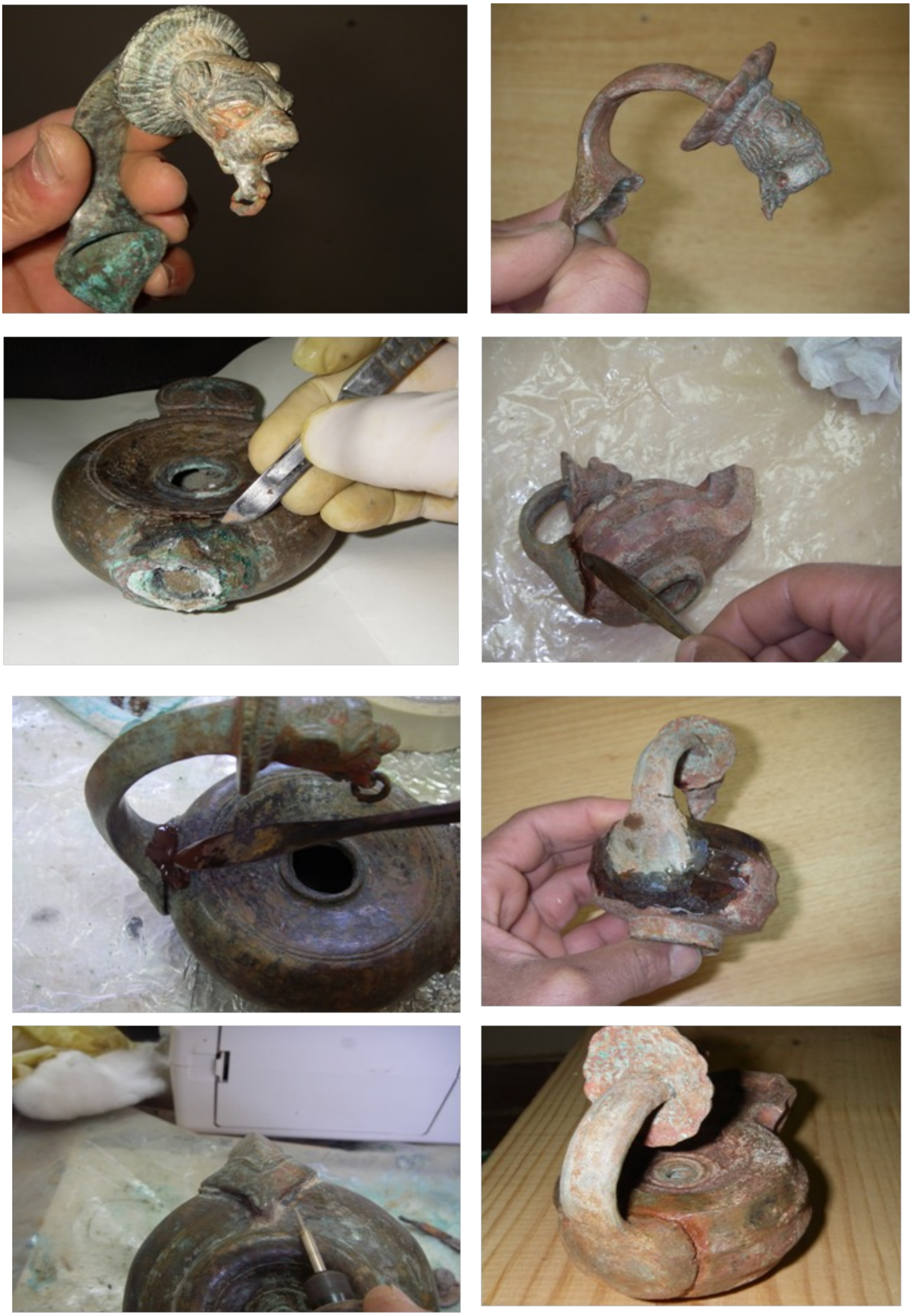
The work on the chains took very considerable time and effort, beginning with separating them from the body of each lamp, then cleaning them by immersing them in solutions and removing the soft corrosion by scalpel and dremel. It was then possible to separate all of the units of the chain from one another. These were then rejoined to one another, fixing them with araldite. The links of the chain were rejoined with araldite. It was thus possible to reconstitute the complete chain and permit free movement.

The stages of work of cleaning, separating, and rejoining the pieces of the links in the chain.

The hooks also had been broken into numerous fragments. These were collected, cleaned, and rejoined with araldite under a heating lamp to permit good penetration of the resin. After drying completely (6-10 hours), they were cleaned using the dremel. The chain was then reattached to the ring on the lion mouth and joined with the hook with resin. The hook of the large lamp, which had adhered as a result of corrosion to the hand and the body of the lamp, was separated successfully with the dremel and cleaned by immersing it in citric acid 10%, as well as by using the dremel and the scalpel, using araldite to rejoin the fragments (fig, e, f, g, h). The ring of the cover of the oil hole was reattached and fixed by resin (cynolite) in a similar color (fig. i, j, k).

(fig. e, f, g, h)
Cleaning and joining the hooks with araldite in similar color and using cynolite resin.

(fig. i, j, k)
Cleaning and joining the ring of the oil hole cover and mechanical cleaning by drill



Removing the corrosion in the zone of the juncture between the hands and the body, and rejoining by araldite in similar color and removing the excess by dremel.

My interpretation of the use of the lamps.

The lamps after restoration.