FIGURINE OF EGYPTIAN GOD BES 1 - ÆIN 223 - LEADED BRONZE - 3RD INTERMEDIATE PERIOD TO LATE PERIOD

Artefact name Figurine of Egyptian God Bes 1 - ÆIN 223

Authors Ida. Langemark (The Royal Danish Academy, Copenhagen, Capital Region, Denmark)

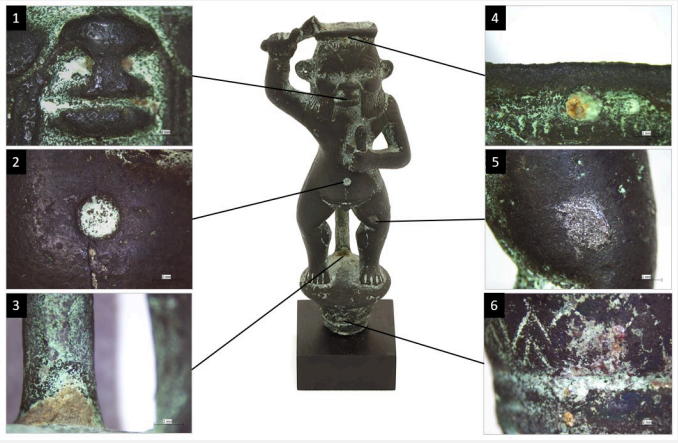
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The object



Credit The Royal Danish Academy, I.Langemark.

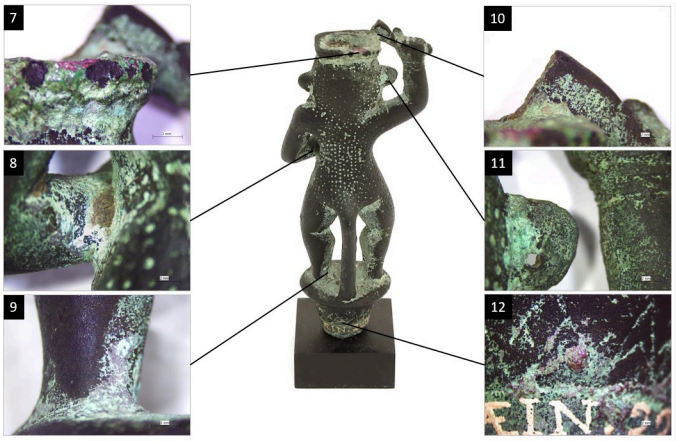
Fig. 1: Face, back and side views of the figurine,



Credit The Royal Danish Academy, I.Langemark.

Fig. 2: Dark patina with light green powdery corrosion products on the surface of the front side (details),

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Credit The Royal Danish Academy, I.Langemark.

Fig. 3: Dark patina with light green powdery corrosion products on the surface of the back side (details),

Description and visual observation

Description of the artefact	Bes appears in his typical form with grotesque face, naked male body, short and hooked legs, lion's mane, mouth, and tail. The god was perceived as a protector who defeated evil forces with force of arms or magical music and is here depicted as a snake slayer with a sword raised in his right hand and a cobra in his left hand. Dimensions: Height=11.6cm; Width=4.8cm; Thickness=3.3cm. The figure has lost its crown, which was shaped like a feather tassel, but its original existence is revealed by an empty mounting hole at the top of the head. The figure originally stood on vertical stands that illustrated the flowering papyrus stalks, symbols of health and freshness, wadj, but only sparse remains are preserved under the figure's feet. The wadj-symbol with the god on top may have been mounted at the top of a ceremonial staff or had a place on a base, possibly together with other figures (Jørgensen 2009 23.1.). The figure is covered with a dark corrosion layer which could be an original artificial patina, with light green powdery corrosion products located in and around engravings, edges, and curves, as well as horizontal surfaces and the insides of legs and tale (Fig. 2 and 3).
Type of artefact	Votive figure
Origin	Archaeological, ancient Egypt, exact provenance unknown
Recovering date	Recovered late 19th century
Chronology category	3rd Intermediate Period to Late Period
chronology tpq	1080 B.C.
chronology taq	300 B.C.
Chronology comment	None.
Burial conditions / environment	Unknown
Artefact location	Ny Carlsberg Glyptotek, Copenhagen
Owner	Ny Carlsberg Glyptotek, Copenhagen
Inv. number	ÆIN 223
Recorded conservation data	N/A

