

## COMPOSITION OF GOLD AND SILVER OBJECTS FROM THE SOUTH URALS BURIAL MOUNDS (XV-II c. BC)

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**ABSTRACT.** The composition of auri- and argentiferous products from ten burial mounds of different age (XV-II c. BC) from the South Urals has been studied. Using microprobe analysis of Au, Ag, Cu, Sn, Pb, Zn ratios have been determined in the artefacts presented by pendants, torques, ear-rings, bracelets and foil from quiver cover plate, bridle cover plate, and saddle-tree cover plate. The characteristic composition of auriferous alloy for each period has been established: in the Bronze Age pure native gold has been used for the manufacture of jewellery; for the Early Iron Age application of binary alloys is observed; while in the Late Iron Age three-part artificial alloys have been documented. Some conclusions for the possible sources of gold and silver are made. The most certain source of gold is suggested for objects in which Os-mineral inclusions are presented that are typical for inclusions in the ultrabasic rocks in the East-Urals Fault zone.

### Introduction

Since the end of the last century there has been a plenty of publications, devoted to the research of ancient gold. Besides the archaeological description and dating of artefacts, these studies discussed problems of the reconstruction of some objects, possible manufacturing technique, definition of geochemical features of ancient alloys and the identification of ore sources (Northover et al., 1995).

In this paper, the composition of 32 auri- and argentiferous products (collections of A. D. Tairov, S. G. Botalov, N. A. Polushkin, D. G. Zdanovich) from ten different in age (XV-II c. BC) burial mounds of the South Urals have been studied and discussed (Table 1-3). The characteristic of the burial mounds and tested materials were presented in several papers (Bushmakin et al., 1999; Zaykov et al., 1999; Zaykov, 2003; Zaykov et al., 2008). The ancient objects are torques, bracelets, rings, ear-rings, pendants, tress ornaments. Overwhelming majority of the jewellery is covered by a thin gold foil.

The gold composition study was carried out by using microprobe analyzers JCSA-733 JEOL and REM-202M at the Institute of Mineralogy Ural Branch, Russian Academy of Sciences (operators: Eu. I. Churin and V. A. Kotlyarov). Gold particles (with the size of 0.5-2.0 mm) from objects have been cut off, put in epoxies pitch and carefully polished. In order to reveal structural heterogeneity in the metals, part of the samples was etched in acid exhalations that was subsequently studied under optical microscope. The alloy composition was

defined using microprobe analysis in several points, with calculated average values of the main element contents. For some objects microgeochemical mapping of the main component distributions was carried out. Os-bearing mineral grain inclusions have been found out in some gold objects for the first time. This mineral is rare, acid-resistant, and has high hardness and refractoriness.

### Gold objects compositions

From the Kichigino burial mounds, gold compositions of 12 artifacts have been studied, including a torque, bracelets, a ring, a pendant, and a foil (Table 1). Especially interesting was a female burial in grave pit 5. The sleeves and the top of her dress have been covered with fine beads, and her right sleeve cuff – with leaflets of a thin gold foil. The bracelets on her wrists (1.5 turns) had a bronze base covered by gold sheets and were decorated with banded agate beads. On her neck there was a torque with zoomorphic ends presenting laying predators. Its base is a smooth bronze half ring made of wire with round cross-section wire faced with gold sheets.

Three groups of analyses have been carried out. Five objects have similar composition (%): Au 82-83, Ag 12-14, Cu 3.4-4.4, which allows the suggestion that they were made by the same master from the same material. The gold foil has a complex composition. Using microgeochemical mapping it was established, that in its marginal part it has higher gold content than in its interior part (%): Au 77 and 65, Ag 21 and 32.

