



A BRONZE OSIRIS STATUETTE FROM THE EGYPTIAN MUSEUM IN CAIRO: MICROSTRUCTURAL CHARACTERIZATION AND CONSERVATION

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ABSTRACT

An Egyptian bronze statuette of the god Osiris has been discovered along with other ritual deities' statuettes and other metallic ritual equipment at Sais. It was temporarily inventoried with number 31/12/26/11C at the Egyptian Museum in Cairo. Its period, its specific burial place, and the certain excavation date were unknown. The statuette is an uncommon case; it was heavily corroded, covered with a thick crust of green corrosion products, has textile impression, missing its head, and has an unusual deep crack into its feet. It was examined, analyzed and conserved. Visual and stylistic examinations revealed that it is most probably dating to the Third Intermediate Period (1070-664 BC) or the Late Period (664-323 BC). Its style belongs to the Lower Egyptian style, and the direct solid lost-wax technique was used in the manufacturing process. Stereo-microscopic images revealed the Pseudomorph phenomenon on its surface.

X-ray diffraction (XRD) analysis revealed that the main compositions of the corrosion layer are oxychlorides, carbonates and sulphates covering copper and tin oxides. Structural examination and the elemental analysis by scanning electron microscopy (SEM) equipped with dispersive spectrometry (EDS) proved that the statuette was made of bronze material of Cu-Sn-Pb alloy. The high amounts of tin and lead affected on the mechanical properties of the bronze alloy and surely on its deterioration. Mechanical cleaning was applied so as to remove the superficial deposits / encrustations in a controlled and minimally obstructive way and then reaching a smooth layer which preserves the detail and shape. The surface of the Osiris statuette was protected with a corrosion inhibitor and protected against further corrosion attack with a protective coating.

KEYWORDS: Osiris; Sias; bronze corrosion; SEM-EDS analysis; X-ray diffraction; conservation

1. INTRODUCTION

Bronze figures of deities, sacred animals, and emblems are familiar category of Egyptian antiquities. Majority of these figures dates from Saite (c. 664-525 B.C.) and Ptolemaic (305-31 BC) Periods. They were produced at temple workshops on for ritual or religious purposes by the lost-wax technique. Solid casting was normally the most basic type of casting used in antiquity for small statuettes while larger statues were produced by hollow-cast technique to save the amount of metal (Taylor et al., 1998).

From time to time a cache of these figures is discovered and the probability is that most are votive offerings made at a temple or shrine from which they were cleared and disposed of by burial within sacred precincts. Excavated bronzes are frequently found in these deposits, which were created when temple personnel buried large numbers of statuary and ritual equipment after long period of use in temples (Emery 1970; Gosling et al., 2004). These metal figures undergo corrosion and degradation phenomena that may occur during their burial period and/or after excavation during storage or exhibition. Many of these excavated figures were studied and were conserved (Shore, 1966; Jedrzejewska, 1976; Bianchi 1989; Nasr, 1995; Scott and Dodd 2002; Delange, 2005; Mathis et al, 2009; Gravett 2011; Smith et al. 2011). But many other figures need to be studied as they have interesting features in style, technique, and condition of corrosion.

The Osiris statuette is one of them. It was discovered in association with a group of deities statuettes and other metal ritual equipment at Sais (present day Sa el-Hagar), and was housed at the Egyptian museum in Cairo in 1926. It was temporarily inventoried with number 31/12/26/11C. No further information is given regarding to its specific excavation place where it was originated from, for example temple or tomb, the specific date of the excavation and which era it can be dated to.

The aims of this work are to examine the statuette style and the casting technique, to investigate its surface features, to identify the corrosion products, and to determine the chemical composition of the bulk material. This investigation will assist us to detect its specific provenance

and the manufacturing technique, to understand the corrosion mechanism and the environmental effects, the nature of the patina, the elements and their effects on the alloy deterioration. As the statuette is of unknown date, it is also important to evaluate approximate its date through archaeological and an art historical study. The treatment required and conservation procedures would ensure the treatment and stability of the Osiris statuette, are also discussed in this research.

An integrated examination and analytical approach were required. Visual and stereomicroscopic examination, stylistic analysis, X-ray diffraction analysis, and Scanning Electron Microscopy coupled with energy dispersive X-ray micro-analysis (SEM-EDS) were used to complete the Osiris statuette's investigation.

2. ARCHAEOLOGICAL BACKGROUND

Osiris is one of the sacred deities in Ancient Egypt, his cult evolved from an exclusively royal prerogative during the Old Kingdom to become an integral part of common Egyptian funerary culture by the late period.

