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METHODS OF NATURAL SCIENCES IN THE STUDY OF CULTURAL HERITAGE OBJECTS

Golden Details of a Funeral Wreath and Clothing from the Roman Time Bosporan Crypt: X-ray and Mass Spectrometric Studies

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Abstract—The results of a comprehensive study present the details of the funeral wreath and clothing from the crypt of the Roman period in the area of the modern Malyy Lane in the city of Kerch. A comparative analysis of the metal composition of similar items from synchronous sites of the Northern Black Sea region has been carried out. It has been established that the details of funeral wreaths and appliqués to them are made of a gold-silver alloy that can be easily worked, which was widely used in Roman times throughout the territory of the Bosporos. Items created in a local workshop for funeral vestments have traces of careless or not very skillful application of the image, and damage to the surface, as evidenced by X-ray tomography data.

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INTRODUCTION

An ancient burial was discovered on the site of the Panticapaeum necropolis (on the territory between the right bank of the Bulganak River in the east and the swampy lowland with tributaries of the Katerlez River in the southwest, in the area of the modern Malyy Lane in the city of Kerch) during construction work in 2018.

The burial complex was a stone crypt built of well-worked limestone blocks. The masonry of the western and southern walls of the crypt has been preserved, as well as individual blocks of the eastern wall. The dimensions of the investigated part of the crypt chamber were 3.8 × 3.5 m. During the research, a massive accumulation of fragments of skeleton bones belonging to at least 111 individuals was revealed.

Eleven bronze coins of the 3rd century B.C., a fragmented bronze mirror, a fragment of a fibula, a bronze bracelet with open expanding ends, bronze tweezers, a clasp with a shield in the form of a theatrical mask, a bronze shoe buckle and a detail of the lock of the box in the form of a herm were found in the lower part of the filling of the chamber of the crypt. Fragments of decorations in the form of triangular plaques and complex-shaped objects made of foil, pendants in the form of a medallion attached to a thread, and a rounded medallion (indication) with a chased image of the Bosporan king (?) were also found on the floor of the crypt chamber. Among other things, there were individual glass beads. The material found during the clearing of the ruined crypt can be dated to the 1st–3rd centuries B.C. and belong to the Bosporan burial tradition of the Roman period. The duration of the use of the crypt, the abundance of metal objects, and their good preservation make the analysis of this archaeological complex promising for studying the evolution of alloys and the transfer of technologies for the production of jewelry, prestige items, costume details and funeral clothes in the Bosporos. The purpose of this article is to study the composition of the alloy and methods for making common wreath decorations from thin metal foil that accompanied the Bosporans to the afterlife.

OBJECTS AND STUDY METHODS

The study included eight items that were part of the grave goods of the crypt in Malyy Lane. These are the

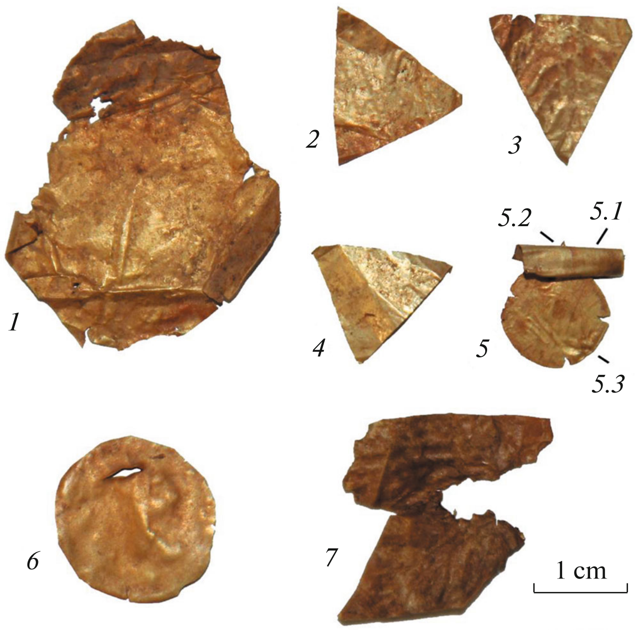

Fig. 1. Details of the funeral wreath and clothes made of thin foil: (*1*) round decoration, (*2*, *4*) triangular decoration patches, (*3*) triangular foil applique with an ornament, (*5*) thread with a disc-shaped pendant, its details (*5.1*, *5.2*, *5.3*), (*6*) decoration pendant-indication with a cut hole, (*7*) decoration in the form of a shamrock.