Table 1

Composition of gold objects from burial mounds in the South Urals

Burial mound	Age	Objects	Number of analyses	Contents, wt. %		
				Au	Ag	Cu
Chekotay	XV BC	ring facing	4	59.75	36.30	0.13
Stepnoe-7	XV-XIV BC	pendant facing	5	86.28	12.13	0.89
Varnensky	VII-VI BC	tress ornament	5	88.16	13.77	0.95
		tress ornament	4	86.69	13.69	0.96
Bol'shoi Klimovsky	VI-V BC	foil	7	76.55	17.68	4.29
Solonchanka-1	V-VI BC	foil from quiver cover plate	6	37.08	56.05	4.66
		foil from bridle cover plate	4	37.00	55.98	5.49
		foil from saddle cover plate	5	41.52	49.52	6.28
		saddle-tree plate	3	38.04	55.11	5.02
		foil from horse statuette cover plate	6	48.73	43.80	6.01
Kichiginsky	IV BC	pendant	4	15.16	84.01	2.46
		torque	12	83.26	12.99	4.06
		bracelet	6	72.68	23.23	3.95
		foil-1	9	64.63	32.43	3.02
		foil-2	6	77.46	21.79	0.43
		ring	6	81.84	14.30	3.77
		pendant	7	82.03	13.99	3.45
		small pendant	10	83.39	11.85	4.47
Sorzhhan-Kystau	IV-III BC	ear-ring	3	79.56	15.00	2.53
		ear-ring	4	69.69	28.82	2.51
		ring	3	84.36	15.05	5.52
Druzhensky	III-V BC	pendant with carnelian	3	87.61	10.48	3.59
Mavrinsky	III-II BC	pendants	3	83.99	15.27	1.56

Notes. Electronic microprobe JXA-733 Jeol; conditions of the analysis U=20 kV, I=20 nA, diameter of a probe 5 µm; operator Eu. I. Churin. REMMA 202M; conditions of the analysis U=20 kV, pencil of electron diameter 5 µm; operator V. A. Kotlyarov.

In bracelet MYa5-br the gold content is less (73%), and in this artefact an Os-mineral oval-shaped inclusion with a size of 10x40 µm has been found (Fig. 1). This mineral has the following composition (wt. %): Os 48-53; Ir 32-37; Ru 13-16 (Table 2).

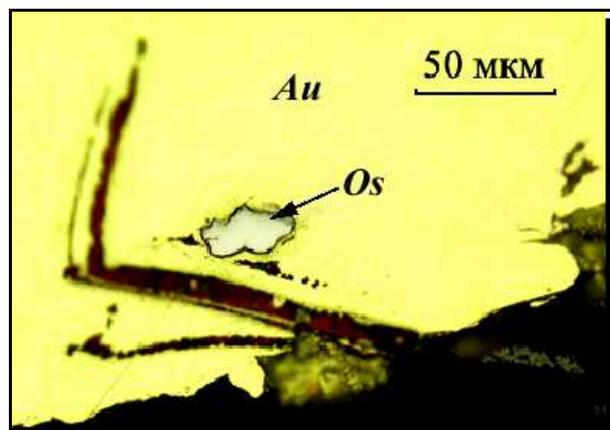


Fig. 1. Osmium inclusion in gold bracelet from the Kichigino burial mound

In the gold foil of pendant from the Stepnoe-7 burial mound, lamellar crystals with the size of 40x400 µm were found (Fig. 2). The mineral surface is plane and often finely serrated. Their composition is listed in Table 2 (wt. %): Os 40-41, Ir 34-35, Ru 24-26 and differ from the mineral of the Kichigino burial mound. The Au-composition is also different. The geochemical mapping shows rather homogeneous distributions of elements within the mineral.

