The Investigation of Bronze Age Metallurgical Slags of the Sintashta Culture in the Southern Ural.

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Introduction.

The Sintashta culture formed in the Southern Ural in XVIII century BC. The forming of the culture was connected with the migration of the Iranian tribes from the Syro-Anatolian region [1; 2]. The aim of the investigation was to reconstruct a metal production technology of these tribes. In framework of the research was set a task to answer the following questions:

1) types of ore (chrysocolla, malachite etc.);
2) types of ore-bearing rock (quartz, serpentine etc.);
3) the smelting temperature (it is diagnosed by means of investigation of melted and non-melted minerals and metals);
4) the atmosphere of smelting (it is diagnosed according to correlation of copper and oxides);
5) the relative rate of smelt cooling (it is diagnosed by means of investigation of forms and sizes of minerals, which were crystallized from smelt);
6) the presence of fluxes;
7) the quantity of copper remaining in slag;
8) the volume of charge (in cases when it is possible).

The main analytical methods were optical microscopy, XRD, spectral and wet chemical analyses. In all 637 analyses of 367 slags and ores were made. Besides, a classification of metallurgical furnaces excavated on Sintashta settlements was made.

Furnaces.

The main type of the Sintashta metallurgical furnaces were small domeshaped furnaces with diameter about 0,8 – 1 m [3]. Some of them were joined to wells and had flues. Wells provided a supply of air in furnaces. Flues appeared after the beginning of sulphide ores exploitation to remove injurious gas from dwellings. These furnaces had multifunctional character (fig. 1).