Osiris and other deities were depicted in metals as cult statuettes or votive statuettes (Kozloff 2001). The cult statuettes that have been the centre of ritual devotion or worship were likely to be smaller, portable and often used for festivals and processions (Robins, 2005). Votive statuettes that dedicated to a particular deity were usually referred to as votive offerings or dedications. Surviving votive statuettes largely date to the Third Intermediate (1070-664 BC) and Late Period (664-323 BC) and most represent gods in standing or enthroned poses (Hill, 2001). Royalty, official and private individuals would donate such objects to temples or shrines with the expectation that the particular deity would bless them; provide an answer to prayers or as a thanksgiving gift [Gravett 2011].

With the increasingly widespread use of bronze by the Late Period thousands of votive statuettes were being produced and many ordinary Egyptians were able to simply buy them at temples where the objects were also dedicated (Kozloff, 2001; Spencer, 2007). Unfortunately in the case of most votive or cult bronzes in Egypt

tian collections their provenance is unknown or uncertain at best (Hill 2001), may be as most of them haven't any inscriptions declare their source.

Excavation has revealed large caches of bronze statuettes as well as ritual equipment at various sites from this period, or slightly later. They are referred to as temple or foundation deposits. The cache of Saqqara and the cache of Kharge Oasis are examples of these caches. Many bronzes have been found in the Sacred Animal Necropolis in Saqqara (Hill, 2001; Sadek, 1987), and many votive Osiris and other bronze statuettes have also been excavated from the temple in Kharge Oasis (Wuttmann et al., 2007). From the excavation, it is clear that these objects were at the time of burial treated with care and respect; many statuettes of gods were found wrapped in linen (Emery 1970).

Sais or Sa el-Hagar, where this statuette was discovered, was an ancient Egyptian town in the Western Nile Delta on the Canopic branch of the Nile. It became the seat of power during the Twenty-fourth dynasty of Egypt (c. 732–720 BC) and the Saite Twenty-sixth dynasty of Egypt (664–525 BC) during the Late Period (Shaw and Nicholson 1995).

By reviewing the excavation history in Sais, it was found that a mass of bronze hoard was found in Sais in 1891, a number of bronzes had been seized by the police in 1893 [Wilson 2006]. Further bronzes were recovered by Alexandre Barsanti in the same year. The last group, for the most part, had been damaged by fire and had not survived well in their damp, salty conditions. Nevertheless, Barsanti retrieved some fine specimens for the Cairo Museum. In 1901 Georges Daressy excavated in Sais, he did not find the bronzes he was looking for, except for a bronze cat and a reasonable amount of small objects and pottery dating from between Dynasty 26 (664–525 BC) and the Roman period (31 BC - 641 AC) (Daressy, 1917). The work in Sais had been stopped from 1907-1930. From the last date till now, excavation at Sais has been accomplished by the Egyptian Antiquities Organization/Supreme Council for Antiquities. In its archives, no metal caches were discovered (Wilson 2006). There was not mention about a group of metals or caches of metals discovered in 1926 as

mentioned in the Museum's record. It is most probably that this group of bronze objects was unearthed before this date and was housed at the Egyptian museum later.

3. DESCRIPTION

Osiris was portrayed (Fig. 1a) in his usual pose: standing, missing its head, his body wrapped in a shroud, typical mummiform shape: feet together and the appearance of being tightly bound in linen wrappings. As the mummified, resurrected king of the underworld, Osiris holds the crook and flail of kingship, symbols of his dominion over the fate of gods and humans. It was already noted that the identity of the pharaoh and that of Osiris merged after death which explains the many allusions to kingship and royalty.

This statuette is missing the elaborate atef crown and the curved, braided beard that are clear indications of the figure's identity that are closely associated with depictions of Osiris. It has suffered from very severe corrosion during burial, completely covered with an inner adherent dark green corrosion crust over 5mm thick in most areas. This crust in some areas intercalated with an overlying loose corrosion layer covered by or incorporated with soil residues. This can be observed from the back of the statuette (Fig. 1b).



Figure 1. (a) Front view and (b) back view of the statuette covered with layer of corrosion products.

The statuette measures 44.4cm in height from the tang to the top of its shoulder. Its current weight is 13.450g. It has a deep crack into the feet 1-2 cm wide, and about 2.5 cm deep (Fig. 2).



Figure 2. The deep wide crack into the feet.

4. MATERIALS AND METHODS

Visual examination supported with stereo microscopy and stylistic analyses were used to get useful information relating to the statuette's provenance, its manufacturing technique and the environmental effects on its surface. Style, fashion and iconography were analyzed as stylistic analysis can be dependent on in an attempt to date non-inscribed statuary.

X-ray diffraction analysis was used to identify the nature of the patina and the corrosion layers as knowledge of the chemical composition of the patina must be established before taking any restoration and conservation procedures. Four samples were taken mechanically by scrapping the corroded surface gently with a very fine tungsten needle from fragment surface. These samples taken from different areas on the statuette's surface represented the different compounds of the corrosive layers. They were ground to a fine powder in an agate mortar and pressed into the specimen holder, then mounted in a Philips X-ray diffractometer type: PW1840. The operating conditions were: Cu target, 40 kV accelerating voltage, 25 mA current, the scanning range of 2θ was from 5 to 60° and the scanning speed was 2°/min.

