SPECTROCHEMICAL ANALYSIS OF FOUR EGYPTIAN BRONZE LATE PERIOD STATUETTES

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The chemical composition of four ancient Egyptian Late Period statuettes (Osiris, Neith, Isis suckling Horus, and fragmentary infant Horus) was determined by inductively coupled plasma atomic emission spectrometry. The results of quantitative analysis demonstrate that three objects are made of a tin bronze, whereas one object is made of a lead bronze. Triangular Cu-Sn-Pb diagram of the four statuettes, along with the additional three Osiris statuettes previously analysed, shows the grouping among the objects. Sampled core material consisted mainly of SiO_2.

Key words: Osiris, Neith, Isis, Horus, Cu-alloy, quantitative analysis, ICP-AES, archaeological bronze, Egypt.

In the present paper, a series of four Late Period (664–332 BC) Egyptian bronze statuettes have been analyzed in order to contribute to the still limited database on Cu–alloy compositions from ancient Egypt. According to Vittiglio et al. (1999: 1698), although the development of metallurgy in Egypt is assumed to start about 5th millennium B.C. "only 200 analysis results are known, many of which were performed before the 1960s and some of undocumented reliability". The chemical composition (major elements to traces) is among the primary type of information which may be obtained with the aim of increasing the knowledge on the used material and ancient production technology, in combination with an archaeological determination of an object, chronological position, cultural context, provenance and distribution pattern.

The first of the analyzed pieces is a standing mummiform statuette of Osiris (fig. 1), Museum of Yugoslav History Belgrade, object number 82A,[1] origi-

[1] Entry 1713 of the inventory book.

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nated from Beni Suef[2] and presented to the Yugoslav president J. B. Tito by the Egyptian president A. el Sadat at an uncertain date between 1971–1974 (cf. Perc 1974: cat. no 52; Cvijović 1986: 172; idem 1991: 27; idem 2003: 21; Anđelković 1991: 70; idem 2002b: 42–43). Osiris, in the round, provided with a trapezoidal plinth (6.6 cm front, 6.75 cm sides, 4.7 cm back, 2 cm height), is holding a flail in his right hand and a peasant's crook with a long stock and a small hook curving to the right, in his left hand. The statuette bears sporadic traces of gilding. A thin, dark or light green and brown patina and corrosion. Osiris wears *atef*–crown on ram's horns, an uraeus and a closely plaited divine beard. He is wrapped in a robe. His hands are protruding from the robe to

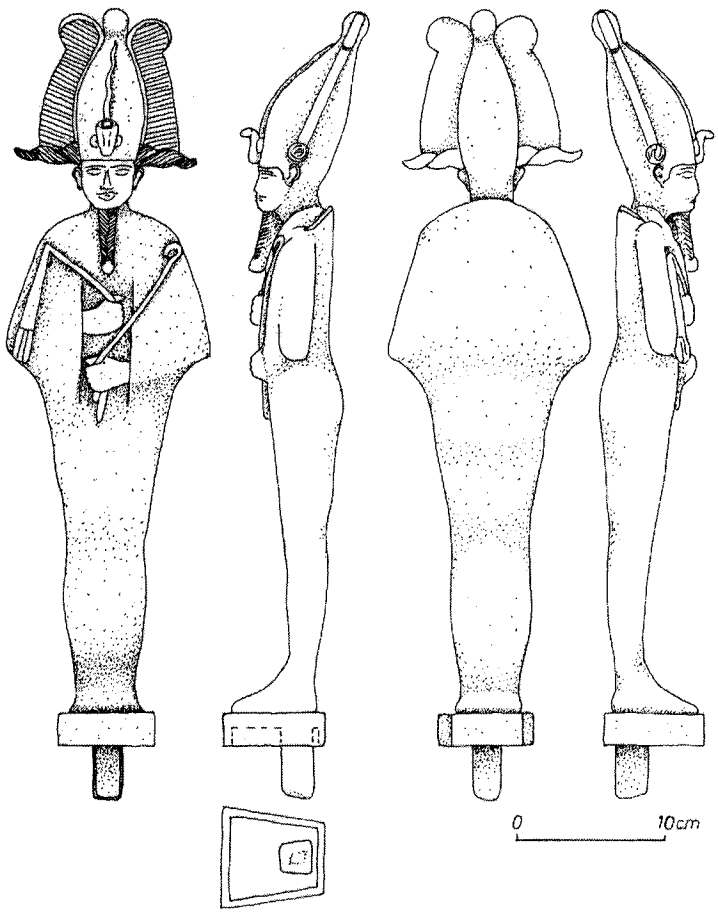

Fig. 1 Osiris, object number 82A

[2] On the modern wooden base there was a label: No. I250–400 bronze OSIRIS Beni Souef.