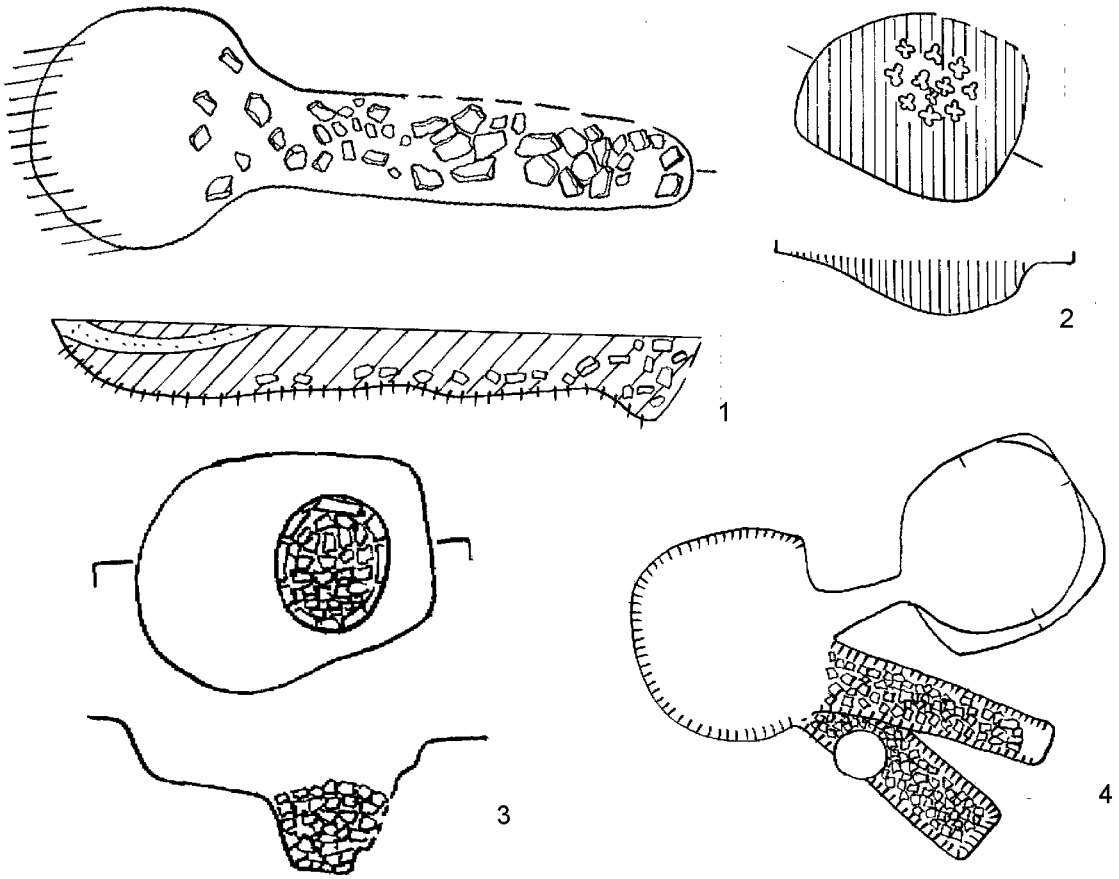

Fig. 1. The furnaces of Sintashta settlements: 1, 3, 4 – Arkaim; 2 – Sintashta.

The furnaces with flue and a little smelting part were more specialized. They were used for ore- and copper-smelting only. The second type of metallurgical furnaces were the furnaces with two parts. The first one was used for ore-smelting. The second one was used as a place for bellows. This type of furnaces appeared at the end of Sintashta stage and was more typical for Petrovka culture, which replaced the Sintashta culture in the XVI century BC [4].

Ores.

The investigation of ores was carried out by means of spectral analysis. According to E.N.Chernykh metallurgists of Sintashta time used two main sources of raw material: copper ores from sandstone's on western slopes of the Ural and ores from Tash-Kazgan deposit [5, p. 28]. The latest source was the most important, because its ores consisted arsenic. The smelting of these ores resulted in production of natural bronzes. However, my investigations of ores allowed me to make another conclusion. The ores from Sintashta settlements did not consist arsenic. On the other hand, the slags consisted the more high content of this element. The most part of ores was mined from deposits in serpentine, though the ore-bearing rock of Tash-Kazgan deposit is quartz. All that means the follows: metallurgists alloyed copper with arsenic on an ore-smelting stage.

Chemical characteristics of ores allowed me to determine 3 chemical types and 8 chemical groups. Therefore, metallurgists used at least some ore deposits.

Slags.

The main part of the research was the slags investigation. There were two sorts of slags: non-forming and flat. The latest slags dominated in the Sintashta collection (76,5%). The Petrovka collection consists 38% of such slags only.

Optical mineralogy allowed me to determine 4 mineralogical groups of slags.

Group I. The main component – large crystals of olivine. Other components are chromites, magnetites, copper (0,1-1%) and ores. These slags got as a result of smelting of ores from serpentine and ferriferous rock. All this group relate to the flat slags.

Group II. The microstructure of slags is similar, but chromites are absent. Slags contain quartz, which was the ore-bearing rock.

Group III. Slags have including of quartz and chromites.

Group IV. Slags have a great number of cuprite includings. The crystallization is very poor.

Technology.

Technological characteristics of slags of I-III mineralogical groups are close enough [6]. The temperatures were more then 1300°C, but less then 1400°C (crystallization of olivine, overheating of cuprite, magnetite is non-smelted, smelted chalcosine, the presence of tridimite and the absence of crystobalite).

A rate of smelt cooling was law because sizes of minerals, which were crystallized from smelt, were small. The atmosphere of smelting was reducing (a rarity of cuprite). The quantity of copper lost in slag was law. The weight of the charge was about 0,5-1 kg, the weight of produced copper – 50-130 g. So, the charge consisted 10-15% of copper.

The second technological type (slags of the IV mineralogical group) was different. The smelting temperature were similar (1300-1400°C), but the atmosphere of smelting was oxidizing and losses of copper in slags were more high. This technological type was not typical to Sintashta metallurgy. It became characteristic for the early Petrovka stage. This situation was determinate by the change of raw material. The technology of newcomers was not adapted for smelting ores with quartz. Then this problem was solved.