details of a wreath and stripes on clothes made of thin gold foil (Fig. 1, *1*–*7*):

1. Round decoration. The image is not readable. Diameter 2.8 cm. Designated during research as Object 1 (Fig. 1, *1*).

2. Triangular patches-decorations (2 pcs.). Dimensions: 1.2 × 1.35 cm (Object 2) (Fig. 1, *2*); 1.2 × 1.3 cm (Object 4) (Fig. 1, *4*).

3. Triangular foil applique with herringbone pattern. Dimensions: 1.25 × 1.35. Object 3 (Fig. 1, *3*).

4. A pierce in the form of a tube with a disc-shaped suspension. The dimensions of the thread: 1.2 × 0.3 cm, the diameter of the pendant is 1.1 cm. Object 5, its details: 5.1, 5.2, 5.3 (Fig. 1, *5*).

5. Round pendant ornament-indication with cut hole. Diameter 1.8 cm. Object 6 (Fig. 1, *6*).

6. Decoration in the form of a shamrock. Dimensions: 2.2 × 2.3 cm. Object 7 (Fig. 1, *7*).

The study of the internal structure of the rounded ornament (Object 1) (Fig. 1, *1*), triangular appliqué (Object 3) (Fig. 1, *3*), thread with a disc-shaped pendant (Object 5) (Fig. 1, *5*), pendant-jewelry with a cut hole (Object 6) (Fig. 1, *6*) was carried out using an industrial X-ray tomograph NSI X5000. Shadow projections were recorded with a Perkin Elmer position-sensitive X-ray detector with a matrix size of 2048 × 2048 pixels, a pixel size of 200 × 200 μm, and a dynamic range of 16 bits. CsI:Tl-based scintillator was used during the study. The tomography of the rounded ornament and the jewelry-pendant with a cut hole (Objects 1 and 6) was carried out using a closed-type tube at a voltage of 440 kV and a current of 1500 μA. The focal spot size was 400 μm. A copper filter of 9.5 mm thick was used. For the rounded ornament the angular step of rotation relative to the vertical axis was 0.225°, the exposure time for one frame was 0.5 s, and the gain was 1 pF. For the decoration pendant, the exposure time for one frame was 1 s, the gain was 1 pF, and the angular step was 0.36°. The pixel size of the obtained images was 67 × 67 μm.

X-ray tomography of a triangular applique (Object 3), a thread with a disc-shaped suspension (Object 5) was carried out using an open tube. Filters were not applied. The triangular applique measurement parameters were as follows: voltage—150 kV; current—250 μA; focal spot size—37.5 μm; angular step—0.24°; exposure time—1 s; gain—1 pF; pixel size of shadow projections—16 × 16 μm. The measurement parameters of a rod with a disc-shaped suspension: voltage—150 kV, current—300 μA, focal spot—45 μm, angular step—0.36°, exposure time of one frame—1 s, gain—1 pF, pixel size of shadow projections—18 × 18 μm. For measurements using an X-ray tomograph, reconstruction of tomographic sections, and volumetric modeling the efX-DR, efX-CT, and Volume Graphics studio 3.5.1 software were used.

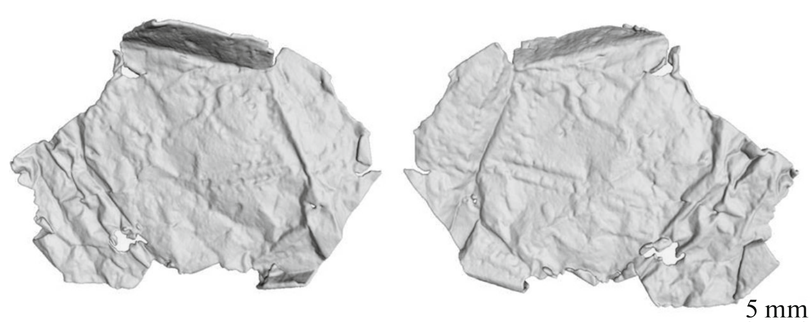

Fig. 2. Volumetric model of the round decoration.