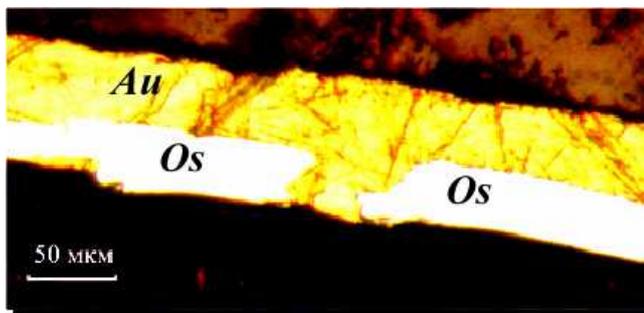


Fig. 2. Osmium inclusion in gold pendant from the Stepnoe-7 burial mound

The identification of Os-inclusions in the gold foil allows a suggestion for the source of raw material. It can be Au-bearing placer, generated at washout of the ultrabasic rocks in large faults. Os, Ir and Ru ratios are similar to a mineral from the Kochkar and Miass placers, both in the South Urals. In other regions, finds of osmium in gold are known from the Filippovsky barrows (personal information by M. S. Shemahanskaya with colleagues) and in Greece (Williams, Ogden, 1995).

The analyses of gold from other burial mounds established that the greatest gold content comes from the jewellery: in the Varnensky hair ornaments, in pendant from the Druzhensky burial mound, in gold ear-rings (samples CK-5 и CK-7) from the Sorzhhan-Kystau burial place, as well as in pendant from the Mavrinsky temple. The gold finesse of these objects is 800-850‰. In alloys used to make gold foil the Au-content is considerably less. These objects are found in the Solonchanka-I, Klimovsky, Chekotai and Krutaya Gora burial mounds.

Table 2

Results of the X-ray-spectral analysis of osmium inclusions in ancient gold objects

Burial mound	Age	Objects	Number of analyses	Contents, wt. %			
				Os	Ir	Ru	Fe
Stepnoe-7	XIV-XV BC	pendant	*5	<u>39.75-41.46</u>	<u>33.56-34.56</u>	<u>24.13-25.75</u>	<u>0.00-0.64</u>
				40.69	34.09	24.85	0.37
Kichigino	V-IV BC	bracelet	*3	<u>48.07-53.24</u>	<u>32.69-35.87</u>	<u>13.80-15.55</u>	-
		bracelet	**5	<u>48.14-51.51</u>	<u>34.89-37.63</u>	<u>13.07-14.43</u>	-
				49.99	34.55	14.79	
				49.61	36.10	13.92	

Notes: The dash – a component is not found. In numerator – limits of fluctuations, in denominator – average contents.

\*Electronic microprobe JCXA-733 Jeol; conditions of the analysis U=20 kV, I=20 nA, pencil of electron diameter 5 µm; operator Eu. I. Churin.

\*\*REMMA 202M; conditions of the analysis U=20 kV, pencil of electron diameter 2 µm; operator V. A. Kotlyarov.

A distinctive feature of the gold found in the Chekotai burial mound, is its low Cu-content (0.10-0.13%). Minor Cu-contents (less than 1%) are noted also in gold objects from the Varnensky burial mound. Hair ornaments (samples 400B/56 and 400B/57) have similar material composition and homogeneous Ag and Cu admixture distribution in the total volume of gold particles.

Based on the difference in composition of artefacts found in the Sorzhan-Kystau burial mound, we conclude that the ornaments are made of gold from different deposits (Au 69.69 and 84.55%, Ag 15.0 and 28.8% correspondently). The gold ear-rings (531CK-5 and 531CK-7) are characterized by similar composition and, possibly, were made using the same raw material and technology. To make the alloy for ring 531CK-6 most likely gold from another deposit was used (with a Au/Ag ratio difference at the same Cu-admixture).

The composition of a gold foil of a plate from the Krutaya Gora burial mound (sample 498K/209) is similar to the alloys and possibly contemporary to the alloys made in the Early Iron Age.

The foil from the Solonchanka burial mound with low gold content differs from the artefacts of all the listed groups.