The origin of Sintashta metallurgy.

Before the Sintashta culture the metallurgy was absent in the Transural. The metallurgists of the Pit-grave culture did not know the way of bronze production. Alloys copper with arsenic were typical to the Circumpontic area of the Middle Bronze Age [7, fig. 5]. But ore-smelting was not known in the Northern Caucasus and Eastern Europe. Metallurgists in Balkans used mainly “pure” copper. Copper alloyed with arsenic or tin was not so typical. The metal structures of the Caucasus and Anatolia are more close to metal structure of the Sintashta culture (fig. 2).

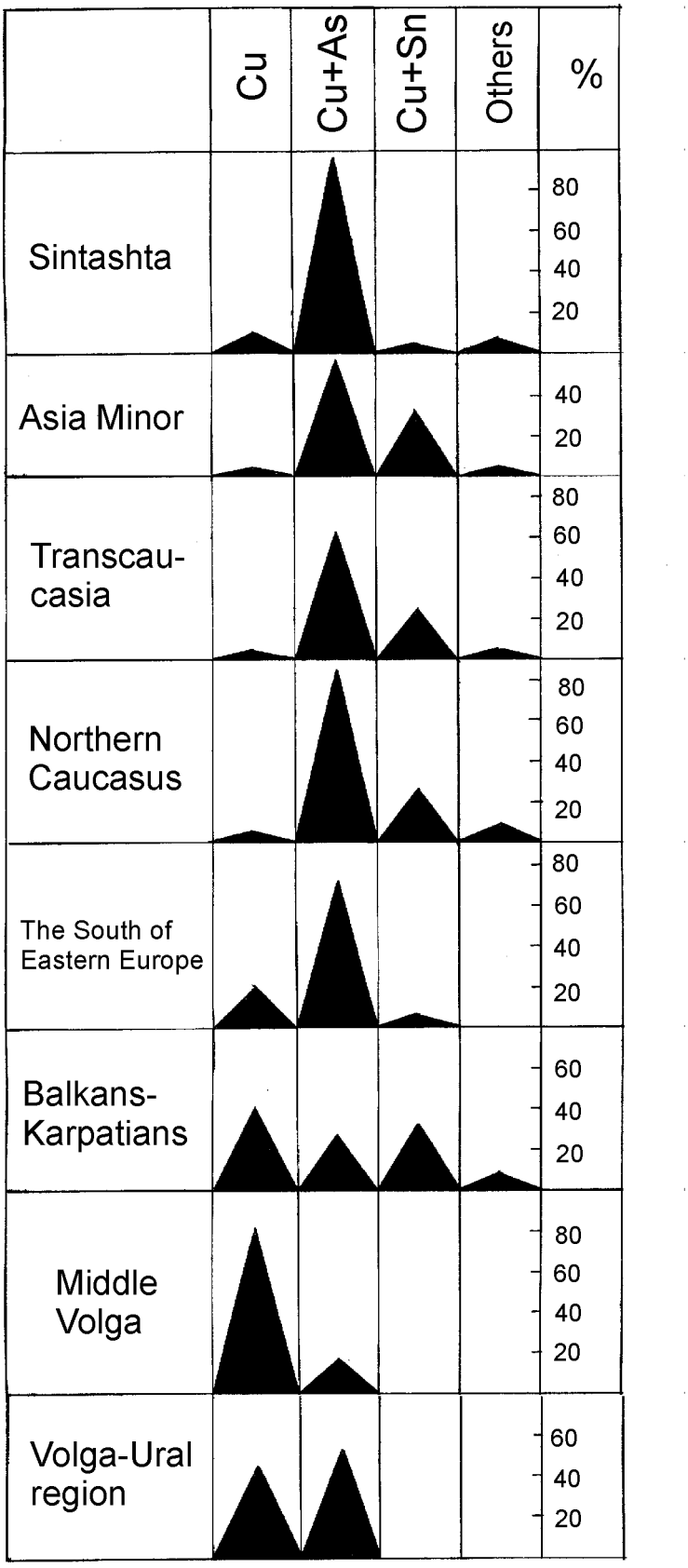

Fig. 2. The types of Sintashta culture metal and types of metal from others regions.

