

Conservation interventions at the site of Berenike (Egypt): challenges and solutions in an ancient city of the Eastern Desert

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Abstract: The desert climate of the Berenike site in the Eastern Desert of Egypt are conducive to the preservation of substantial quantities of both organic and inorganic archaeological remains. Field conservation is thus fundamental and indispensable to each archaeological campaign. All interventions have as the main objective stabilizing the material, facilitating the identification of finds and ensuring artifact conservation as much as possible. The paper focuses on the specific conditions making this site unique and an ideal place for the preservation of all materials, paying special attention to the ancient harbor area with its significant number of remains of carbonized wood belonging on the whole to several ancient Roman ships. Interventions on these materials are discussed with the goal of determining the basic problems faced by conservators working at this site, the extent to which these interventions should be carried and the scientific dialogue with archaeologists and field specialists.

Keywords: desert conditions of preservation, conservation interventions, carbonized wood, organic and inorganic artifacts, stabilizing

The Berenike site is a harbor town founded in the Ptolemaic period (3rd century BC) on the Red Sea coast, today 260 km east of Aswan and 825 km south of the Suez Canal. It is located in a bay strategically conducive to the development of maritime commerce, experiencing its heyday in Roman times but deserted in the 6th century AD. Flourishing during the first centuries of our era, Berenike became a leading commercial emporium thanks to trade with the Horn of Africa, the Arabian Peninsula and India.

Despite this richness, its development was marked regularly and permanently

by the environmental characteristics of its location, that is, the Eastern Desert. These characteristics made it more difficult to ensure the vital logistics involved in day-to-day functioning at the site and they have also affected adversely work conditions for the archaeological team at the site today. Nevertheless, these same conditions have permitted the conservation *in situ* of a tremendous amount of materials, which after their documentation and study; have provided a great deal of data informing us of the social, economic and cultural aspects of the society that used to reside in Berenike.

Thus, getting to know the environmental and geological context in which the Berenike site is set is essential in order to understand the state of conservation of the archaeological materials that are extracted year by year. Without any doubt, the desert climate is one of the fundamental factors that ensured the preservation of these artifacts (made of such diverse materials) in such good condition after more than two millennia.

WEATHER CONDITIONS AT THE BERENIKE SITE

The climate of the Eastern Desert is known for a lack of rain (about 3 mm per year, according to the Global Precipitation Climatology Centre [GPCC]), an everyday thermal amplitude, humidity in the 50–60% range, and as a result of that, a high level of evapotranspiration.

In addition, the fact that the site is so close to the Red Sea coast [Fig. 1] triggers a remarkable salinization of the ground. The extreme evaporation of seawater found in the soil brings a precipitation of salts (especially sodium chloride) and gypsum that accumulates both under and over the ground. This salinization precludes any kind of vegetal growth (Sánchez Vizcaino and Cañabate Guerrero 1998: 99).

This soil is formed basically by sandy areas, limestone, calcareous cements, lime, gypsum and fossilized corals, which causes its alkalinity to be 8–8.5pH (Cronyn 1990). The basicity of these soils creates a serious conservation issue for many materials, such as glass. However, it will also be one of the agents that allows many other materials (like organic objects) to be preserved today.



Fig. 1. *The site of Berenike in the Eastern Desert of Egypt on the Red Sea coast*
(Photo D. Eguiluz Maestro)

ALTERATION FACTORS INFLUENCING ARCHAEOLOGICAL MATERIAL

Whenever speaking of the alteration or degradation of archaeological materials one must take into account the factors and agents taking part in this process, both intrinsic to the physical and chemical characteristics of every material and extrinsic, that is, referring to the environmental, terrestrial, historic and human buried context. Here the focus will be primarily on the entire external context of the Berenike site due to its singularity and the specificity of its characteristics.

The extreme environment of the Eastern Desert makes the alteration suffered by archaeological materials minimal and ensures that artifacts found there stay intact. This is mainly due to soil alkalinity, low humidity and the absence of vegetal and animal organic matter, and it is also the result of decomposition agents. Even so, decay is inevitable. The most important of the decay factors are as follows.

TEMPERATURE

The temperature variation in this desert is quite notable, with a range of up to 20°C between day and night. During winter, for example, it may vary between 12 and 30°C. These great thermal fluctuations provoke some tension both in the soil and in the buried objects, which triggers sudden expansion and contraction of the material. As time goes by, these changes translate into cracks, fissures and even fragmentation.