hold the insignias. The statuette is solid–cast except for the plinth that is hollow–cast. Height 51.5 cm, maximum width 13.7 cm (at the elbows), maximum depth 6.65 cm (at uraeus), weight 8.5 kg. The blackish inner core of the plinth, 1.1 cm deep, is still *in situ.* An integral part of the statuette is a solid–cast tenon of trapezoidal cross–section (1.67 cm front, 2.15 cm sides, 1.9 cm back) that protrudes 3.5 cm from the surface of blackish core at the base of the plinth to be fitted into the pedestal. The whole length of the tenon is ca. 4.5 cm, including 1 cm inside the blackish core. The thickness of the plinth wall is between 0.45–0.65 cm. Three samples were taken for the analysis.

The second is a statuette of the goddess Neith, in the round, solid–cast (fig. 2), City Museum of Vršac, object number *Aeg.* 27. Wearing the *deshret* crown with double uraei. The provenance unknown. Height 11.3 cm, maximum width 3.2 cm, maximum depth 2.2 cm (Anđelković and Panić–Štorh 2002: 26, 27 fig 11).

The third is solid–cast statuette of Isis suckling Horus (fig. 3), National Museum of Belgrade, object number 4/VI. Isis wears a tiara decorated with an uraeus, a vulture's wings, legs and tail, and surmounted by a solar disc between cow horns. Horus, seated on her lap, wears the sidelock of youth. The prove-

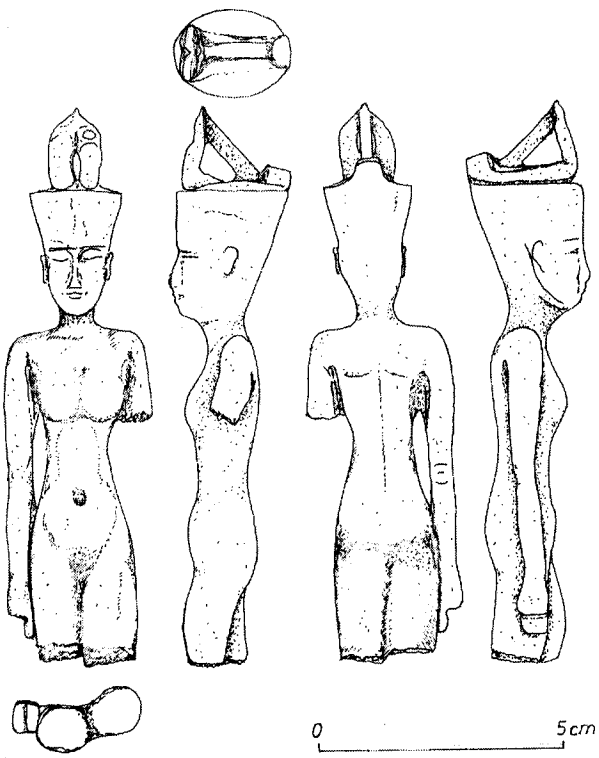

Fig. 2 Neith, object number *Aeg.* 27

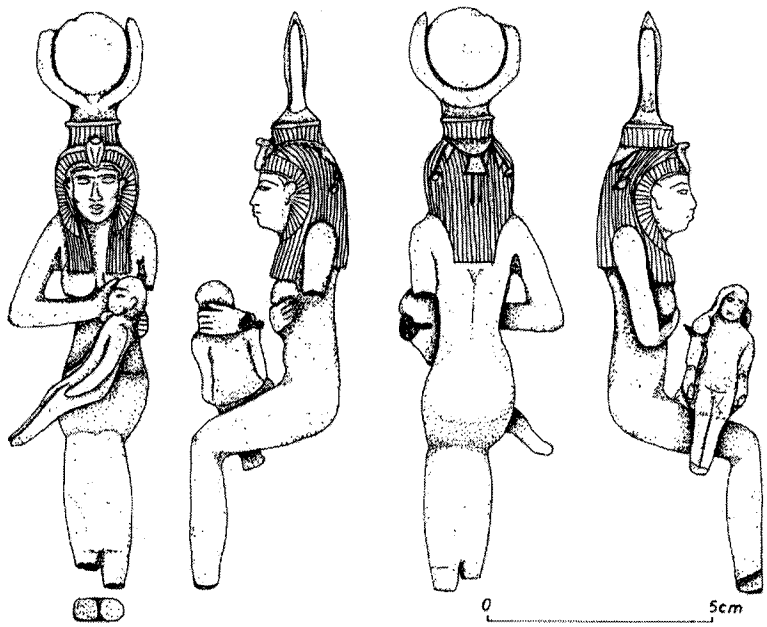

Fig. 3 Isus suckling Horus, object number 4/VI

nance unknown. Height 12.7 cm, maximum width 3.5 cm, maximum depth. 3.1 cm (Anđelković 2002a: 216–217, pl. I d–f).