In order to learn which kind of metal or alloy had been used to create the statues, three samples were examined and analyzed by using a JSM-6380 LA instrument, equipped with energy dispersive spectroscopy (EDS), a link EDS operating up to an accelerating voltage of 20 kV, and a working distance of 9 mm.

Depending on the examination and analysis results, conservation treatment procedures were taken to remove the superficial deposits / encrustations from the surface of the statuette and preserve it against further attack.

5. RESULTS AND DISCUSSION

5.1. Visual examination

Even though more scientific methods are now available for this purpose, visual examination can still provide useful information about ancient Egyptian metal statuettes. In cases where inscriptions appear on votive statuettes, they could reveal the name of the donor who dedicated the work to the temple or give clues to its date, although not many of them carry such texts (Hill 2001).

After performing a close visual examination of the Osiris statuette, it was possible to generally deduce many observations concerning its condition, its casting technique, its original provenance and date.

First, there are no remains of inlays, gilding, or inscription. The statuette was covered by different colored corrosion products incorporated with soil components creating hard, solid accretion from years of burial and up to the present. However, it appears that the statuette has reached a steady state with its corrosive environment. This dense corrosion represent difficult to explore any inscriptions on the surface. However, impressions of the shroud textile can be observed on the corrosion layer (Fig. 3).

The visual examination and the stereo-microscope images (Fig. 4a and b) showed mineralization of the shroud fibers on the metal surface. This phenomenon is something like pseudomorphic substitution in mineralogy. The mineralization of fibers is defined here as the total replacement of the organic matrix of the fiber with an inorganic one (Gillard et al., 1994). Pseudomorph primarily occurs when textile is in contact with metal object as a result of the combination and/or replacement of the organic material in the textile with corrosion products. When the metal breaks down, the concomitant metal salts create a specific type of microenvironment that is ideal for the preservation of textiles. They often leave negative hollows of the

fibers in casings of metal salts, leaving behind the structure of the former textile and hints of the fibers. The mineralization process of the fibers takes place by the migration of the metal products while the form of the braiding is conserved on the metal object. Thus the corrosion products are found again in the structure of the impressed textiles fibers. This usually happens with certain metals whose ions have an antibiotic, antimycotic and/or antifungic activity. Primary corrosion products as well as secondary and tertiary ones are responsible for mineralization effects of the fibers (Mircea et al., 2009). We can deduce from the Stereo-microscope images that the technique of the shroud textile is the plain weave technique and its fibers most likely from linen.

Visual examination may also reveal, in a limited manner, which casting technique was used to create this statuette. In Ancient Egypt, bronze statuettes were generally cast by means of the lost-wax technique. From the visual examination of the feet's crack, the appearance of the missing head's area where must be the neck, and the heavy weight of the statuette, all of them are indicators that it was made by use of the solid cast technique. This technique was the most basic type of casting used in antiquity and small solid-cast copper figures were common by the Middle Kingdom Period (ca. 2055-1650 BC) in Egypt [Taylor et al., 1998]. According to Lucas [1962] this technique was already employed in Egypt as far back as the Predynastic period (ca. 5500-3100 BC). A model of the object was first made in beeswax and then coated in clay. When it was heated, the clay hardened and the wax melted and filtered through the holes that were left in the clay. When the clay mould had hardened, the metal was poured into the mould

through the holes. Once cooled down, the mould was broken. Most small objects were cast by this technique as solids [Smith et al. 2011].

The tang underneath the statuette servicing as a pouring point of the solidified metal, used to secure it onto a base of wood or stone [Spencer 2007]. It is believed that this tang can also be helpful indicator of a possible date: before the New Kingdom (ca. 1550-1070 BC) it appears irregular in shape and size, while afterwards taking on a canonical form of being rectangular with a flat end [Schorsch 2007]. If we took by this belief, so this Osiris statute's tang can be dated to after the New Kingdom. The metal tang indicates a possible function as cult statuette that was usually kept inside a portable wooden shrine by this tang. This wooden shrine was fitted into a slightly larger stone one, located within the sanctuary of the temple. As representations of deities cult statuettes were housed inside temples, which were regarded above all as the abode of gods [Gravett 2011], while the votive statuettes were probably smaller than often thought just between twenty and thirty centimeters tall.



Figure 3. The textile impression on the outer corrosion layer of the Osiris surface.