SALTS

The high levels of salt in the soil of this site are the main degradation agent of

archaeological artifacts. As said above, these salts, dissolved in seawater, enter the soil through humidity, the soil's capillarity and seasonal rains. The high temperatures that are characteristic of the desert climate make the water found in the soil evaporate quickly, which results in the solidification of the dissolved salts within and over the archaeological objects. This results in extensive saline concretions or even fissures in materials such as ceramic and bone, especially when the salts solidify within the pores of archaeological artifacts.

OXYGEN AND HUMIDITY

In this case, the two factors are linked, as the presence of oxygen in alkaline soil and the humidity introduced by the sea activates the physical and chemical reactions that trigger the alteration of materials as delicate as metals, among others. Thus, when metal comes into contact with oxygen or water, the corrosion process of this material begins a process that cannot be reversed.

The depth at which an object is found can influence its state of conservation as well. Artifacts located in more superficial layers will be in a drier environment, but more exposed to oxygen, whereas objects lying deeper will be affected by the presence of water and humidity.¹

It is important to note that despite the fact that the action of these agents is not very high and that materials remain in very stable conditions while buried, all mechanisms of alteration are speeded up dramatically once these objects are

¹ Soil begins to be humid at 20 cm of depth due to phreatic zones that are found deeper (approximately at 3.50 m).

extracted from the soil and come in contact with the atmosphere. Degradation increases consequently. Because of this, the conservator must be aware of all the diffe-

rent materials present in these objects, as well as their main physical and chemical characteristics and their intrinsic alteration processes in order to stop this activation.

MATERIALS PRESERVED AT THE BERENIKE SITE

Berenike has yielded a varied set of objects made of materials of different inorganic (ceramics, metal, stone, etc.) and organic origin (bone, wood or vegetal fabric).

METAL ARTIFACTS

Metal artifacts are among the most frequent finds at the site, next to ceramics and malacofauna. Bronze objects such as nails, small plaques, etc. of everyday use are excavated on a regular basis. It is quite common to find coins and, in very specific contexts as in a temple for instance, small votive sculptures [*Fig. 2* top left].

Metal is a highly unstable material that, from the moment it is created, starts a natural process of degradation. The metal objects at Berenike are usually in an advanced state of corrosion² and these are the principal agents of alteration: the presence of humidity, oxygen and salts—even though their presence is not very high, it is certainly active—and the alkalinity of the soil, because alkaline ground is known to have a high electric conductivity, thus favoring chemical reactions that produce metal corrosion (Gómez Moral 2004: 43).

However, objects made of copper and bronze, a copper alloy, usually have a large quantity of metal in their composition; up to a point where coins can be found in a perfect state of conservation, within

an intense and compact accumulation of corrosion [*Fig. 2* top right].

POTTERY

The amount of pottery found at the site in comparison to objects made of other materials is quite large. The state of preservation is generally good, except for the fact that they have large quantities of salt accumulation both within the paste and on the surface, which creates big saline concretions. Nevertheless, amphorae and other vessels need to be lifted and transported to storage; if fragmented, pieces have to be mended [*Fig. 3*]; and when ostraka are found, it is essential to bring out the ink in order to facilitate the reading. Moreover, small objects of faience are also found, being usually in very fragile condition.

STONE

This is the least common group, as not many objects made of stone are found in the current excavation. There are rare exceptions, like the remains of a pillar and stela fragments with relief decoration and inscriptions [e.g., *Fig. 2* center]. However, the field conservation laboratory has never been required to intervene with specific preservation procedures apart from guaranteeing environmental stability in order to avoid potential alteration of the

² Corrosion leads not only to changes in the material, but also to severe and permanent plastic deformations, cracks and even breaks (Meyer-Roudet 1999).