The fourth is a fragmentary solid–cast statuette of the infant Horus who wears the sidelock of youth, in sitting posture (fig. 4), National Museum of Belgrade, object number 6/VI. The statuette was originally a part of an Isis suckling Horus group, similar to the previous one. A fragment of Isis' hand is visible on the back of Horus' head. The provenance unknown. Height 3.3 cm, maximum width 1.8 cm, maximum depth 1.4 cm (Anđelković 2002a: 217, 223, pl. IVc–d).[3]

Sampling

The needed samples for analysis were very carefully taken by a fine dental borer.

Sample 1a. Osiris, plinth, back wall, surface.

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[3] Thanks are due to Ms. Lj. Cetinić, Director and Mr. M. Cvijović, Curator, Museum of Yugoslav History, Belgrade, for permission to publish the Osiris statuette; Mr. J. Rašajski, Director of the City Museum Vršac, enabled the publishing of Neith statuette, whereas statuettes of Isis suckling Horus and infant Horus are published courtesy of the National Museum, Belgrade. The authors are grateful to Dr. B. Jovanović and Dr. M. Jovanović who took the samples in October 16, 2003. The authors would also like to thank Mr. C. Robertson for correcting the English text.

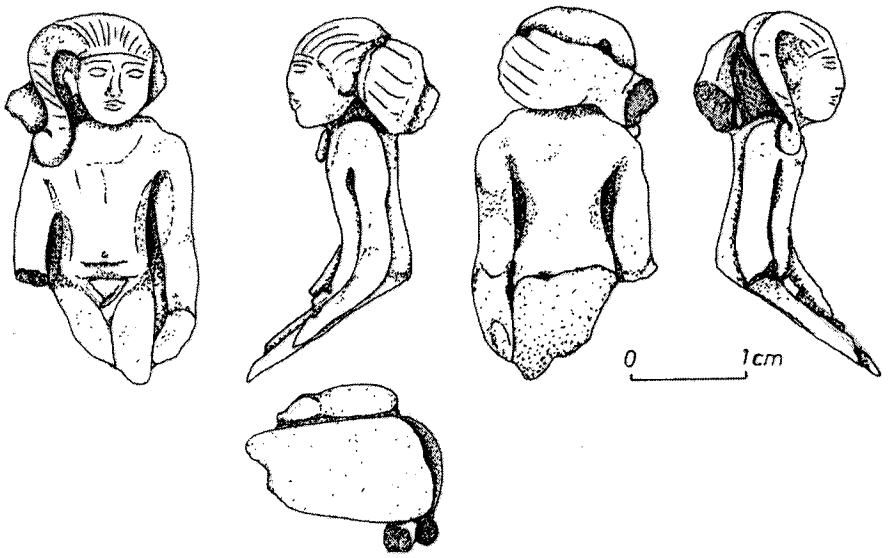

Fig. 4 Infant Horus, object number 6/VI

Sample 1b. Osiris, plinth, back wall, depth 3 mm.
Sample 1c. Osiris, base, blackish silicate core.
Sample 2. Neith, right leg, depth 2 mm.
Sample 3. Isis suckling Horus, the back of a hip, depth 3 mm.
Sample 4. Infant Horus, the back of a hip, depth 1 mm.

Sample and standards preparation

Approximately 50 mg of metallic parts of each sample was weighed and a mixture of HNO_3 and HCl was added. The samples were then heated gently until dissolution was complete. After cooling, sample solutions were made up to a volume of 50 ml. The original sample solutions were used for trace elements determination and diluted solutions for the major constituents determination. Calibration standards were prepared in appropriate concentration range from multi–elemental stock solutions. The matrix matched calibration standards and blanks were used for all measurements.

Apparatus

The chemical composition of the four ancient Egyptian statuettes was determined by inductively coupled plasma atomic emission spectrometry (ICP–AES). ICP spectrometer SPECTROFLAME (Spectro Analytical Instruments, Germany) operating at 27.12 MHz and 2.5 kW was used. The results of quantitative analysis are shown in Table 1. The relative standard deviation was 1–10% depending on the measured concentration range.