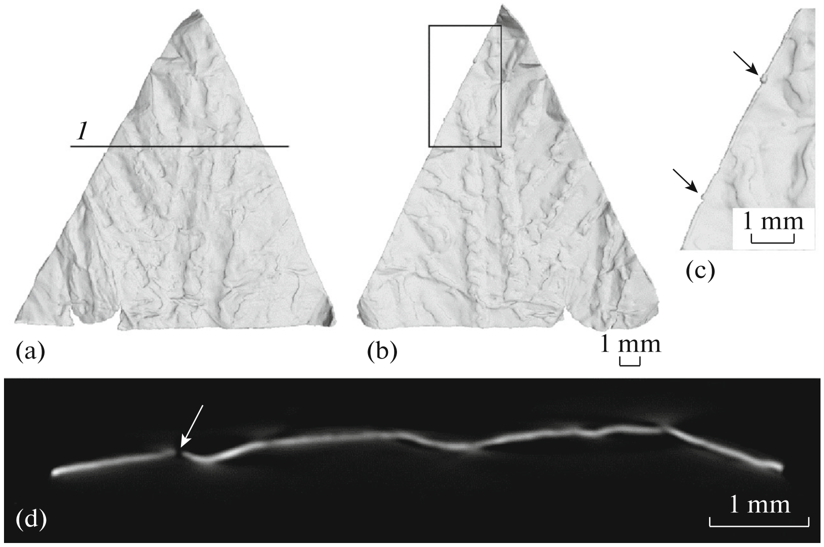

Fig. 3. Results of a triangular applique tomography: (a, b) three-dimensional representation with a pattern relief; (c) a fragment of a three-dimensional model with traces of a cutting tool (marked by arrows) on the edge of the applique, the position of the fragment is indicated by a frame in (b); (d) tomographic section with a through hole (marked with an arrow), the position of the section is indicated by 1 in (a).

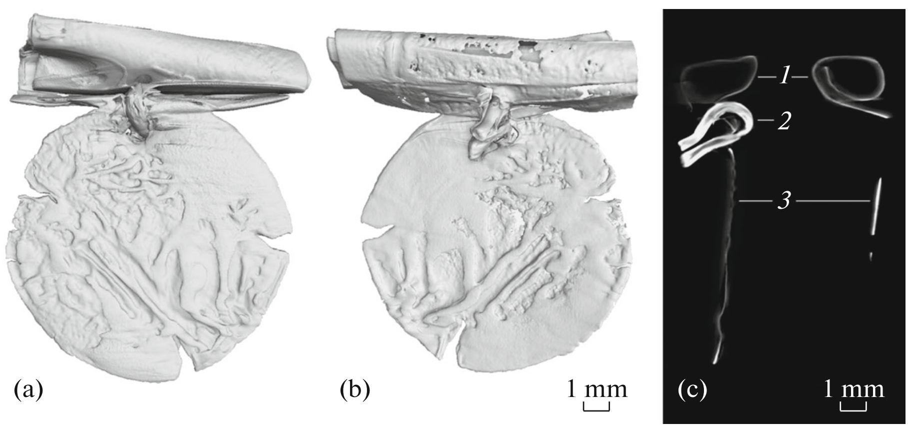

Fig. 4. (a, b) A three-dimensional model of the thread with a disc-shaped pendant. (c) Longitudinal tomographic sections of thread (*1*) with disc-shaped pendant (*2*, *3*) fastening wire.