Solonchanka gold foil is characterized by high Ag-contents, which considerably reduces its finesse. Besides, each object found in this burial mound, has significantly different Cu-content. The average Cu-content value in the foil ranges from 4.66% to 6.28%. It is noticed that the Cu-content in alloys is extremely non-homogeneous. It is especially noticeable for the quiver overlays foil (551C-79) where Cu-contents vary from 2.67 up to 7.62%.

### Silver objects composition

The study of Ag-bearing objects was carried out for samples from the Iron Age burial places in the South Urals. Some data comes from the Kichigino barrow with a rich burial place, other data is from burial places of the Southern group (Table 3).

By preliminary microprobe study it was established, that to manufacture products of Cu-Ag-alloys, Zn-, Pb- and Sn-additives were used as ligatures, for giving of certain properties to the metal phase (Table 3). Pure silver is well processed, but the products are easily deformed and quickly worn by use. The 5% Cu additive allows increasing of the metal hardness twice. The alloys of the same composition are characterized by high casting and processing capacity, but they are not suitable for filigree works.

Table 3

Results of the microprobe analysis of silver objects from Early Iron Age burial places in the South Urals

N	Objects	Numbers of analyses	Contents, wt. %					
			Cu	Au	Ag	Zn	Pb	Sn
1	pendant	4	<u>2.3-2.7</u>	<u>14.0-15.8</u>	<u>83.0-84.8</u>	-	-	-
			2.5	15.2	84.0			
2	spiral	6	<u>0.9-2.3</u>	-	<u>97.1-98.8</u>	-	-	-
			1.8		97.9			
3	torque	9	<u>2.3-3.8</u>	-	<u>94.2-98.4</u>	-	-	-
			3.0		96.3			
4	cover plate	5	<u>0.2-5.5</u>	<u>0.2-1.1</u>	87.2-99.0	<u>0.2-4.8</u>	<u>0.0-1.8</u>	-
			3.0	0.4	91.7	2.8	0.8	
5	cover plate	4	<u>4.0-5.2</u>	<u>0.2-0.4</u>	<u>86.4-90.1</u>	<u>3.8-4.6</u>	<u>0.0-1.8</u>	-
			4.6	0.3	88.4	4.3	1.2	
6	cover plate	3	<u>7.7-23.3</u>	<u>0.0-0.3</u>	<u>75.2-90.4</u>	<u>0.2-0.3</u>	<u>0.0-3.9</u>	<u>0.2-0.5</u>
			13.2	0.2	84.3	0.2	1.3	0.2
7	cover plate on belt	1	2.99	0.63	94.99	0.38	0.00	3.06

Notes: 1-3 – Kichiginsky burial mound; 4-7 – barrows from the Southern group.

The dash – a component is not found. In numerator – limits of fluctuations, in denominator – average contents.

Electronic microprobe JCXA-733 Jeol; conditions of the analysis U=20 kV, I=20 nA, pencil of electron diameter 5 µm; operator Eu. I. Churin.

The analysis showed low heterogeneity of the samples. The Ag-content of the products vary from 84 up to 95%, Cu – from 2 up to 13%. High-standard Ag-alloys have been used, with Ag contents more than 850‰. Ag-Cu alloys are characterized by limited solubility and a non-homogeneous chemical composition. It is established, that the admixture content in the alloys is non-homogeneous. Maximum Zn- and Pb-contents are found in parts from the fastening places of the objects. Possibly, they were introduced by the ancient master from a solder or metal at rough stamping.

The absence of green patina on the surface formed by sulphurous and ammoniac copper compounds, indicates that after the casting, the products most likely have been repeatedly etched, for Cu-removal from the near-surface layer and for increase of the chemical stability of the alloy.

The low gold content (0.16-0.63%) in alloys, allow its consideration as a natural admixture in the silver ore. But a silver pendant МЯ-4П from the Kichigino burial mound with gold content up to 14-16% is known. Zinc in contrast to gold, was deliberately used in alloy. Its content is different in various objects and it is concentrated mainly in fastening places. Possibly, zinc in this case was used as addition to obtain solders. Also Zn-additives can considerably raise the Ag-Cu alloy fluidity and to improve its found properties. These alloys are characterized by a high plasticity and state of polish. Lead also can be used from a special fusible solder, and it makes the object more fragile thus its presence is undesirable.