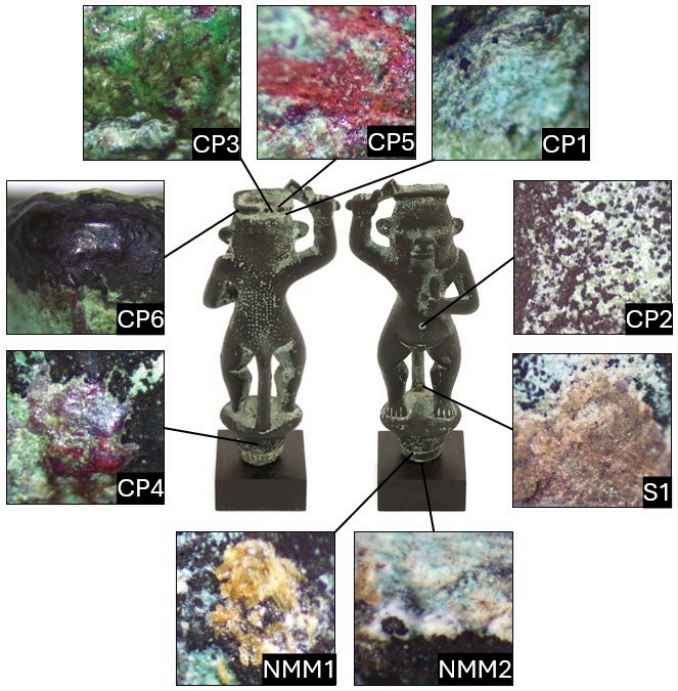
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Complementary information

Mounted to wooden plinth.

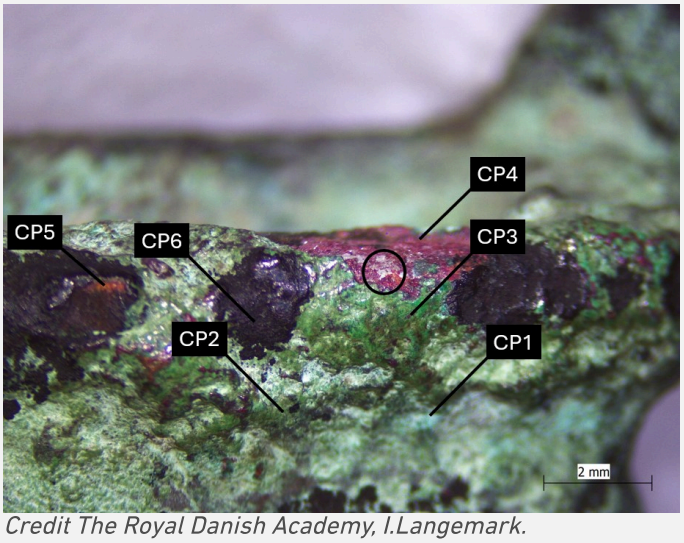
Inventory number applied in gold ink of unknown composition.

Study area(s)



Credit The Royal Danish Academy, I.Langemark.

Fig. 4: Details of corrosion forms as observed under binocular microscopy,



Credit The Royal Danish Academy, I.Langemark.