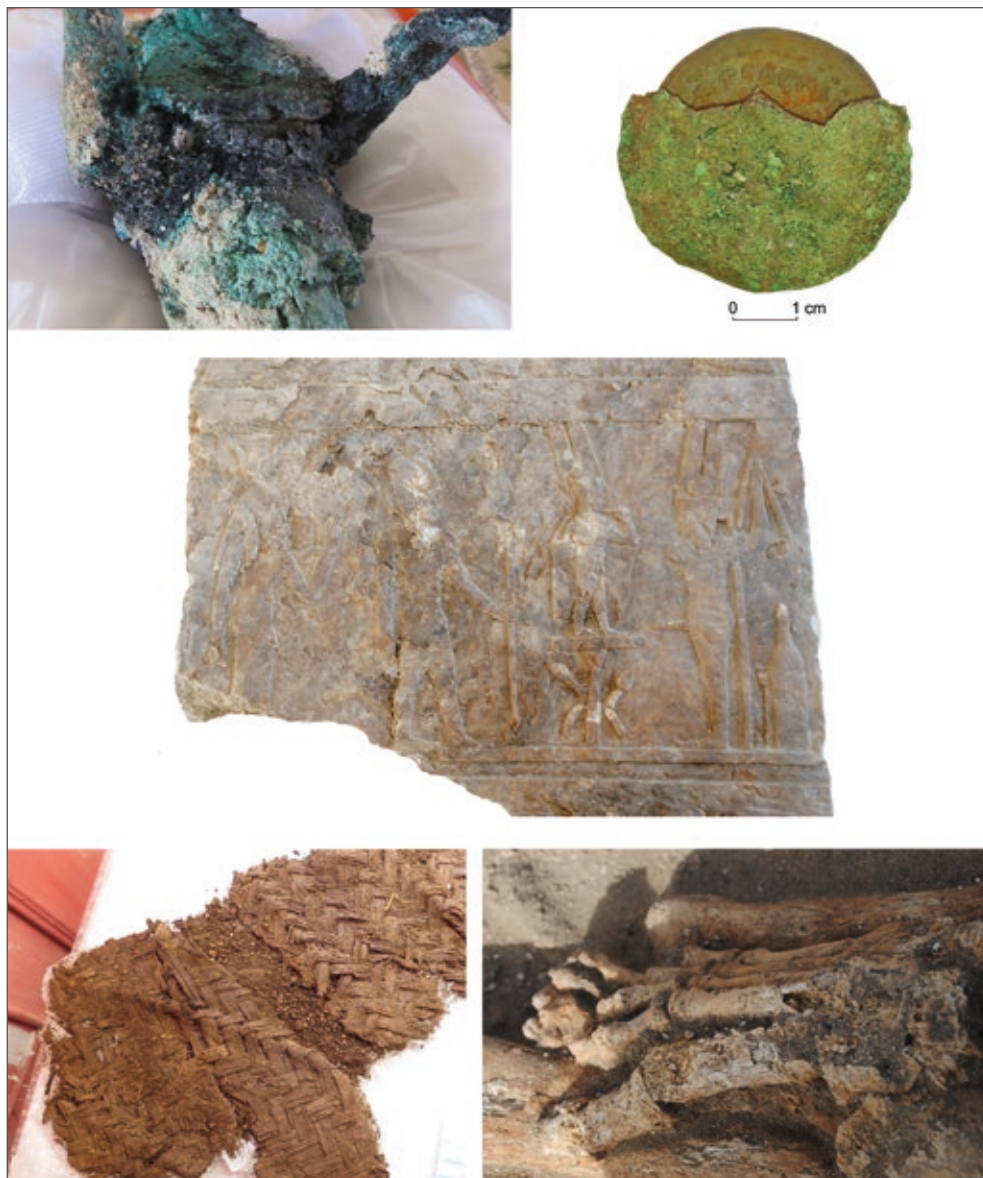


Fig. 2. Artifacts found at Berenike representing different kinds of materials: top left, small bronze figure (BE13/61/126) from the late Harbor Temple found in 2013, showing advanced corrosion; top right, corrosion formed on a bronze coin; center, detail of a limestone stela (BE15-111/011/002) found in the Berenike Isis Temple in 2015; bottom left, basketry fragment in situ (BE15-109/017/054); bottom right, saline concretions covering the preserved osseous tissue of human bones (Courtesy PCMA–University of Delaware Berenike Project/photos D. Eguiluz Maestro)

stone support (for earlier field conservation work at Berenike, see Lach 2017).

VEGETAL

In relation to organic materials, one of the most common objects found in Berenike are those made of vegetal tissue, such as rope, baskets and mats. Once again, the deposition of these objects in an arid soil has favored their sometimes excellent conservation. Nevertheless, this material is found in extremely altered state. The fabric is very dry and surrounded by precipitated salts [Fig. 2 bottom left].³ This forces loss of flexibility, making the artifacts extremely rigid and fragile.