The elemental composition of the metal of each item was determined by inductively coupled plasma mass spectrometry with laser ablation sampling (MS-ICP-LA). The use of this method makes it possible to establish the composition of the alloy impurity with high accuracy (up to trace concentrations). For measurements, an ELAN DRC-e inductively coupled plasma mass spectrometer with an NWR 213 laser ablation system was used with the following parameters: RF generator power, 1100 W; mass measurement time, 25 ms; the number of replicas—15; sample—0.5 dm^3/min, laser operation mode—continuous, laser beam spot diameter—110 μm, laser beam power—60%, laser beam pulse frequency—5 Hz, laser beam energy flux density—1.8 J/cm^2, scanning speed template—80 μm/s.

In order to build a calibration dependence for the Au, Ag, Ni, Zn, and Cu elements, a standard reference sample of the gold alloy ГСО 10283-2013 юЗл750—10 (GSO 10283-2013 yuZl750—10) was used; for the remaining elements—NIST 610. The results of the measurements obtained were normalized to 100% of the sum of the measured elements.

The study of the elemental composition via the SEM/EDS method was carried out using a Helios Nanolab 600i dual-beam scanning electron microscope with a focused ion beam (Thermo Fisher Scientific) equipped with an EDS system (EDAX) at an accelerating voltage of 30 kV in a high vacuum mode

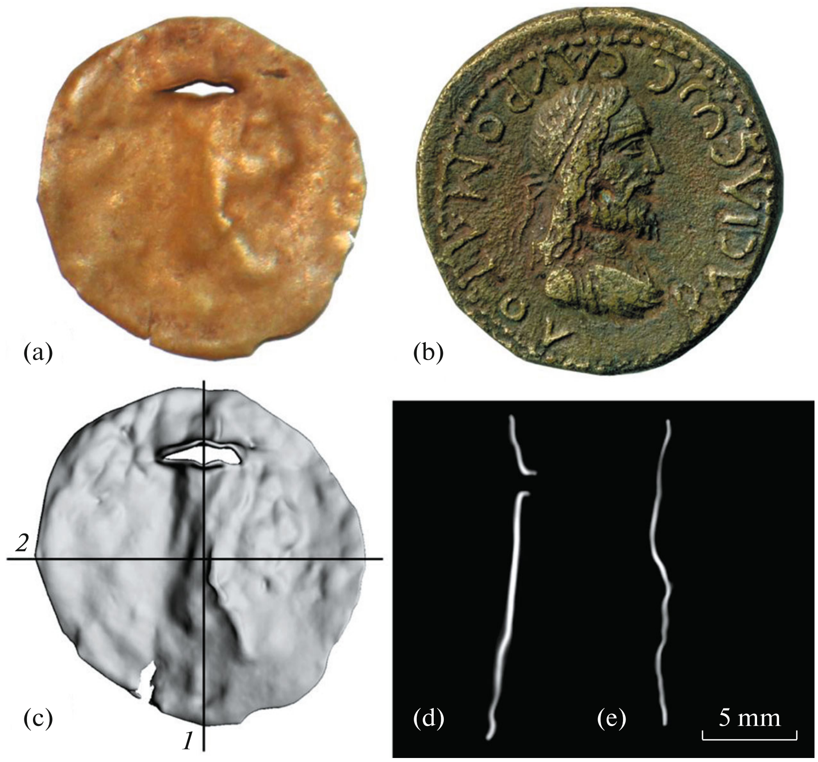

Fig. 5. (a) Photograph of the pendant-indication (Object 6); (b) the double denarius of Sauromates II (ca. 186–196 AD, weight 8.93 g, diameter 27 mm, Kerch Museum, KN 7397); (c) a three-dimensional model of the pendant; (d, e) an orthogonal tomographic sections of the pendant. The position of the sections is marked on the three-dimensional model (c): 1 (d), 2 (e).

(10^{-4} Pa). The EDS spectra were processed using the TEAM (EDAX) software. The obtained results were considered semi-quantitative since the total content of the detected elements was reduced to 100%. The sensitivity of the method is 0.1–0.5 wt %. The EDS study of the elemental composition was carried out for three to five areas on the surface of the products, the obtained data were averaged.