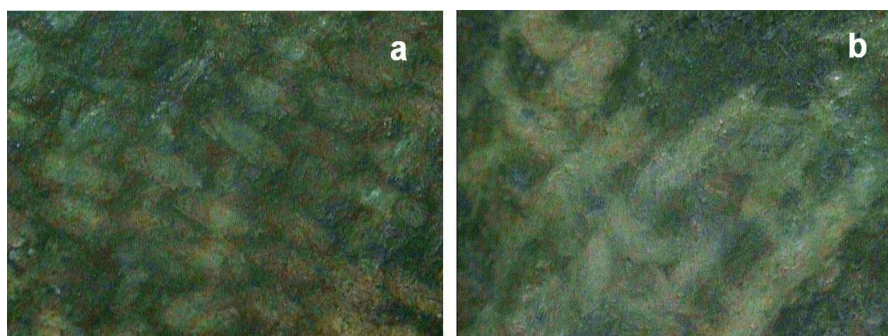


Figure 4. (a) Stereo microscope images of the shroud textile show the plain weave technique. (b) The Pseudomorph phenomenon or the mineralization of the textile fibers on the Osiris surface.

5.2. Stylistic analysis

Stylistic analysis is frequently used when analyzing Egyptian bronzes. It was used to study the details of the Osiris statuette as a common way of studying various stylistic aspects of ancient Egyptian art in an effort to date them. However, complications may arise when an Egyptian bronze figure is examined stylistically because many of these objects originated from a time during which deliberate archaism became popular, namely the Third Intermediate and Late periods [Hill 2001].

Facial features and style of dress can be used to match a statuette to a similar one but securely dated figure. But this type of analysis comes with many complications. Both the Third Intermediate Period and Late Period that produced most of the bronze statuary being studied today were known for deliberate archaism in their art and furthermore there is the possibility that the postures of the figures depended on their place of manufacture [Scott and Dodd 2002; Gravett 2011].

Unfortunately we can't use the facial features, the kind of the crown or the shape of the beard and its position as stylistic indicators in an attempt to find possible time period for the statuette as they were lost. Nevertheless, the body features may help us in this manner. The overall impression that can be deduced is a statuette tightly wrapped in linen, revealing only minimal amount of features such as the board outlines of arms held tightly against the chest and the faintest suggestion of legs. The legs are only indicated by swellings on the side and in profile. It is possible to see a slight curve that denotes the buttocks. This elongated body shape seems to negate a twenty-fifth Dynasty (ca. 1080-650 BC) origin for the bronze as Osiris shapes were generally squatter during that period [Raven 2007]. In contrast Osiris statuettes from the Twenty-sixth Dynasty were more elegantly shaped.

The position of the arms in particular varied considerably among bronze Osiris figures. Studies have revealed that these differences in postures were often linked to regional traditions [Odgen 2000]. In Upper (southern) Egypt, figures of Osiris usually show the arms crossed over each other. In Middle Egypt representations show the god holding them at the same

level and in Lower Egypt his one arm is on his chest and the other on his stomach. Similar variations were noted regarding the rest of the body. For example Osiris figures from Lower Egypt do not show the arms through the outer robe, they reveal minimal detail of the god's legs [Wilkinson 199; Griffiths 1980; Gravett 2011]. Applying this principle on our Osiris statuette indicates a Lower Egyptian style which assures that it was discovered at Sais Lower Egypt. However, we have to keep in mind movement of craftsmen from region to another in Egypt. Some bring with them particular local styles (Grajetzki 2006). So oversimplifying connections between stylistic elements and geographical provenance is dependable [Aldred 1969].

Cracking the head of the deities' statuettes was not customary in ancient Egypt. It can be deduced from the appearance of the cracking on the neck and feet (Fig. 5a and b) and from the burial condition that these cracks happened accidentally, not intentionally. It is most probable that these cracks happened during the working process as errors in the casting technique, taking into consideration that the neck and the feet are the weakest areas of the statuette. The corrosion layer on the cracks areas takes the same nature and the same thickness of the corrosion layer on the other areas of the statuette surface. This assures that they passed the same time of deterioration and exposed to the same corrosive factors. All of these indicate that these cracks happened before the burial especially the neck's crack that can be assured by the fact that the head has not been discovered with the rest of the group of objects.

It is likely that this group of metal objects including this Osiris statuette and the other objects is a foundry for a bronze forge that came from a temple. It is known that large quantities of statuary ritual equipment were periodically cleared out after long periods of use in temple and buried under the temple building [Gravett 2011]. Such caches may contain votive and cult statuary that are representative of several different dates. This will be a challenge to archeologists, conservators, and therefore will call into question any general policy of recycling 'sacred' copper alloy objects. This would suggest that the temple workshops required a steady source of

newly mined raw material. However, these sanctified objects were still as possessing some kind of ritual potency even after their use in temples; as such they were generally buried inside the sacred confines of temple complexes rather than being recycled for scrap metal [Gravett 2011; Odgen 2000].



Fig. 5. The appearance of the two cracked areas.