Fig. 5: Distribution of corrosion forms on the crown (detail) observed under binocular microscopy,

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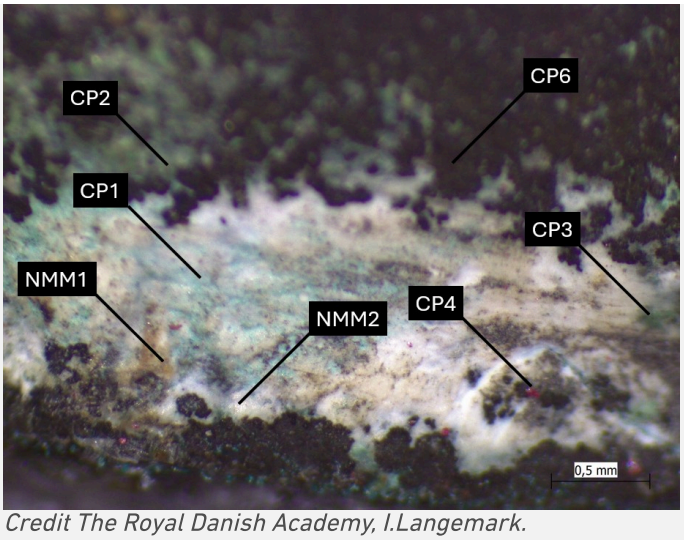


Fig. 6: Distribution of corrosion forms on the standing base (detail) observed under binocular microscopy,

Credit The Royal Danish Academy, I.Langemark.



Fig. 7: Location of XRF measurements,

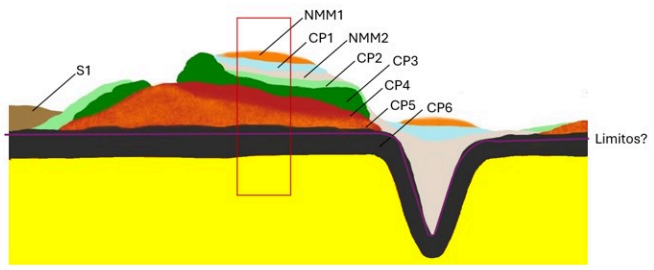
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Binocular observation and representation of the corrosion structure

Stratigraphic representation:

The schematic representation below gives an overview of the corrosion structures encountered on the figurine from a first visual macroscopic observation.

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Captions	Colour, aspect, hardness and cohesion
S1	Remains of sediment.
NMM1	Orange non-metallic substance. Waxy, semi-translucent, loosely adhered with sharp transition to underlying layer. Can be removed in malleable flakes.
NMM2	White, matte, non-compact substance. Very loosely adhered to underlaying layer. Removes as powder under action of a scalpel blade. Presumed to be precipitation of calcium (alternatively lead or tin corrosion products)
CP1	Light blue corrosion products. Matte and powdery. Very loosely adhered to underlaying surface.
CP2	Light bluish-green corrosion products. Matte and powdery. Distributed in a very thin, loosely adhered layer. Mainly located in engravings, craters, or edges across the figure's surface. Sharp transition to underlaying layers.
CP3	Bright green corrosion products. Opaque and slightly reflective. Apparent as small compact and cohesive lumps. Removes in brittle flakes when shaved with a scalpel blade.
CP4	Dark red corrosion products. Semi-translucent and reflective. Found in lumps that are compact and very cohesive, with sharp transition to other corrosion layers. Powdery under action of a scalpel blade.
CP5	Orange powdery corrosion products. Located beneath CP4, directly on top of CP6.
CP6	Black dense corrosion layer. Very small homogenous crusts strongly adhered to underlaying surface (probably M1 – surface not observed). Opaque, matte or slightly reflective surface. Traces of engravings.
M1	Leaded bronze.

Credit The Royal Danish Academy, I.Langemark.

Fig. 8: Stratigraphic representation of the corrosion structure of the figurine by macroscopic and binocular observation, with indication of the corrosion structure used to build the MiCorr stratigraphy of Fig. 9 (red rectangular),

MiCorr stratigraphy(ies) – Bi

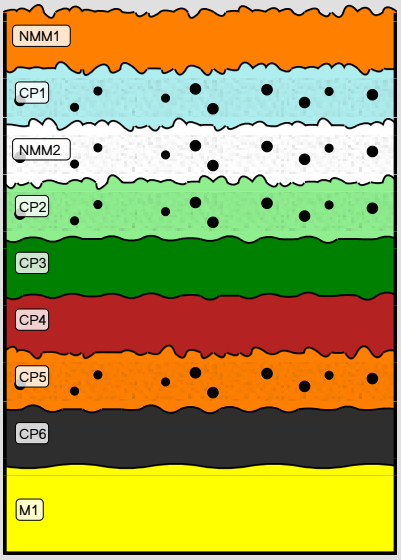


Fig. 9: Stratigraphic representation of the corrosion structure of the figurine observed macroscopically under binocular microscope using the MiCorr application. Credit The Royal Danish Academy, I.Langemark.