Table 1. Elemental study results according to SEM/EDS, wt %

Elements	Objects								
	1	2	3	4	5.1	5.2	5.3	6	7
Mg	<0.5	<0.5	0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5
Al	0.7	–	<0.5	–	–	0.9	1.1	–	<0.5
Si	3.0	2.3	3.4	1.9	2.9	4,9	2.0	1.5	1.6
P	1.3	1.8	1.1	1.0	1.1	1.0	1.1	1.3	1.0
S	1.5	1.3	1.2	1.1	1.5	2.1	1.3	1.6	1.2
Cl	–	<0.5	<0.5	<0.5	<0.5	–	–	–	–
Ca	0.9	2.1	–	<0.5	1.0	1.1	0.7	<0.5	–
Fe	0.6	<0.5	1.0	0.5	0.7	0.8	0.8	0.5	0.5
Cu	0.8	1.0	1.1	1.4	0.9	0.8	<0.5	1.0	0.9
Br	2.2	2.5	2.0	1.6	1.4	1.5	–	2.3	2.2
Ag	20.2	15.0	19.5	13.8	19.7	23.8	31.7	14.6	13.4
Au	68.4	73.0	69.8	77.7	70.0	62.7	60.7	76.6	78.9
Hg	–	–	–	–	–	–	–	–	–

ELEMENTAL STUDY RESULTS

A preliminary elemental study of golden items of the funeral dress was carried out via SEM/EDS method (Table 1).

For a product made of a thread bent from a sheet with a round pendant, interconnected by a wire (Object 5), the composition was determined on each structural element. According to the results of the study, it was found that all the studied items were made of gold of a sufficiently high fineness (Au 60.7–78.9%) with a significant content of silver (Ag 13.8–31.7%), and small impurities of copper (Cu 0.8–1.4%). The presence of silicon, phosphor, sulfur, and bromine was also registered within 1–2%. These elements are probably related to surface contamination (see Table 1, objects 5.1, 5.2, 5.3).

The results of elemental analysis according to the ICP-LA MS data (Table 2) are comparable with the data obtained by the SEM/EDS method for the concentration of gold (Au 68.5–77.3%) and copper (Cu 0.74–1.47%) in the products, and somewhat differ in the silver content (Ag 21.1–30.4%). The presence of lead, tin, titanium, sodium, magnesium, phosphor, and potassium is determined in hundredths of a percent. The last four elements are most likely to be surface contamination, as those are presented in tenths of iron and aluminum. It is important to note that the ICP-MS method detected the presence of platinum in the composition of gold items, which presumably is a gold ore microimpurity.

RESULTS AND DISCUSSIONS OF X-RAY TOMOGRAPHY

The most detailed and illustrative data on relief images and the thickness of the foil of funerary details of wreaths, diadems, and appliques were obtained via X-ray tomography.

According to the data, no layering of the rounded decoration (Object 1) was found. The thickness of the foil from which it has been made was about 230 μm. The imprint of the image on the decoration is not clear, its contours and individual elements can be traced on both sides of the product (Fig. 2). Presumably, this small fragment that was left with the deceased, symbolized the presence of the entire object as a whole, possibly a funeral wreath [1, p. 9].

The method of X-ray tomography allows us not only to get an idea of the detailed morphology of a triangular appliqué surface with a herringbone ornament (Object 3) but also to draw conclusions about the method of its manufacture. The product was cut from the sheet with a cutting tool with a step of 3.0–3.7 mm, as evidenced by marks along the edge (Figs. 3a, 3c). There are through holes in the object with a diameter of 20–80 μm (Fig. 3d). The application thickness was ~70 μm. Presumably, the ornament was embossed using the metal-plastic technique, as evidenced by the holes-ruptures on the surface of the product. No traces of preliminary marking of the ornament were found.

The tomogram of the tube-shaped piercing with a disc-shaped suspension (Object 5) clearly shows that it was cut from a forged sheet. The product has numerous tears and irregularities along the edges, the surface is wrinkled, and the image on it cannot be interpreted (Figs. 4a, 4b). The blank for the piercing was cut out according to the shape of the entire product. Then the upper part was folded into a tube in one and a half turns (Fig. 4c, *1*), the edges of which were fastened with a round in the cross-section wire, passing through the upper part of the disc-shaped suspension and the bent long side of the thread. The hole was punched from the other side to the outer side, the edge was not processed. The ends of the fastening wire are open (Fig. 4c, *2*). The thicknesses of the sheets from which the piercing and suspension are made coincide and amounted to ~70 μm. The wire diameter is about 0.5 mm.