BONES

Bones are similar to vegetal material: bone is easily preserved at the Berenike site due to the alkaline pH level of the

soil and to the absence of organic matter and superior plants. Therefore, it is quite common to find large quantities of animal remains: cats, dogs, turtles, monkeys, and even human bones in some instances. Nevertheless, this material is extremely friable, mainly due to salts [Fig. 2 bottom right]. Its crystallization within the osseous tissue triggers massive alterations such as fractures, erosion and decohesion, which in most cases causes the pulverization of the osseous tissue when excavated. This bad preservation makes it impossible to run any kind of conservation treatment after lifting from the trench.

WOOD

One of the characteristics that make Berenike such an important site is the preservation of numerous wooden elements coming from naval structures

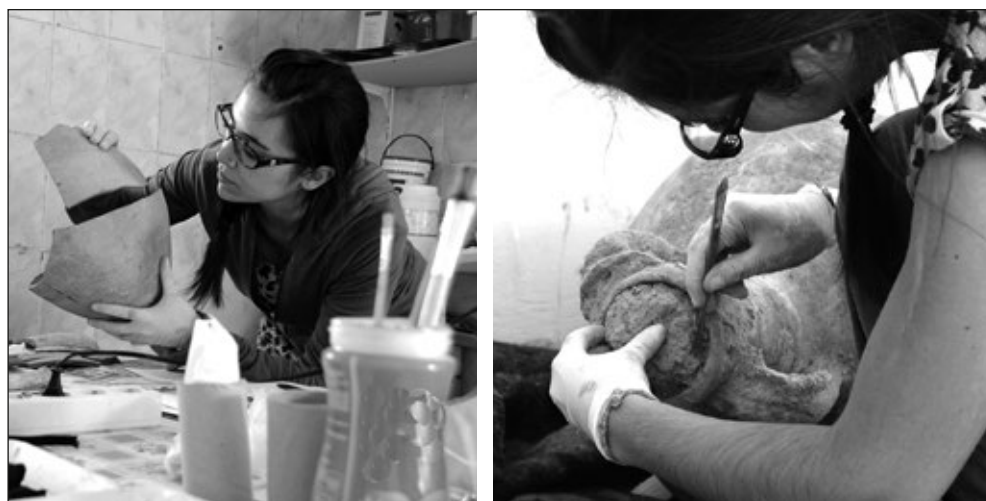


Fig. 3. Pottery interventions: left, field conservator Delia Eguiluz Maestro recomposing joining pieces for documentation purposes; right, opening of a sealed amphora under controlled conditions (courtesy PCMA–University of Delaware Berenike Project)

³ This precipitation of salts is mainly due to the hygroscopicity that is characteristic of vegetal matter and every organic matter in general.

that date from the Roman period. Several fragments of Roman vessels have been recovered over the years. They are usually found completely carbonized [see *Fig. 6*], which makes it possible for these fragments to preserve their original morphology. Hence, the volume of information gathered from these objects is quite remarkable.

Nevertheless, this situation raises several problems for conservation with regards to its preservation, extraction and manipulation, due to the fragility of the wood that has gone through a carbonization process.

Regarding the combustion process wood goes through, the following should be emphasized: dehydration (as it loses water, carbonic anhydrides and organic gases), torrefaction (which occurs at 170°C), pyrolysis (where the complete chemical

decomposition of the organic matter takes place and thus turns into charcoal, a process occurring at 270°C) and the final stage (this process can reach 700°C and turn wood into ashes). Therefore, the fact that this wood has been preserved is due to the combustion process that never reached the final phase. Thus, the wood became charcoal, but it was never completely consumed (Diloli Fons et al. 2014: 60).

The physical and chemical changes that this carbonized material suffers are fundamentally the conversion into charcoal, its dehydration and the loss of volume. However, its microstructure is preserved almost intact and the fact that its chemical composition changes makes it more resistant and stable when exposed to degradation agents such as humidity and oxygen (Diloli Fons et al. 2014: 61).