Sample(s)

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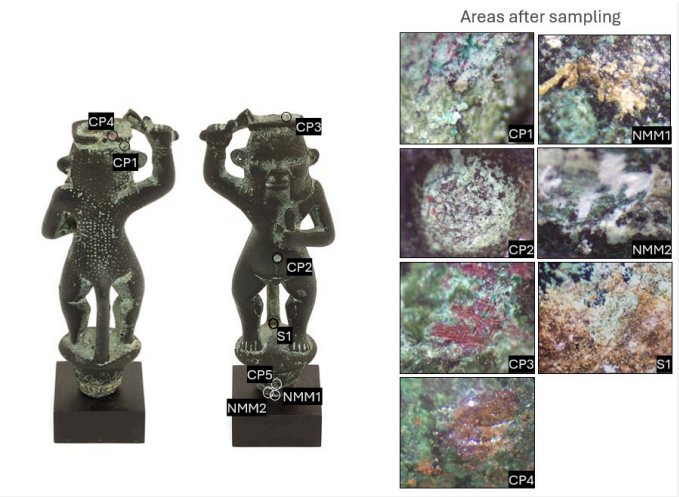


Fig. 10: Front and back of the figurine showing the sampling areas,

Credit The Royal Danish Academy, I.Langemark.

Description of sample	Seven samples of corrosion products and non-metallic material were taken and observed under polarized microscopy (Fig. 9), two samples (NMM2 and S1) were examined with SEM-EDS and 1 sample under P-XRD.
Alloy	Leaded Bronze
Technology	Cast
Lab number of sample	
Sample location	The Royal Danish Academy (Langemark Ida), Copenhagen, Capital Region
Responsible institution	The Royal Danish Academy (Langemark Ida), Copenhagen
Date and aim of sampling	March 8th 2024, chemical and molecular analyses of corrosion products

Complementary information

None.

Analyses and results

Analyses performed:

Non-invasive approach

- Portable micro-X-ray fluorescence (μ-XRF) on different measuring locations across the metal surface (Fig. 7). Measurements were made with a portable Bruker Tracer 5G XRF, with an analysis time of 30 sec and a spot size of 8 mm, mode general metal.

Invasive approach

- Polarized microscopy on 4 corrosion samples (CP1-CP4) and 3 samples from non-metallic compounds (NMM1, NMM2, and S1)(Fig. 10).
A small amount (1>mg) of various corrosion types was removed from the surface with scalpel under binocular microscope. The corrosion powder was placed in a drop of Euparal, covered with an object glass, and left to dry for some days. The corrosion samples were observed with a Leica 750P-microscope, and micrographs obtained with the software LAS X.

- Scanning electron microscopy /Energy Dispersive X-ray Spectrometry (SEM-EDS) on samples from NMM1, NMM2, and S1. Samples was prepared by scraping of material from the surface with scalpel under binocular microscope. The sample material was attached to steel pins with double sided carbon tape. Analyses were performed with a Hitachi S - 3400N SEM-EDS, 15,0 kV and 300 sec.

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- Powder X-Ray diffraction (PXRD) on samples from CP1 and CP2. Due to the amount of material required for PXRD-analysis, sampling was done on all areas with a sufficient amount of corrosion products. PXRD-analyses were performed with a PANalytical X'Pert Pro diffractometer at the Faculty of Farmacy, Physics and Chemistry, University of Southern Denmark. Measurements were obtained with the software Data collector, and subsequent data processing was done with the applications HighScorePlus and Match! respectively.