Table 2. Elemental study results according to MS-ICP-LA, wt % data

Element	Objects						
	1	2	3	4	5	6	7
Au	71.9	73.9	76.1	75.0	68.5	77.1	77.3
Ag	25.0	23.1	22.6	23.0	30.4	21.1	21.3
Pb	0.037	0.008	0.006	0.005	0.018	0.003	0.004
Sn	0.013	0.029	0.020	0.011	0.003	0.010	0.014
Cu	0.740	1.47	1.05	1.45	0.860	1.23	1.17
Zn	0.004	0.028	0.019	0.018	0.003	0.011	0.016
Fe	0.556	0.800	0.091	0.214	0.122	0.417	0.081
Pt	0.008	0.003	0.003	0.003	0.003	0.002	0.003
Sb	0.001	0.002	0.002	<0.001	<0.001	<0.001	0.001
Na	0.021	0.024	0.003	0.017	0.009	0.013	0.014
Mg	0.072	0.081	0.007	0.032	0.012	0.011	0.005
Al	0.558	0.479	0.055	0.170	0.046	0.053	0.043
P	0.015	0.009	0.004	0.009	<0.001	<0.001	<0.001
K	0.032	0.046	0.002	0.014	0.003	0.004	0.020
Ti	0.030	0.022	0.003	0.006	0.002	0.008	0.001
Mn	0.002	0.002	<0.001	0.001	<0.001	<0.001	<0.001

According to tomographic data, a round ornamental pendant-indication with a cut hole (Object 6) was made from a sheet about 260 μm thick. The hole has uneven edges and a maximum size of 3.7 × 1.0 mm (Fig. 5). Perhaps this is an indication from the coin of Sauromates II (Figs. 5a, 5c), at least the portrait features of the Bosporan king (see Fig. 5b) clearly appear both in the photograph of the indication and on its tomogram (see Figs. 5a, 5c).

RESULTS AND DISCUSSIONS

Most of the studied objects were parts of funeral decorations and wreaths. The tradition of making metal funeral wreaths originates in Ancient Greece back in the 5th century B.C. and goes back to the custom of decorating the head during the holidays with wreaths of flowers, fragrant herbs, and plant branches. Wreaths originating from the necropolises were made of gold, silver, and bronze and were used exclusively for the funeral rite. They are made of the thinnest foil, very light, with fragile petals, whereas the minimum amount of precious metal is spent on them ([2], pp. 283, 285, 293–294). The largest number of funeral wreaths in the Northern Black Sea region was found in the necropolises of the cities of the Bosporan kingdom—Panticapaeum ([3], p. 222, Table 2, *13–15*), Gorgippia ([4], pp. 193, 195, Figs. 137, 140), Tanais ([5], tab. XXIX, *6*), Phanagoria ([6], Tables 4–6 and 7, *1*, *10*, *15*) but they are also common for Chersonesos ([1], pp. 9–24).

In the first centuries A.D. on the territory of the Bosporan kingdom, a simple form of a funeral wreath usually was made of thin gold foil in the form of a ribbon, with riveted or glued leaves, usually shamrocks, imitating celery leaves or three combined leaves of laurel or olive ([1], p. 9). Often, a coin-like indication was placed in the center of such a wreath ([7], pp. 184–185).

In addition to shamrocks, funeral wreaths were also decorated with other superimposed elements: smooth or ornamented circles, plates with relief images, indications or imitations of coins, and rectangular and triangular applications ([8], pp. 55, 61–62). Details of the simplest diadems and wreaths made of gold plates and leaves are also found on the monuments of the barbarian population of Crimea. Gold front plates come from the mausoleum of Scythian Naples ([9], pp. 108–110). A large number of such items were found at the Ust'-Alma necropolis ([10], Figs. 109, *1*, *3*; 112, *1*, *8*; 119, *1*, *3–5*; 121; 122), ([11], Figs. 4, *1*, *2*, *9*, *10*; 5, *1–4*; 6, *1*, *7*), ([12], Fig. 5, *1–3*).