CONSERVATION CRITERIA AND OBJECTIVES

The conservator's main duty is to guarantee the conservation of the objects that are excavated at the site, trying to secure the highest physical and chemical stability. In order to meet this objective, it is essential to apply the minimum intervention criteria, to always use reversible materials and to carry out a methodical written and photographic register of the state of conservation of the objects and of every and each of the treatments applied. These tenets were established in the 1987 Charter for the Conservation and Restoration of Cultural and Art Objects.

At the Berenike site, the conservation of archaeological objects is essentially the result of a joint interdisciplinary approach of the whole excavation team. For this reason, on many occasions, stabilization and conservation interventions are linked

to other interventions, such as lifting from the archaeological context, which helps the field archaeologists to continue their work, or the recovery of the writing on some altered objects, which the specialists need to obtain as much information as possible. Needless to say, most of the information about this site comes from data collected in the course of several campaigns of excavations.

Regarding lifting of artifacts from their archaeological context, field intervention will be effective, if it is fast and efficient (Masetti Bitelli 2002: 27–62). It should permit gathering as much information as possible about the context of the find without compromising the material's future once it has been extracted.

At the Berenike site, lifting artifacts from their position in the field is a very

important part of the conservator's task and ensuring that these three premises are met becomes essential. On the one hand, because the adverse weather conditions in which the excavation is carried out imply that the job needs to be done as fast as possible in order to avoid unba-

lancing the stability of the pieces. On the other hand, the fact that these extractions are carried out by conservators guarantees minimum loss of information and maximum chances for long-term conservation (Burgaya Martínez 2012: 85).

EXAMPLES OF CONSERVATION INTERVENTIONS AT THE SITE

Berenike field conservators need to focus in their job on recovering as much information as possible about the objects that are being excavated campaign after campaign. They need also to guarantee the integrity and stability of the material that artifacts are made of. In order to make this happen, the conservator must know the material that is being recovered, its forms of alterations—suffered while buried and appearing after extraction—and the atmosphere surrounding it (Burgaya Martínez 2012: 17). It must be kept in mind that extraction from conditions of deposition breaks the stability of the environmental conditions in which an object was found (Marichal and Rebé 1992: 280). Changes of temperature and humidity, increased exposure to oxygen, exposure to the sun and potential problems during manipulation can trigger severe degradation of the materials.⁴ It is essential to avoid an abruptness of this change and tasks in the laboratory concerned with stabilization and consolidation must be prioritized.

Under normal conditions, a laboratory may have the necessary resources to perform certain physico-chemical tests to help determine more accurately the state of an object's degradation and the machinery needed to ensure more efficient and effective treatment. The difficulty in the case of Berenike is a lack of rudimentary basics: electricity, running water, etc.. Therefore, the laboratory is a place adapted to these deficiencies and, in spite of them, there is never any risk to the life of an object at any moment.

METAL ARTIFACTS

Metal objects require faster procedure during this type of intervention. The treatment fundamentally is to get rid of corrosion in order to make these objects as legible as possible, and to put an end to processes of active corrosion.

Cleaning is mixed, combining always the mechanic, which involves using a micro motor, and the chemical,⁵ which consists, when it comes to copper and bronze, of a bath in a 3% EDTA solution in deionized

⁴ Due to the action of new agents or the reactivation of a passive degradation process during burial (Cantos Martínez 1993: 21).

⁵ It is true that chemical cleaning is a very aggressive intervention for metals (as water oxidizes metal). That is why mechanic cleaning is frequently prioritized, and if chemical cleaning needs to be used, concentrations are made as low as possible and always under a conservator's control, especially when it comes to the drying of the metal after its neutralization (Meyer-Roudet 1999: 98–99).

water. The objective of both procedures is to eliminate as much rust, copper carbonate and chloride as possible. Once neutralized, metal objects made of copper and bronze are stored in small chambers of progressive drying, and in some occasions they are even covered in alcohol and acetone in order to accelerate the drying.

In order to inhibit corrosion of bronze and copper, artifacts are placed in a 3% benzotriazole solution in alcohol for 24 hours. A layer of protection is thus created around the object in order to protect it from corrosion due to oxygen and humidity, as benzotriazole acts as a physical barrier. Finally, a thin layer of 5% solution of PARALOID B-72® in acetone is applied, the main objective in this case being to create a lasting protective layer that will slow down the corrosion processes even more.

POTTERY

It is very uncommon for the Berenike conservator to carry out many interventions in ceramics, as the state of conservation of the pottery is generally good. Nevertheless, some procedures are required on occasion.