Element	Concentration (%)					
	Sample No. 1a	Sample No. 1b	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 1c
Cu	73±4	71±4	68±4	87±4	81±4	0.23
Sn	5.27	5.20	3.60	4.78	4.50	<0.05
Pb	1.55	1.51	12.1	1.05	3.69	0.06
Sb	0.25	0.27	0.05	0.24	0.12	<0.05
Fe	0.25	0.52	0.032	0.39	0.022	1.03
Ca	0.87	1.50	0.65	0.80	0.78	0.54
Mg	0.12	0.17	0.09	0.10	0.008	0.28
Si	0.30	0.30	1.43	0.30	0.30	35
As	0.040	0.032	0.022	0.014	0.027	<0.05
Ti	0.005	0.006	<0.003	<0.003	<0.003	0.25
Ba	0.003	0.005	0.002	0.002	0.001	0.012
Al	0.10	0.10	0.02	0.02	0.02	0.50
Bi	0.05	0.05	0.04	0.04	0.04	<0.03
Ag	0.02	0.02	0.02	0.03	0.03	<0.02
Mn	0.002	0.002	<0.001	<0.001	<0.001	0.020
Co	0.02	0.02	0.08	0.12	0.05	>0.02
Ni	0.01	<0.01	0.05	0.03	0.09	0.38
Sr	0.01	0.01	0.01	0.02	0.01	<0.005
Zn < 0,04; not detected: Au, Cd, Ce, Cr, Hg, Mo, Sc, C, W, Y.						

Table 1.

Results and discussion

From the results listed in Table 1. we can conclude that the objects No. 1, 3 and 4 (Osiris, Isis suckling Horus and fragmentary infant Horus) are made of a tin bronze (Cu–Sn alloy) with a few percent of lead (Pb), whereas the object No. 2 (Neith) is made of a lead bronze (Cu–Sn–Pb alloy). The tin (Sn) content of the two groups is similar. The low antimony (Sb) content in all objects suggests that it is not added intentionally to the alloy, but it was perhaps present, at the impurity level, in the copper ore.

Triangular Cu–Sn–Pb diagram (fig. 5), of these four statuettes, along with the additional three Osiris statuettes previously analysed (Anđelković, Pavlović and Savović 2002), clearly demonstrate the grouping among the objects. Two groups can be discerned in the data set: one (Cluster 1)[4] containing on average 78±7% Cu and limited amount of Pb (<4%), while the second group (Cluster 2)[5] shows a lower Cu content (60±8%) and more Pb (12–15%). The average Sn content is similar to both groups (<5%).

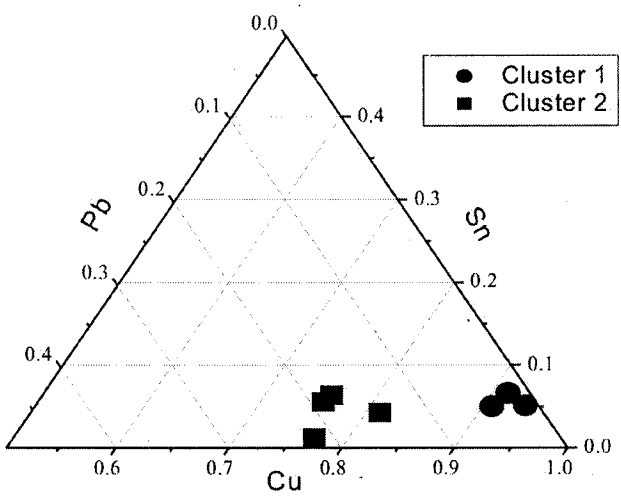

Fig. 5. Triangular Cu–Sn–Pb diagram showing the grouping among analyzed objects. In the diagram normalized concentrations are plotted

As noted by Vittiglio et al. (1999: 1705) the bronze objects easily oxidize, that gives rise to the formation of crystalline Cu^{2+} salts (acetates, sulfates, carbonates) which can be easily removed from the surface. On the other hand, Pb and Sn are also easily oxidized but form stable and insoluble corrosion products that stay on the surface. That is why the remaining superficial layers of metal become depleted in Cu and tend to show higher Pb and Sn concentrations than the original alloy. In other words, the surface layer from corroded bronze object (cf. Scott 1994), very often included in the analyzed sample, can influence the accuracy of the results. However, if the corroded layer is thin and autochthonous (i.e. not polluted by some other adjacent corroded object), one can still estimate to a reasonable approximation, the original major components of the alloy. This seems to be confirmed by the Osiris samples 1a and

[4] Osiris, object number 82A, Museum of Yugoslav History, Belgrade; Isis suckling Horus, 4/VI, and infant Horus, 6/VI, National Museum of Belgrade.