As we see from Table 2, all the studied parts of the funerary decorations are made of a gold-silver alloy of approximately the same composition, with a gold content of 68 to 77%, silver from 21 to 30%, and small additions of copper (up to 1.5%). A very similar composition of the alloy is observed in similar details of funerary wreaths of the second half of the 2nd–3rd centuries from Phanagoria ([13], pp. 293–294).

On the contrary, to create details of funeral wreaths and diadems from the necropolis of Chersonesos, much more high-grade gold was used (up to pure gold). The average content of gold in the leaves of wreaths and ribbons from diadems—89%, in front and round plates—85%, in sewn-on plaques—91%, and in coin-like indications—86%. The second component in the alloy is silver (3–21%). The allow also contains small amounts of copper (0.5–3.8%)([14], pp. 219–222). It is possible that lower-grade gold was used in the Bosporos due to the high demand for funeral wreaths, which were very often used in burials of the first centuries.

A round plate with an image imprinted from the "matrix," the so-called indication, deserves special attention. These products are most often imprints of coins. As part of the grave goods, they act as substitutes for a full-weight coin, its light, thin, almost weightless likeness. The widespread practice of placing an indication or a coin in the grave is usually explained as a payment to Charon for transportation to the underworld ([15], pp. 85, 89). The use of indications in Hellenic burial practice is recorded in the necropolises of Kos, Dardanus, and Athens. On the territory of the Northern Black Sea region, imprints of coins are often found in the Chersonese necropolis ([1], pp. 169–194, 329–349) and especially often in burials in the Bosporus of the Roman period. Finds of indications are known in the necropolises of Nymphaeum, Kytei, Phanagoria, and Gorgypia. Separate indications have holes for sewing to the textile base of the wreath (usually in the central part) or clothing, others were placed on the body of the deceased along with gold plaques from gold foil. The indications on the central shields of golden funeral wreaths are well known. Another type of funerary indication is an imprint from the coins of Roman emperors on gold plates, which served to decorate wooden coffins ([7], pp. 182–184). A tube-shaped piercing with a disc-shaped pendant has analogies in the grave goods of the Phanagoria necropolis, where similar items were found as part of necklaces in the burials of middle of the 2nd–3rd century A.D. ([6], cat. no. 197A, 197B, tab. 66, *7*, *8*), ([16], p. 232).

CONCLUSIONS

In the crypt in Malyy Lane, both utilitarian items used by the owners during their lifetime, and things that had symbolic purposes and were created exclusively for funerary purposes were found. The first category includes findings made of bronze and coins. The second category includes items made of gold and copper foil. According to the results of elemental analysis according to MS-ICP-LA and SEM/EDS data on the details of funeral wreaths and appliques to them, it was established that they were made of a fairly high quality gold (Au 68.5–77.3%) with a very noticeable silver additive (Ag 21.1–30.4%). The gold-silver alloy is easy to process, both mechanically and via casting. Such an alloy was used in Roman times throughout the Bosporos, both on the territory of it's European part (the necropolis of Panticapaeum) and in the cities of the Asian Bosporos. The X-ray tomography has confirmed that a thin foil of a gold-silver alloy was made by mechanical processing—forging a sheet, from which products of the required shape were then cut. In this case, a sheet thickness of 70 to 260 μm was achieved. Further, if necessary, an embossed ornament was applied to them. Coin indications were made by wrapping them in foil, then in a lead plate, which was struck with a wooden mallet. After obtaining the image, the indication was cut off at the edges ([1], p. 170). As evidenced by X-ray tomography data, things created for funeral vestments have traces of careless or not very skillful drawing of the image, and damage to the surface. Coin-like indications, as well as other details of funeral wreaths made of thin metal foil, are indicators of local jewelry production since their fragility made it impossible to transport them over long distances ([1], p. 170). An additional proof of the local, Bosporan, production of our indication is, possibly, an imprint from a coin of the Bosporan king Sauromates II.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

OPEN ACCESS

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