Sn-Ag alloys (Sn 0.20-3.06%) are fixed only in 2 objects. They are characterized by high softness and plasticity. The objects have less shine and a low wear-resistance.

#### Possible sources of gold and silver

To define the possible gold ore sources processed in ancient times, the obtained data was compared with gold composition from the Urals deposits. According to several studies (lessen, 1948; Petrovskaya, 1973; Murzin, 1983; *Mineralogy of the Urals*, 1990) native gold contains silver up to 50%, and other elements – less than 0.5%. Cu-admixture may vary up to 10%, but only in single cases.

The foil from the Chekotai and Krutaya Gora burial mounds is close in composition to the metal of Au-Ag-deposits, which are located in volcanogenic sequences. Most likely, to manufacture the gold foil from the Chekotai burial mound electrum – a natural Au-Ag-alloy has been used.

The compositions of the gold objects found in the Varnensk burial mound is close to gold particles with similar chemical composition from the chalcopyrite-sphalerite association of the Urals massive sulphide deposits (*Mineralogy of the Urals*, 1990).

The Au/Ag ratios in objects from the burial mounds of Varnensk, Klimovsk, Sorzhan-Kystay, Mavrinsk and Druzhensk correspond to native gold of the sulphide-quartz veins in granites and oxidation zones of volcanic-hosted massive sulfide (VHMS) deposits. Possibly, this raw material was also used by ancient metallurgists in double alloys [Au+Ag]-[Cu].

Besides the difference in Au and Ag contents, there are considerable Cu-content variations. They are indicative for a

change in the technology of production. This is especially valid for the gold-containing products from the Solonchanka burial mounds. As a whole, Solonchanka foil corresponds to billon, but sometimes features of three-part artificial alloys [Au]-[Ag]-[Cu] are present.

The most certain evidence obtained in this study concerns the gold source of the bracelet from Kichigino and the pendants from the Stepoi burial mounds. Here Os-mineral inclusions, specific for the ultrabasic rocks of the East-Urals Foutl zone, were found. Probable silver source were the ancient mines Tash-Kazgan and Nikol'skoe – in ores from these deposits a high content of this metal has been reported (Chernykh, 1970).

The secure definition of gold sources needs a detailed study of the geochemical and isotope characteristics of the Au-bearing object and the native gold of primary deposits in the region. Obtaining new data for all types of available Au-bearing objects in the region will give the opportunity to trace ancient metal mining sites. It also demands a study of the Pb-isotopes (low content) in the metal and in the native gold from the Urals and Kazakhstan deposits. The study of the chemical composition and the ration between the main elements in the alloys is probably sufficient for the possible identification of the time and place of manufacture of these artifacts.

#### Conclusions

Each period has a specific gold-containing alloy:

- in the Bronze Age pure native gold was used for production of jewellery (Chekotay burial mound);
- in the Early Iron Age binary alloys [Au+Ag]-[Cu] were used (the Varnensky Klimovsky, Sorzhan-Kystay, Mavrinsky burial mounds);
- in the Late Iron Age three-part artificial alloys [Au]-[Ag]-[Cu] were used (the Solonchanka and Druzhensky burial mounds).

The microgeochemical mapping of gold particles shows depletion of their marginal parts in silver. Similar phenomenon has been observed at placers formation.

Very important is the identification of osmium micromineral inclusions in the gold that opens new possibilities for determination of the metal source.

For the manufacture of silver products, Cu-Ag alloys with additives of zinc, lead and tin have been used. The low gold contents (0.16-0.63%) in the alloys, allow its consideration as a natural admixture of the silver ore.

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