Non invasive analysis

The µ-XRF-measurements have been performed on un-polished surface areas. They should be seen as indicative. Still the metal is a leaded bronze.

Measurement no.	Cu	Pb	Sn	Sb	Ag	Zn	Ni
1385	71.3	19.6	9.2	<	<	<	<
1386	81.8	16.9	1.3	<	<	<	<
1387	72.4	20.3	7.3	<	<	<	<

Table 1: Chemical composition (Elements mass (%)) of the figurine in the areas located on Fig. 7.

The µ-XRF-analysis shows a content of approx. 19 % (in weight) lead as an average of measurement 1385, 1386, and 1387. The lowest tin-content of 1.3 wt% Sn is seen in measurement 1386 (crown, red corrosion products), the highest of 9.2 wt% Sn in measurement 1385 (powdery corrosion products accumulated in the navel).

Based on the figure's visual dark appearance, traces of elements commonly associated with artificial patination of archaeological bronze, such as gold (Au) and silver (Ag), was expected to be found in the metal alloy (Benzonelli 2017, Berger 2015, Mohamed & Darweesh 2012). However, the performed measurements showed no trace of gold, silver, or other alloying elements.

Metal

None.

Microstructure None

First metal element Cu

Other metal elements Sn, Pb

Complementary information

None.

Corrosion layers

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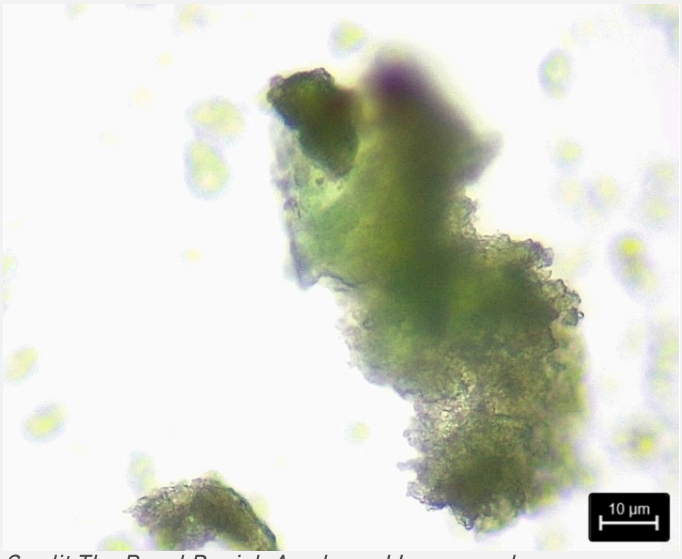
The heterogenous corrosion crust covers the whole object with various types of corrosion products, mostly Robbiola type I. Most of the metal surface is covered with a dark grey patina, with powdery light green corrosion products located in and around engravings, edges, and curves, as well as horizontal surfaces and the insides of both legs and tail.

Six corrosion products and three non-metallic materials have been identified and can be visualised on Fig. 4 and as stratigraphies on the crown (Fig. 5) and the standing base (Fig. 6) respectively. As a reminder:

- CP1: light blue corrosion product found on a few localized spots,
- CP2: a thin corrosion layer consisting of light green powdery corrosion products (Fig. 11),
- CP3: a dense bright green layer found at a few localized spots (Fig. 12),
- CP4: a hard, brittle red layer (Fig. 13),
- CP5: powdery orange corrosion products located beneath CP4.
- CP6: a dense black/dark grey, very hard corrosion layer, that contains corresponding markers to the limit of the original surface (Fig. 8). In some areas the sequence has an unevenness surface (with a mattifying effect), in other areas the surface is more regular and more reflective. At some locations on the crown, the original surface has been replaced by structural voids in form of small craters.

