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A summary of the Ph.D. dissertation entitled: „Methods and techniques of obtaining raw materials and production of copper and bronze items in the period from the middle of the 4th to the middle of the 2nd millennium B.C. on the territory of Georgia”
prepared under the supervision of dr hab. Dorota Ławecka

Problems related to the methods of obtaining raw materials in the form of metal ores, as well as issues related to the methods, techniques and tools used for the production of copper and bronze items in the period from the mid-4th to the mid-2nd millennium B.C. in Georgia are extremely important research topics in the history of metallurgy throughout Western Asia. Metallurgical activity in Transcaucasia is one of the oldest examples of the use of pyrometallurgical processes, which in terms of age can compete with the first known centers of this type located in Egypt, Mesopotamia or eastern Anatolia. At the same time, however, it is much less known and researched.

A very large number of objects made of copper and its alloys as well as precious metals (mainly gold) dating back to the Early and Middle Bronze Age have been preserved in Georgia. The pinnacle of metalworking skills was reached in the Late Bronze Age. Metallurgists in the second half of 2nd Millennium B.C. had already mastered many hard techniques to perfection and achieved extremely high craftsmanship and artistry in copper processing. However, this happened thanks to two earlier stages of the Bronze Age. In this dissertation, the author decided to trace the development of this production.

This dissertation attempts to fill this gap and contributes to a better understanding and knowledge of the copper-based metallurgical activity carried out in Georgia in that time. The dissertation includes items from various archaeological sites covering the entire area of the country. This is the first attempt at a comprehensive elaboration of artifacts made of copper and its alloys found in Georgia dated to the Early and Middle Bronze Age.

The main purpose is to trace the entire metallurgical process from beginning to end, i.e. from the extraction of the ore to the finished product. It reveals the successive stages of the object's creation: the location of deposits, the process of their extraction in outcrops and mines, learning about needed tools, transport of the raw material to the place of its further processing, where copper was smelted or alloy compositions based on it were created, and finally, using

the metal obtained in this way to produce the desired item, and learning about the techniques and tools used by the ancient specialists.

Very important and other detailed goals are to systematize knowledge about the metallurgy of the region and to collect known items made of copper and its alloys in one place, as well as categorization by creating a typology based on morphological analyzes and chemical tests, presented with an appropriate description, a database of spectrometric test results existing for a given group, supplemented with new results, and appropriately selected illustrative material.

The important matter is to determine when arsenic copper really went out of use, and tin bronze became the leading alloy in Georgia. It is also important to trace the role of lead and antimony in the development of ancient metallurgy in this area, and answer the question whether there are actually marks of local antimony mining and whether it was widely used in copper metallurgy as a special distinguishing feature characteristic of Transcaucasian metals in the Bronze Age.

The great value of this work is the presentation of many own analyzes and arrangements. Laboratory and traseological research will shed more light on the issues related to the extraction of raw materials and the general activity of ancient mines located in Georgia, using the example of tools found in the famous Sakdrisi mine. Spectrometric tests and other archaeometallurgical analyses will enable a thorough trace of the metallurgical and production processes used to make Kuro-Araxes, Martkopi-Bedeni, and Trialeti items. It is also important that for some categories of objects, the first results of their chemical composition will be established.

The work contains an introduction to the problems related to the chronology of Georgia and the region of Transcaucasia. To obtain a broader picture mentioned chronology was shown in the context of the current chronology of Western Asia.

The characteristics of the three most important Transcaucasian cultures developing between the mid-4th and mid-2nd Millenium B.C. (Kura-Araxes, Martkopi-Bedeni and Trialeti), which include metal objects that are the subject of the study, are also presented in chronological order.

The geography, geology, geomorphology, metallogenesis and mineral resources of Georgia are shown. The focus was not only on the availability, type, and location of raw materials in the form of non-ferrous metal ore deposits but also on other resources that an ancient metallurgist needed to initiate metallurgical processes, such as wood or water. The problem of the occurrence of tin ores in Transcaucasia and potential alternative places of its extraction, taking into account the region of the whole of Asia, was also presented.

In dissertation author presents methods and techniques used during various stages of ancient mining activity. The work also collects in one place information on the tools found in Georgia related to the extraction and enrichment of ores. The purpose of stone, bone and obsidian tools found in prehistoric sites was discussed, as well as the nature of the work performed with the discovered tools was determined through microscopic and traseological analyses. All laboratory and morphological research of selected mining tools were summarized.

The properties and characteristics of pure copper are also presented, and the influence of other elements on copper, when they are included in the alloy composition as a secondary or tertiary element, is also discussed. The influence of arsenic, antimony and tin in various configurations on the physico-mechanical properties of copper in alloys was described.

The remains of metallurgical centers in Georgia are also discussed in detail. Issues such as the construction of furnaces are presented, a brief overview of tools for the production of metal objects is also included, and traces of metallurgical activity are described and analyzed.

At the end of the work there is also one of the most important parts of this dissertation, i.e. the typology and categorization of products made of copper and its alloys. In total, 22 types of items were distinguished in it. There are also results of research on selected metal products approved for chemical analysis. The author's research covered a total of 60 samples that were subjected to specialist tests using a mass spectrometer (ICP-MS and LA-ICP-MS methods). In addition, for some products, additional macro- and microstructural observations were applied. In special cases, data from new Georgian studies of the ratio of lead isotopes ($^{207}\text{Pb}/^{206}\text{Pb}$ to $^{208}\text{Pb}/^{206}\text{Pb}$) were also used. Methods of recovering copper from various types of ores were also presented and the processes used for its recovery and smelting were traced and briefly defined. The development of metallurgical production methods is also described, indicating the moment of emergence of new solutions and briefly presenting what they consisted of. The main and characteristic elements of non-ferrous metallurgy for the Kura-Araxes, Martkopi-Bedeni and Trialeti cultures are also highlighted, and any significant changes are presented in the form of a small summary for each era. Copper alloys used in the Early and Middle Bronze Age were analyzed, and the development of metallurgical production methods was traced and described in the context of changes in the chemical composition of objects, at the same time indicating the moment of appearance of new solutions and briefly presenting them.

In the end, the whole knowledge gathered during the dissertation was summarized, as well as the final conclusions were presented.