However, tin-bronzes were used in these region more extensively, then in Sintashta metallurgy. That may be explained by the deficit of tin in the Ural. The tradition of alloying on an ore-smelting stage was fixed on the Uzerlik-Tepe settlement in the Transcaucasia. That corresponds to my preliminary conclusion that the Sintashta people migrated from Anatolia or Northern Syria.

Conclusions.

After the appearance of Iranian tribes in Northern Eurasia, They settled mainly in the Transural and on Belaya river. As a result in a vast region from Dnieper up to the Ural two zones formed: metal-producing (the Southern Ural) and metal-consuming (other). Metallurgical slags dated by the end of the Middle Bronze Age are found in the first zone only. This situation reflects a cultural and “political” system, which formed as a result of Iranian migration from the Near East.

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Abstract
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The main part of the research was the slags investigation. Optical mineralogy allowed me to determine 4 mineralogical groups of slags. Technological characteristics of slags of I-III mineralogical groups are close enough. The temperatures were 1300-1400°C . A rate of smelt cooling was law. The atmosphere of smelting was reducing.

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Before the Sintashta culture the metallurgy was absent in the Transural. The metal structures of the Caucasus and Anatolia are more close to metal structure of the Sintashta culture. The tradition of alloying on an ore-smelting stage was fixed in the Transcaucasia. That corresponds to my conclusion that the Sintashta people migrated from Anatolia or Northern Syria.

Key words: slag, Bronze Age, Sintashta culture, metallurgy, technology.
Pages 3, Figure 1, table 1.

Автореферат статьи
Исследование металлургических шлаков синташтинской культуры эпохи бронзы Южного Урала.
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Синташтинская культура сформировалась на Южном Урале в XVIII в. до н.э. Основной целью исследования ее шлаков была реконструкция технологии металлургического производства.

Основным типом синташтинских металлургических печей были небольшие печи диаметром 0,8 – 1 м. Второй тип – двухкамерные печи. Первая камера использовалась как плавильная полость, вторая – как место для размещения мехов.

Исследование руд проводилось с помощью спектрального анализа. Руды синташтинских поселений не содержали мышьяк. Содержание мышьяка в шлаке было, напротив, повышенным. Это означает, что осуществлялось легирование мышьяком на стадии плавки руды. Химические характеристики руды позволили выделить 3 химических типа и 8 групп.

Основной частью исследования было изучение шлаков под микроскопом, что позволило выделить 4 минералогические группы шлака. Технологические характеристики шлаков I-III

минералогических групп довольно близки. Температуры колебались в пределах 1300-1400°С, скорость остывания расплава была низкой, атмосфера плавки – восстановительной. Второй технологический тип (IV минералогическая группа) отличался. Температура плавки была близка (1300-1400°С), но атмосфера плавки была окисленной, и потери меди были более высокими.

До синташтинской культуры металлургия в Зауралье отсутствовала. Структуре металла синташтинской культуры наиболее близки структуры металла Анатолии и Закавказья. Традиция легирования на стадии плавки руды зафиксирована в Закавказье. Это соответствует моему выводу о миграции синташтинских племен с территории Анатолии или Северной Сирии.

Ключевые слова: шлак, эпоха бронзы, синташтинская культура, металлургия, технология.
Страниц 3, рисунков 1, таблиц 1

Подписи к иллюстрациям:
Fig. 1. The furnaces of Sintashta settlements: 1, 3, 4 – Arkaim; 2 – Sintashta.
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