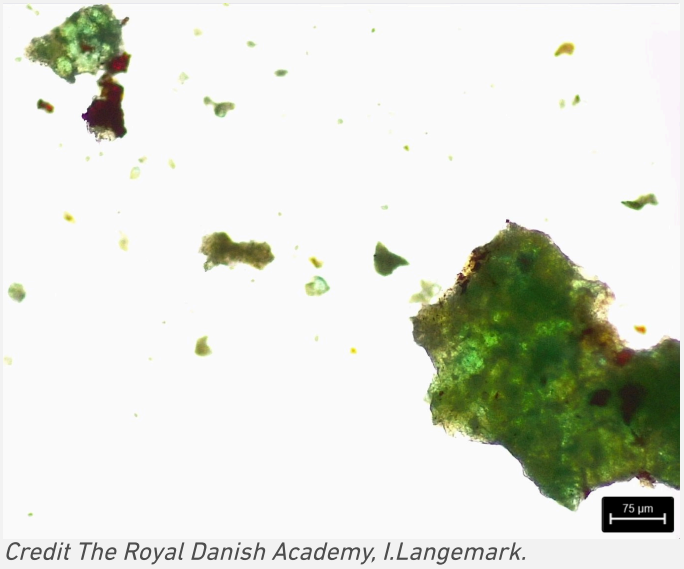
PXRD-analysis of corrosion powder obtained from CP1 and CP2 show the presence of the copper tri-hydroxychloride paratacamite (Fig. 14), and traces of spertiniite (full data-sheet available on request).

SEM-EDS-analysis of the white substance found on the standing base (NMM2) shows a high content of calcium (Fig. 15). In some areas, the white layers have an almost waxy appearance, a feature that is often associated to the presence of nantokite (copper oxychloride). Distinguishing between areas of calcium precipitation and nantokite would require more samples to be analysed.



Credit The Royal Danish Academy, I.Langemark.

Fig. 11: Microscopic examination of sample obtained from CP2,



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Fig. 12: Microscopic examination of sample obtained from CP3,

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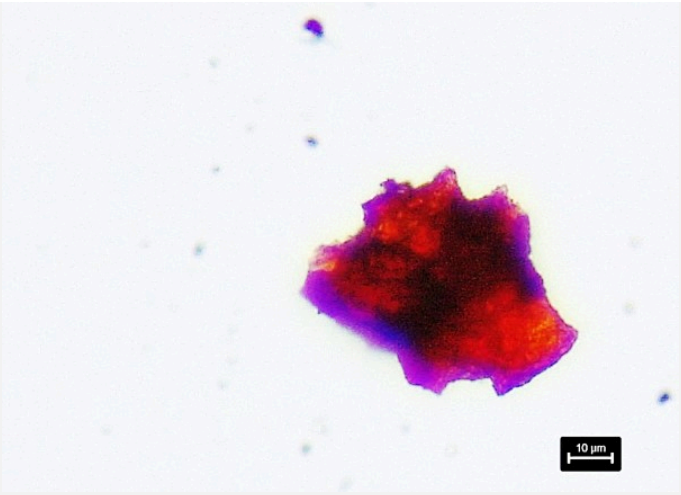


Fig. 13: Microscopic examination of sample obtained from CP4,

Credit The Royal Danish Academy, I.Langemark.

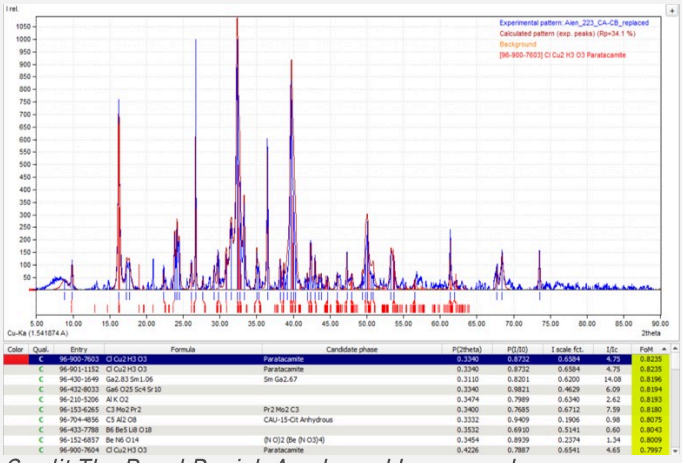


Fig. 14: XRD spectrum obtained from PXRD-analysis of CP1 and CP2,

Credit The Royal Danish Academy, I.Langemark.

