Investigation of The Ancient Slag of Copper Smelt from Central Asia

S.A.Grigoryev
grig@sci.urc.ac.ru
Institute of History and Archaeology
Ural Branch of Russian Academy of Sciences
Chelyabinsk.Russia

Introduction

Slags from three areas of Central Kizilkum were included in this research: from Liavliakan (10 sites), Ayakagitma (8 sites) and Besh-Bulak (5 sites). The main analytical methods were spectral analysis (98 samples) and optical mineralogy (108 samples).

Chemical groups of slag

To determinate a presence of different chemical groups of slag, results of spectral analysis were put to the statistical processing of data. After the constructing of histograms of the distribution of elements concentrations was revealed an irregular of the selection (asymmetry of histograms of Co, Cr, Pb, Ag, As; two tops of the histograms of Zn and Sb) (fig.1). That indicates the using of diverse raw materials.

Fig. 1. Histograms of the elements concentrations distribution.

The determination of chemical groups was made by means of graphs of various elements correlation (fig.2). As a result, 2 groups have been determinate for Liavliakan, 3 – for Ayakagitma and 2 – for Besh-Bulak.

Fig. 2. The graphs of elements correlation.

Mineralogy of slag and smelting technology

Visually some types of slag were picked out: 1) formless heavy slag with fused surfaces; 2) formless heavy flat slag with fused surfaces; 3) flat heavy slag, the one surface is fused, the second – slag soldered to sandstone.

Quartz was an ore-bearing rock, that confirmed by a presence of its inclusions in the most part of samples. The malachite was the main ore. But sulphides of copper were found enough often. The presence of sulphides probably made for success of smelting, because a temperature rises when a sulphur burn out. Besides, in conditions of high temperatures this process kept a reducing atmosphere and prevent from the process of cupritization.

Ferriferous components are represented mainly by magnetite. The content of it in slag of diverse sites is various, that explains a using of different raw materials. Magnetite formed in slag from limonite, as a result of a dissociation in a smelting process. Fluctuations of magnetite contents were caused by a bad preparation of a charge. Slag of the 3d group are an exception. The quantity of magnetite in these slags is very seldom more then 1%. In this case we can discuss a more carefully preparation of the charge and a conversion of the all magnetite into olivine.

Temperatures of smelting

As a rule, such components of slag as copper, covellite, chalcosite and cuprite are smelted, and olivine is crystallized well enough. Cuprite formed dendrites, that explains a superheating of it. Hence, temperatures reached always 1300°C, but they were lower then 1570°C, because hematite is not smelted. Magnetite in slag of the 2d group is often fused. In slag of the 3d group that was observed in a half of samples. So, temperatures fluctuated in a range of 1300 – 1550°C, but slag of the 2d and 3d groups gravitated to the more high temperatures of this range.

Atmosphere of smelting

The atmosphere of smelting was reducing, because cuprite was observed not too often. However, there are in slags of all groups (except the 2d group) samples (12-25%) with a more high content of cuprite (5-10%).

That explains an absence of a right balance among a character of ore, an intension of the blowing and a quality of the fuel.

Relative rate of a smelt cooling

The relative rate of a smelt cooling was judged depending on crystallization of olivine. Large crystals mark a low rate of the smelt cooling. In slag of the 3d groups they were fixed in 8,5% samples, in slag of the 1st group – in 37% samples, in slag of the 2d group – in 50% samples, and in slag of the 4th group – in 62,5% samples. Hence, slag of the 3d group were getting cold faster then other.

Losses of copper

Losses of metal in slag are small – 3,4 – 4,2%. The minimum losses (1%) are in slag of the 2d group, which had a less viscosity and were getting cold slower.

Dating of slags and technological schemes

The all slags from Kizilkum desert are dated by the period of the Early and Late Bronze Ages The correlation of the revealing of slag and ceramics allows me to date the slag of the 1st and 2d groups by the Late Bronze Age. The slag of the 3d group were dated by the Early Bronze Age. Basing on that conclusion we can describe history of metallurgical technologies in Kizilkum.

For the first time the metallurgical production appeared in this region at the Early Bronze Age. The slag soldered to the sandstone is connected with the production of this time. Ores were represented by malachite, but sulphides (including chalcopyrite) were using for smelts too. The charge was sorting very carefully, but fluxes were not applying. The temperature of smelting was enough high (1400-1550°C). The analogous slag (by a form and a microstructure) was excavated on the settlement Dashli-3 in Bactria. It is very important that a crucible full of malachite was found together with this slag [1]. Slag has a zone structure. His upper surface is impregnated with cuprite. The crystallization of olivine is very slight. All that allow us to make a conclusion that the smelting was carried out in a crucible. At the end of the smelting metallurgist splashed out slag, which had accumulated in the crucible on the surface of the melt. That resulted in forming of slags, which are soldered to sandstone.

This technology provided with high temperatures and reducing atmocphere. The latter supported also by additions of sulphides, which were used by metallurgists of the Early Bronze Age more intensive, then by the metallurgists of the Late Bronze Age. Therefore, a partly cupritization occurred already at the moment when slag was splashed out. Besides, this technological scheme explains relatively a fast rate of smelt cooling.

Metallurgists of the Late Bronze Age used another technological scheme. The ore base was not replaced, but the charge was prepared less carefully, that was connected with an increase of volumes of furnace feeding. Sulphides got in the smelt not so often. They were used not purposeful, as at the Middle Bronze Age. The sulphides were only minerals, which accompanied malachite.

A charge placed directly into a furnace. A rate of smelt cooling and viscosity of slag were various. Slag of the 2d group were getting cold slower, and their viscosity was lower by comparison with slag of the 1st group. Besides, losses of metal in slag of the 2d group were negligible.

Technologies resulted in slag of both these group were close, but technology of the 2d type was more perfect. Therefore, it is possible that these types of slag were left by different peoples. In general, forms and microstructures of both these groups are identical to forms and microstructures of the slag from Northern Eurasia.

Conclusion

So, we can see two main impulses caused metallurgy development in this region. The first one – from the West (Near East and Iran) and the second – from the North (Kazakhstan).

References

1. Sarianidi V.I., Terekhova N.N., Chernykh E.N. (1977): O ranney metallurgii i metalloobrabotke v Drevney Baktrii // Sovjetskaya archaeologiya, № 2 (in Russian).