It might even have been sacrilegious to destroy votive objects which were originally consecrated to the temple. This can be accepted if we take in mind that many examples of these votive statuettes were found in a pristine condition, wrapped in linen. However, this can't

be applied in our cache as many of the statues were in a bad condition, cracked, destroyed, in a complex position and in a mess. It is apparent that they were put in the cache randomly as if they were cleared out.

5.3. Nature of the Patina and corrosion

It is generally accepted that the surface layer of soil-buried archaeological copper alloy consists of Cu (II) salts and salts of the sharing metals in the alloy. The resulted salts or corrosion products usually cover a red cuprous oxide layer that is adjacent to the metal core. The structural characterizations of the corrosion products grown on the statuette were determined by X-ray diffraction analysis.

The XRD analysis results on the scraping powder of the corrosive layers given in Table 1 and Figure 6 have shown the presence of copper, lead and tin compounds. Most of these compounds are of copper oxychlorides, carbonates and sulphates over copper and tin oxides.

Table 1. Mineralogical composition of corrosion products samples on the Osiris statuette obtained by XRD.

Sample	Minerals	Formula	Card No.	Content
Sample 1	Brochantite	$\text{Cu}_4\text{SO}_4(\text{OH})_6$	3-0282	major
	Atacamite	$\text{Cu}_2(\text{OH})_3\text{Cl}$	2-0146	trace
	Paratacamite	$\text{Cu}_2(\text{OH})_3\text{Cl}$	15-0694	major
	Brochantite	$\text{Cu}_4\text{SO}_4(\text{OH})_6$	3-0282	
Sample 2	Azurite	$\text{Cu}_3(\text{OH})_2(\text{CO}_3)_2$	11-0682	minor
	Cuprite	Cu_2O	05-0667	
	Atacamite	$\text{Cu}_2(\text{OH})_3\text{Cl}$	2-0146	trace
Sample 3	Brochantite	$\text{Cu}_4\text{SO}_4(\text{OH})_6$	3-0282	major
	Malachite	$\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$	10-0399	minor
	Atacamite	$\text{Cu}_2(\text{OH})_3\text{Cl}$	2-0146	minor
	Cassiterite	SnO_2	3-1114	trace
Sample 4	Cerussite	PbCO_3	5-0417	major
	Cassiterite	SnO_2	3-1114	minor
	Paratacamite	$\text{Cu}_2(\text{OH})_3\text{Cl}$	15-0694	trace
	Calcite	CaCO_3	5-0586	trace

Crystalline phases of different copper oxychlorides such as: paratacamite $\text{Cu}_2(\text{OH})_3\text{Cl}$ and atacamite $\text{Cu}_2(\text{OH})_3\text{Cl}$ were detected. Paratacamite was the major component in sample No.2 (Fig. 6b), while atacamite was detected as minor component in sample No.3 (Figure 6c), and as trace component in samples No.1 (Fig. 6a) and

No.2 (Fig. 6b). These two oxychlorides are mainly formed owing to the presence of very high chloride content in the burial environment. Harmful cuprous chloride nantokite CuCl was formed first during the burial via the interaction between copper and Cl^- ions coming from the soil's salts especially sodium chloride NaCl salt.

And as a result of contacting with oxygen and water, it continues to be oxidized to powdery greenish patina of oxychloride paratacamite or atacamite. The concentration of CuCl_2 and NaCl were critical in determining which isomer of the copper trihydroxychlorides system might be expected to form. With copper and NaCl alone, paratacamite formed, the addition of NaCl to CuCl_2 between 0.1 and 1M Cl^- favoured atacamite, with higher concentrations again producing paratacamite [Sharkey and Lewin 1971]

The green basic copper sulphate brochantite $\text{Cu}_4\text{SO}_4(\text{OH})_6$ was the main corrosive product in samples No. 1 (Fig. 6a), No. 2 (Fig. 6b), and No. 3 (Fig. 6c). It might be expected on bronze exposed to sulphur-bearing water. The source of sulphur seems to be the liberating hydrogen sulfide resulting from decomposition of organic matter by sulfate reducing bacteria in soil. When this gas is in sufficient concentration, sulfide formations in the bronze patina are to be expected. After subsequent oxidation, they will be transformed to sulfate.

The two basic carbonates of copper, the green malachite $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$ and the blue azurite $\text{Cu}_3(\text{OH})_2(\text{CO}_3)_2$ were detected. The first as trace component in sample No. 3 (Fig. 6c) and the second as minor component in sample No. 2 (Fig. 6b). Both malachite and azurite form principally when copper alloy comes in contact with soil waters or with water formed by surface condensation and charged with carbon dioxide (Scott 2002). Malachite that has pale to dark green color can be a significant component of patinas developed during the corrosion of copper alloys buried in soil. It usually forms over cuprite, the first product to form adjacent to the metal. Azurite that has the blue color is observed only on copper alloys that have been excavated from soil, and formed from solutions with high concentration of the hydrogen carbonate ion (HCO_3^-), due to considerable concentration of calcium hydrogen carbonate (Franke and Mircea 2005). This may be assured by the presence of calcite CaCO_3 in sample No. 4 (Fig. 6d), which indicates that the burial soil may be calcareous aerobic soil. Such soil usually has high carbon dioxide contents and may be chemically very aggressive because the carbon dioxide may react with water to form carbonic acid, which

attacks metals directly and prevent the formation of a protective film on the metal surface.