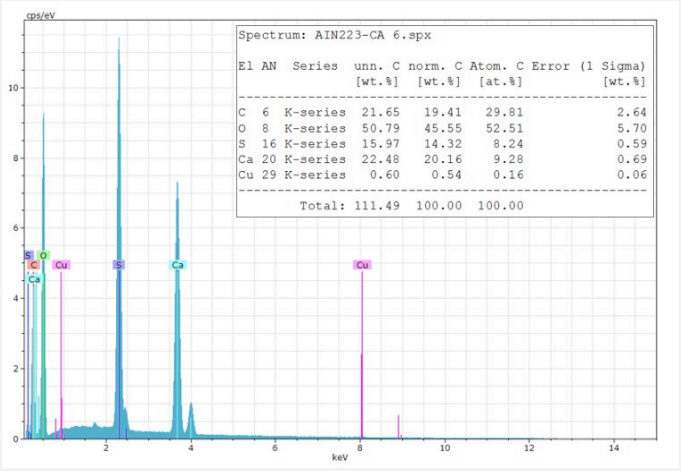


Fig. 15: SEM-EDS data from analysis of NMM2, showing a high amount of calcium,

Credit The Royal Danish Academy, I.Langemark.

Corrosion form	Multiform
Corrosion type	Mostly type I with locally type II (Robbiola)

Complementary information

Small amounts of white and waxy corrosion product have been observed (encircled in Fig. 5). Based on the presence of high amounts of copper tri-hydroxychloride (paratacamite) in the sample obtained from CP1 and CP2, this substance could very well be nantokite (CuCl).

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MiCorr stratigraphy(ies) – CS

Synthesis of the binocular / cross-section examination of the corrosion structure

None.

Conclusion

The figurine is a leaded bronze.

The corrosion products, which cover the entire object, are multi-layered. Most of the corrosion layers correspond to type I of Robbiola.

The presence of copper tri-hydroxychloride paratacamite was detected by PXRD in a sample of corrosion powder obtained from CP1 and CP2. PXRD analysis also detected small amounts of spertiniite, which is consistent with the visual aspects of CP1. However, it could also be the formation of chalconatronite ($Na_2Cu(CO_3)_2$ - $3H_2O$), a corrosion product associated with archaeological bronze from Egypt (Frondel 1955). CP3 is thought to consist mainly of malachite, CP4 and CP5 of cuprite. The dark corrosion layer CP6 might consist of tenorite as an original artificial patina.

The presence of paratacamite and white waxy spots suggest the possible presence of active corrosion, although the white waxy spots were located on top of CP4 and not at the interface between the remaining metal and CP6.

Three non-metallic compounds were found on the figurine: wax remains (NMM1), calcium precipitation confirmed by SEM-EDS (NMM2) and sediment remains (S1).

References

References on object and analytical methods

Reference object

1. Jørgensen, M. (2009) Katalog Ægypten V. Ny Carlsberg Glyptotek 2009, 23.1.
2. MiCorr_Figurine of man with baboon - AEIN 784

Reference analytical method

3. Benzonelli, A., Freestone, I. C., Martinón-Torres, M. (2017) A better shade of black: effects of manufacturing parameters on the development of ancient black bronzes in Archaeometry, Volume 59, Issue 6, 1034-1049. DOI: 10.1111/arcm.12299.
4. Berger, D. (2015) Artificial patination in Early Iron Age Europe: an analytical case study of a unique bronze artefact, in Journal of Archaeological Science, 57, 2015, 130-141. DOI: 10.1016/j.jas.2015.01.025.
5. Frondel, C., Gettens, R.J. (1955) Chalconatronite, a new mineral from Egypt in Science, 122, 75-76.
6. Mohamed, W. & Darweesh, S. (2012) Ancient Egyptian Black-Patinated Copper alloys, in Archaeometry, 54, 175-192.

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