A commonality is the recomposition of ceramic objects, if found somewhat fragmented. In the laboratory, fragments are pasted with a nitrocellulose adhesive, UHU®, always from the base towards the edge (Burgaya Martínez 2012: 49). The purpose as a rule is to facilitate the documentation process; once the drawing and photography have been completed, the pieces are detached again and the adhesive completely removed, as there is no reason to store it reconstructed. In addition, the use of chemical products that are alien to ceramic is avoided, as

this may cause long-term damage to the material structure.

A frequent task for the conservator is the cleaning and consolidation of ostraka. These interventions are generally mild. They involve removing the superficial salts by applying deionized water with dressings, and providing the written pieces with



Fig. 4. Ostrakon (BE15-105/008/006) in the process of surface cleaning and consolidation, before (top) and after treatment (Courtesy PCMA–University of Delaware Berenike Project/photo D. Eguiluz Maestro)

a layer of protection by applying a thin layer of 3% to 5% solution of PARALOID B-72® in acetone with a paintbrush. This way, reading the text becomes possible again and the conservation of both text and ceramics is guaranteed [Fig. 4].

VEGETAL MATTER

Intervention in vegetal matter is one of the most complex and delicate tasks faced by the conservator at the site of Berenike. Dehydration suffered by these materials is absolute. This allows their conservation for more than 2,000 years, but it is also turns them into fragile, barely flexible and



Fig. 5. *Process of covering with gauze before lifting and cleaning artifacts made of vegetal fiber, Berenike 2015 (Courtesy PCMA–University of Delaware Berenike Project/ photo D. Eguiluz Maestro)*

easily broken tissues. For these reasons, conservation work is based on mechanic, mild and dry cleaning, using an air blower pump in order to remove any sand from the surface.

For lifting in the field, gauze is usually applied over the object using as adhesive a 10% solution of PARALOID B-72 in acetone [Fig. 5]. This acrylic resin is undeniably not very flexible, but as it is soluble in acetone, hence avoiding any adding of non-controlled humidity to the fabrics that could destabilize their physical and chemical properties.

Due to the lack of specific resources at the field laboratory for the recovery of this type of fabrics, the conservation team always chooses to guarantee the conservation of these vegetal fabrics by keeping them in conditions that are as stable and as similar to the ones they had underground. Thus, if in the future they can be treated in order to give them back the flexibility and hydration they need, there will always be a chance to resort to it.

BONES

Treatment of osseous material is invariably based on their consolidation during excavation, the main intention being to avoid pulverization and to permit the bones to be lifted from the archaeological context. As specialists usually require no more than to be able to measure the bones and to examine them for marks, no further treatment is undertaken. PARALOID B-72® diluted in acetone with diverse concentrations (3%, 5%, 10%) is used to consolidate the bones.

Worked bone artifacts in the form of small figures or tools have been found occasionally. They are generally dirty and fragmented. Each fragment needs to be

cleaned with water and a paintbrush in order to remove the superficial dirt, and it is then consolidated. Finally, pieces are pasted, if possible, with a nitrocellulose adhesive.

CARBONIZED WOOD

As said above, wooden remains found at the Berenike site are one of the most important elements for treatment by the conservation team.

As the wood is carbonized, conservators face an utterly dehydrated, fragile and decohesioned material. That is why the most important intervention to be

carried out is *in situ* consolidation [Fig. 7 left], as these pieces, whose size is about 150 cm long, could not be extracted or manipulated without a proper consolidation that completely reinforces them.

In this example, the conservator had to take into account the material that was being treated, the environmental conditions in which the intervention was taking place and the need of finding a consolidate with low molecular weight (Masschelein-Kleiner 2004: 78) that guaranteed great penetration and adhesion. An acrylic resin was chosen, PARALOID B-72, diluted in acetone with diverse