The presence of cerussite PbCO_3 as the main component in sample No.4 (Fig. 6d) resulted from the same reason, and indicates that the composing statuette's alloy contains lead potentially in high content.

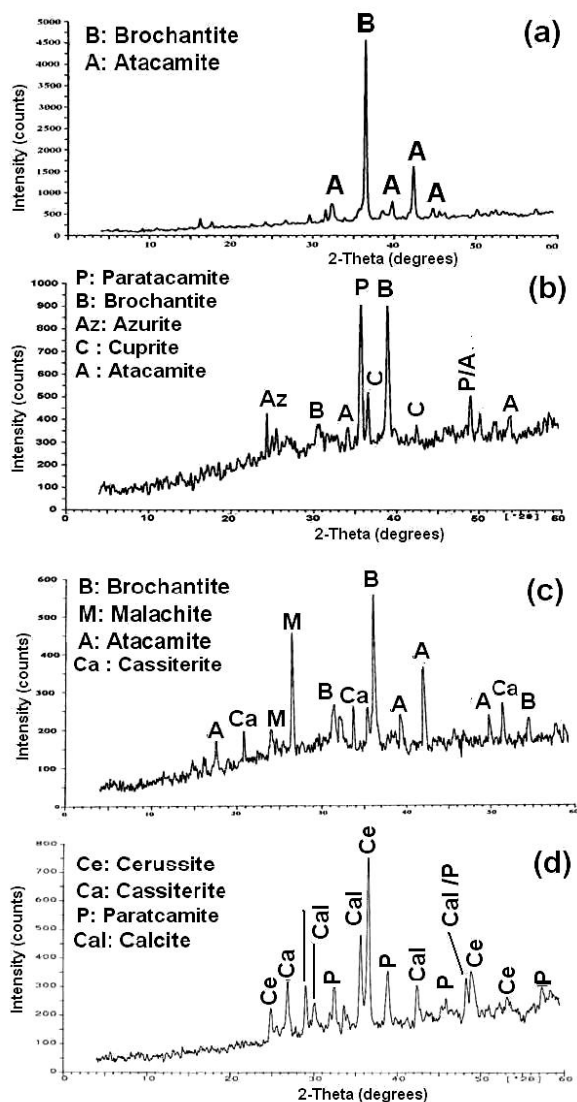


Figure 6. XRD spectra of the corrosion products; (a) the compact dark green crust, (b) the greenish blue corrosion product; (c) light green corrosion product; (d) the outer light green corrosion product incorporated with soil residues.

Oxides are the most common alteration products on archaeological metals as a result of direct contact between the metal or the alloy and the oxygen that may be in every environment. Cuprite Cu_2O that was detected as minor component in sample No. 2 (Figure 6b), is the first corrosion product formed in most environ-

ments. It is formed by the direct oxidation of copper or maybe as a result of reaction of nantokite with water (Organ 1963). Usually most of it is concealed beneath overlying green basic salts of copper, and it seems to be an intermediate compound in the conversion of metal to basic salt. Cassiterite SnO_2 , was detected as minor compound in samples No. 3 (Fig. 6c) and No. 4 (Fig. 6d). This tin oxide, which usually takes the grey-green color, is an important alteration product on the surfaces of ancient high-tin bronze excavated from the damp environment containing corrosion stimulators such as chlorides or sulphates. It appears first as spots and then as a crust or as hard warts or pits (Cronyn 1990).

5.4. Elemental analysis

Three samples (about 3-5mm) were taken from three different areas, one from the neck's area, second from the deep crack on the foot, and the third from the back surface of the statuette. Their surfaces were finely polished with emery paper up to the grade 1200, and examined and analyzed by SEM-EDS. The determined elemental composition of the statuette was represented in Table No.2 and (Fig. 7).

It can be deduced from these results, expressed as weight percentage (wt.%), that the examined statuette was made of Cu-Sn-Pb bronze alloy. Copper was detected as the main component. Its amount in the analyzed samples ranges from 82.33 wt. % to 89.51 wt. %.