[5] Neith, *Aeg.* 27, Osiris, *Aeg.* 24, Osiris, *Aeg.* 25, and Osiris, *Aeg.* 26, City Museum of Vršac.

1b: the former was taken from the surface, whereas the later was obtained from the same spot some 3 mm deeper; their composition was practically identical.

According to Lucas and Harris (1962: 222) several examined specimens of core material from Egyptian bronze statuettes "all consisted of blackened sand (...) The black was chiefly an iron compound together with occasionally a very small proportion of organic matter". The sampled siliceous blackish core material (sample No. 1c) from the Osiris plinth[6] consisted mainly of SiO_2 (75±4%), probably powdered quartz sand. Our previous analysis of the blackish (first) and greyish (second) core of two hollow–cast Osiris statuettes also confirmed SiO_2 (50±4% first, 70±4% second) as the major constituent (Anđelković, Pavlović and Savović 2002: 245–247). Nevertheless, it is not quite clear what exactly was used as a binding medium.

The results of spectrochemical analysis of four Late Period statuettes presented here, along with three copper–alloy pieces already analysed by the present authors (Anđelković, Pavlović and Savović 2002), will hopefully contribute to the growing body of analytical data and facilitate in the compilation of a series of objects of statistical significance, necessary for a better understanding of the evolution of Cu–alloy metallurgy and its working technology in Ancient Egypt, as a reflection of technical, economic, social, cultural, religious and artistic changes of Egyptian society.

[6] As we have already noted, this Osiris statuette is solid–cast except for the plinth.

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* With English summary

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СПЕКТРОХЕМИЈСКА АНАЛИЗА ЧЕТИРИ ЕГИПАТСКЕ БРОНЗАНЕ СТАТУЕТЕ ИЗ ПОЗНОГ ПЕРИОДА

Резиме

Спектрохемијски су анализирани узорци са статуете Озириса (сл. 1) из Музеја историје Југославије, инвентарски број 82А. Узорак 1а узет је са површине статуете, док је узорак 1b узет са истог места, али на дубини од 3 mm. Добијени подаци су приближно истоветни, што показује да се у сличним случајевима, при танком слоју аутохтоне патине и корозије, без изражене калцинације, узимање узорака евентуално може вршити и кроз корозивни слој, без већег утицаја на тачност резултата. Статуета Озириса је урађена од тзв. калајне бронзе, у техници пуног лива (тежина 8,5 kg), осим стопне плоче која је изведена у техници шупљег лива. Црнкаста испуна, узорак 1с, састоји се 75 % од силицијум диоксида (SiO_2), вероватно спрашеног кварцног песка. У продужетку ножног дела статуете је трн, благо трапезалног пресека, за углављивање на подлогу. Узорак 2 потиче са статуете Неит (сл. 2), из Градског музеја у Вршцу, инвентарски број *Aeg.* 27, која је урађена у пуном ливу од тзв. оловне бронзе. Узорак 3 је са статуете Изиде која доји малог Хоруса (сл. 3), Народни музеј у Београду, инвентарски број 4/VI, док је узорак 4 узет са фрагментарног Хоруса (сл. 4), Народни музеј у Београду, инвентарски број 6/VI, очито првобитно дела фигуралне композиције куротрофне Изиде, сличне претходној. Оба предмета су урађена од тзв. калајне бронзе у техници пуног лива. Квалитативна и квантитативна анализа узорака извршена је емисионо спектрометријски (идуктивно спрегнута плазма), а добијени резултати приказани су у табели 1. Триангуларни Cu–Sn–Pb дијаграм (сл. 5) анализираних узорака, заједно са узорцима претходно публиковане три статуете Озириса (Anđelković, Pavlović and Savović 2002), показује јасно груписање. Легура од које је направљена прва група предмета (групација 1: Озирис, Изида са Хорусом и фрагментарни Хорус) садржи приближно 78±7% бакра и малу количину олова (<4%), док друга група предмета (групација 2: Неит и три статуете Озириса из Градског музеја у Вршцу) показује нижи садржај бакра (60±8%), и више олова (12–15%). Просечан садржај калаја је сличан код обе групе (<5%). Статуете се датују у Позни период (664–332. године пре наше ере).

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