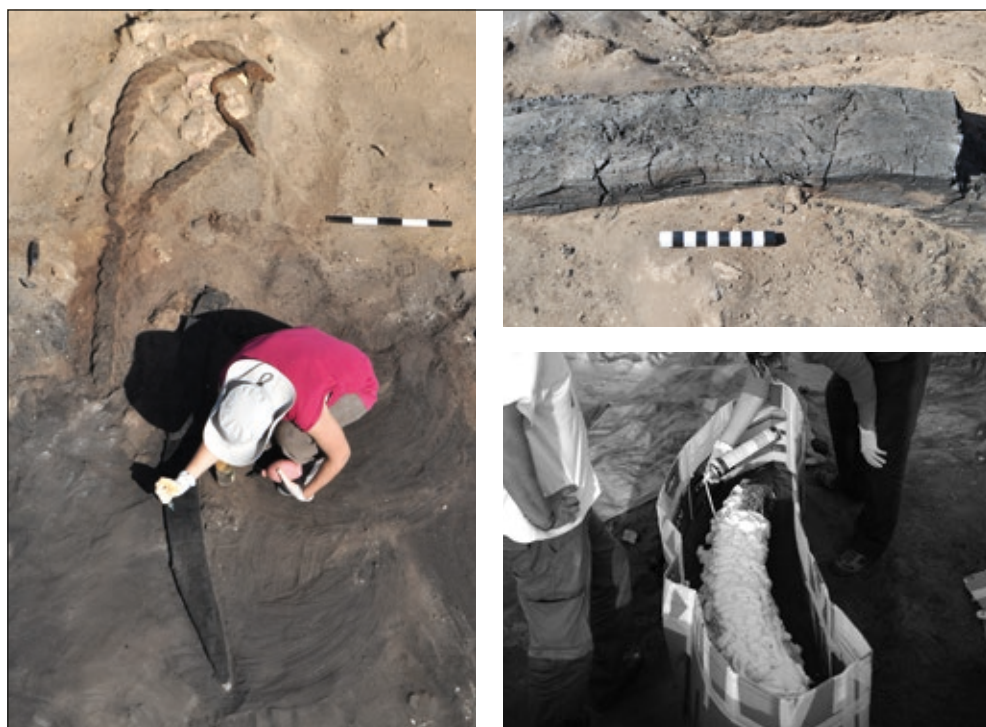


Fig. 7. Wooden intervention on site: top right, a Roman ship timber (BE14-98/013/001) found in completely carbonized state in 2014; left, conservator applying an acrylic resin in the field; bottom right, preparing the protected timber for lifting and transport to storage (Courtesy PCMA–University of Delaware Berenike Project/photo D. Eguiluz Maestro)

concentrations (3%, 5%, 10%), depending on the moment of application and the desired depth. A syringe was used for these applications, as the charcoal on the wood is very friable and does not allow the use of paintbrushes or brushes; instead a small air blower pump was used for the removal of superficial sand (Marichal 1992: 287).

Once consolidated, the best way of extracting the timber was to build a polyurethane mummy [Fig. 7 right]. These types of mummies are commonly used in paleontology for the extraction of big, heavy bones, as this structure is very compact, light, resistant to knocking and thermic changes, cheap and easy to make (Marichal and Rebé 1992: 282). Once the piece was extracted, it was taken to the laboratory where the face that was

hidden in the field was cleaned, drawn and photographed.

PREPARATION AND STORAGE

Following treatment, the conservator's duty is to pack all the artifacts properly for transport to a distant store. In terms of storage, in Egypt the responsibility rests with the host country's institutions, technicians, etc. (Burgaya Martínez 2012: 21). The Project conservator's duty is to ensure that the finds that are transported are protected against vibration, knocking or abrupt changes of temperature and humidity. Nevertheless, in places like Berenike, access to suitable packing materials is limited, constituting a challenge whenever needs exceed the conservator's imagination when organizing supplies before the season.

DISCUSSION AND CONCLUSIONS

The special conservation conditions characteristic of Berenike allow the conservation of a large quantity of different materials; hence, the necessity of having a conservator in the field. This involves a constant scientific dialogue with archaeologists and specialists, and thus creates an interdisciplinary approach during every campaign.

Nevertheless, the logistics in an excavation of this kind make it more difficult and exceedingly restricts the kind of conservation interventions both in the field and in the laboratory. The field lab needs to be equipped in an ingenuous manner with the basic materials that

are indispensable and that allow for the consolidation, stabilization, reinforcement and, essentially, preservation of every archaeological object excavated campaign after campaign.

In this regard, remarkable instances such as the ones involving wood imply strong challenges during the intervention process, both during the *in situ* consolidation and the preparation for their lifting. After all, resolving the existing difficulties is clearly compensated when obtaining a large amount of data thanks to the recuperation and study of pieces that would be almost impossible to document in other contexts.

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