Tin Sn, which is the main alloying element for producing bronze and properties of bronze, was between 4.33 wt. % to 10.06 wt. %. It is known that bronzes containing much more 10 wt. % cannot be satisfactorily worked without some danger of breaking. The majority of Egyptian bronzes have up to around 10% tin, as is generally typical in antiquity [Gravett 2011], but there is occasionally higher level though very rarely over about 16%. But there appears to be a dip in average tin content in the Third intermediate Period, while Ptolemaic and Roman-period objects more frequently have higher tin levels [Odgen 2000]. Lead is a common addition to bronze carried out in antiquity for producing objects characterized by low mechanical proper-

ties to be utilized at room temperature. It was detected in a weight percentage from 4.30 wt. % to 10.58 wt. %. An addition of lead up to 2% improves the fluidity of the melted bronze alloy, even though, a loss of mechanical properties could be induced, and if the lead amount is increased up to 3-4 wt. %, hardness and toughness are consequently reduced. So, with higher amount of Pb, mechanical properties deteriorate. The addition of lead to copper alloys is rare before the Middle Kingdom and lead levels over about 2% are rare prior to the late New Kingdom. In the Third Intermediate Period copper lead alloys, some with over 20% lead, were becoming more common. However, high lead content is typically a Late Period phenomenon that continued into the Ptolemaic period, when over 20% is not unusual, and over 30% is reported in some instances [Odgen 2000]. Varying in the amount of the three metals (Cu, Sn and Pb) composing the bronze alloy from one area to another proves the heterogeneity in the alloy composition that affected the mechanical properties of the alloy.

Table 2. The Chemical composition of the three samples taken from Osiris statuette as detected by EDS.

Sample	Cu wt.%	Sn wt.%	Pb wt.%
Sample of the neck's area	85.09	4.33	10.58
Sample of the statuette's surface	89.51	6.18	4.30
Sample of the feet's crack area	82.33	10.06	7.61

These results make us suspect that the crack into the feet and the neck were resulted from the loss of mechanical properties because of the high percentage of tin and lead. Lead in the alloy does not become part of its crystalline structure, increasing the fluidity of compound when it is in its molten state. This facilitates casting, particularly the casting of finely detailed artistic objects. However, lead bronze is softer than normal bronze, and therefore vulnerable to mechanical and chemical damage. Lead plays a crucial role in the corrosion mechanism because lead does not completely mixed with copper in

the solid solution of the bronze alloy, and during the solidification process it tends to form intergranular isolated islands that become the

place where the process of corrosion are baited (Alberghina et al., 2011).

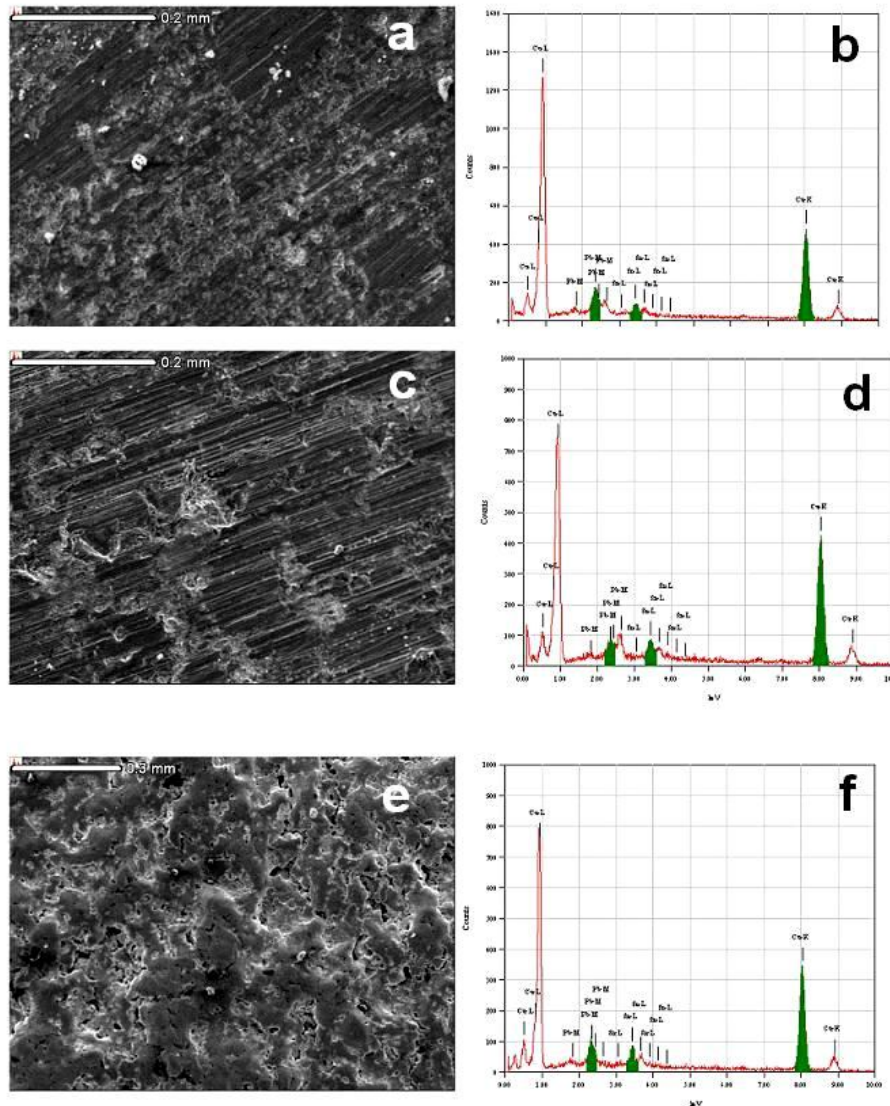


Figure 7. (a and b) SEM image and EDS spectrum of a sample taken from the neck's area. (c and d) SEM image and EDS spectrum of a sample taken from the statuette's surface. (e and f) SEM image and EDS spectrum of a sample taken from the feet's crack area.

The high level of lead was characteristic of copper-alloy statues made during the Late Period and was a rarity in those from the Middle Kingdom (ca. 2030-1640 BC) [Gravett 2011]. This elemental analysis and the stylistic analysis assure that the Osiris statuette dates to the Third Intermediate (ca. 1070-664 BC) or the Late Period (664-332 BC).

6. TREATMENT AND CONSERVATION

The visual examination of the Osiris statuette revealed that it was covered with a hard superficial crust of corrosion layer. Mechanical

cleaning was applied so as to remove the superficial deposits/encrustations in a controlled and minimally obstructive way and then to reach a smooth layer which preserves the detail and shape. Features of interest included surface inscriptions and manufacturing details. The cleaning procedure involved removing the soft smooth corrosion and soil residues and manual disencrustation that were carried out exclusively by mechanical means, for example by glass-bristle brushes, careful use of scalpels and dental and ultrasonic descalers. Direct application of blunt chisel was used to split and lift the hard thick crust layer. The chisel was held so securely

that impact of the hammer will not make it touch the original surface. The chisel directed to cut across the engraved lines to avoid splitting the line itself, so the incrustation divided sprang away from the original surface and leave the bronze with its fine layer of the patina untouched. To inhibit further corrosion after mechanical cleaning, the statuette was degreased through swabbing with acetone and inhibited with 3% on Benzotriazole in ethanol by brush (Madsen 1971). The statuette was given three coats, one hour between each application to be air-dried. Finally the statuette was coated with a protective coating of Paraloid B-44 5% in ethanol (Scott, 2002). Paraloid B-44 has good properties such as flexibility and its Tg is 60°C that makes it suitable for the atmosphere in Egypt. The coating was applied in 3 layers. In between each application the film was allowed to dry and polymerize for 8 hours. The final appearance can be seen in Figure 8.



Figure 8. (a) Front view and (b) Back view of Osiris statuette after cleaning and conservation processes.

7. CONCLUSIONS

It is very likely that the Osiris statuette and the other objects discovered by it as a group, come from a temple rather than a tomb. The Osiris statuette was probably manufactured by a temple workshop to function as a cult statuette used in processions or other temple perfor-

mances. The phenomenon of temple deposits, this group being one of them, indicates that the numerous small statuettes found in such foundation deposits probably had a much more complex function in that religious environment than being mere donations of wealthy patrons.

The position of the statuette's arms, one on his chest and the other on his stomach indicates a Lower Egypt style that assures the possibility that it was discovered in Sais, Lower Egypt, according to the Museum's record. The examination indicated that it was produced by the soild-cast manufacturing technique.

Pseudomorph phenomenon that is apparent on the statuette's surface indicates that it was wrapped in a shroud most likely from linen; its fibers were woven in the plain weave technique. Analysis of the patina gives evidence that the outermost corrosion layers of the Osiris statuette are formed via the interaction between soil constituents (Cl, Si, S, and CO₂) and metal corrosion products mainly composed of copper. It has been buried for a long time in a salty soil where the corrosive ions of chloride and sulphide as well as carbon dioxide, oxygen and water are regarded the most powerful corrosion agents for the statuette.

The statuette was made of bronze alloy with high tin and lead amounts that most likely affected on the condition of the statuette and on cracking the head and into the feet. The chemical composition of the statuette gives evidence that it is most likely dated to the Third Intermediate and Late Period as bronze was a very popular medium for works produced during these two periods.

Mechanical cleaning provides the only safe technique to be employed in conservation of metallic objects. It is easy, enables the conservator to have maximum control over the cleaning process, provides greater familiarity with the object and ties in once more the principles of minimum intervention. However, it requires, skill, patience, keeping examining the object with the naked eye or any means of magnification. Great care should be taken especially when there are inscriptions or pseudomorphic replacement of organic materials on the metallic surface.

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