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Letters to Editor

ORIGINATION AND DEVELOPMENT OF ORE MINING AND METALLURGY IN THE BALKAN REGION

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Abstract

The metallurgy and ore mining in the Balkan region appeared and developed relatively early. This region had a significant technological success in the field of metallurgy in the 5th millennium BC, already. There are serious reasons to think that some technical and technological inventions appeared for the first time in the Balkan region. This determines the important success in the domain of material culture in this early period of the history of humanity. Gradually, metallurgical centers in the territory of the Balkan countries were founded and developed and some of them remained up to the present. The paper shows the contribution of different nations inhabiting Balkan region to the development of metallurgy.

Keywords: Metallurgy, Balkans, archeoetallurgy, equipment, technology

1. Ancient Ore Mining and Metallurgy in the Balkan region

Concerning the geographical position, the Balkan is situated in the

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immediate proximity of Anatolia and Cyprus, where agriculture was implemented for the first time more than 9000 years ago. The farming technology provoked one of the greatest revolutions in the domain of material culture on the Earth. It required tools for soil cultivation, crop production and processing, and preparation of foods. This necessity stimulated the development of various human activities, including ore mining and metallurgy [1-16].

A new impetus to the development of tools and technologies was given by the emergence of plough farming. The introduction of the plough, draught animals and wheel led to a multifold increase in the productivity of farming labor. In its turn, this created the necessary conditions for the emergence of the slavery, which contributed to the development of mining and metallurgical production.

It is assumed that the metals, which found earliest application, were the native ones - namely gold, silver, copper, and meteoritic iron, but due to their limited incidence they could not be used permanently in the making of instruments for labor or weapons. At the beginning, man began producing copper through ore processing. Being a mild metal, the copper was in position to replace stone tools completely, but as it could be worked more easily, people began making decorations, tools and weapons, e.g. awls, knives, and less often work- or battle-axes. Later on, they started to make copper vessels. This period of the history of humanity is known as the stone-copper or also Chalcolitic and Eneolitic age.

Specialists on history of technology assume that copper melting began in the 7th or 6th millennium BC in Anatolia, i. e., in the neighborhood of our region. The items of the Chalcolitic treasure found near Varna are dated back to a bit later period: 4600 - 4200 BC [10]. At that time, the Balkans were at the head of human pogress. And this was not due to accidental factors. Metal tools increase several times the productivity of labor. It was found out experimentally, that cutting a tree with a copper axe is done 2 to 3 times faster than in the case of using a stone one, and boring a hole in wood with a copper drill is done 22 times faster than if a stone drill was used. Not less is the importance of metal weapons used in hunting, defense and conquest.

One of the extensive copper ore mining development from that time, were found near Stara Zagora. The copper mines at Ay-Bunar are dated back to the

5th millennium BC. They are considered to be among the oldest mines in the world. Researchers [3] suppose that the ore was not processed at the site, but was transported away, i.e. there existed differentiation between miners and metallurgists. Small pots (crucibles) for copper production have been found at Ay-Bunar, Karanovo (in the district of Nova Zagora) and Zavet (in the district of Aytos) [1]. They are similar to pots found in Egypt, which indicates that the level of metallurgy development in the Balkans was analogous to that of contemporary leading centers.

At that time copper ore was also produced at Rudna Glava (Eastern Serbia) [11]. Facilities for extensive metallurgical production existed here during a long historical period. That exerted a positive effect, not only on the development of the Balkan Peninsula, but also on the human civilization as a whole.

In this period, the lands of present-day Bulgaria, Macedonia, Greece, Serbia and Romania were a center of high-level material and spiritual culture: well developed settlements, production of highly artistic golden objects (the finds at the Chalcolitic necropolis in Varna, the finds at Trebenishte in the district of Ohrid), first attempts of writing characters using. During that age, the Balkans was the most developed region of the European continent.

Some ambitious researchers attempt to demonstrate that ore mining and metallurgy had evolved autonomously in the Balkans, independently from Anatolia and the Middle East. This, however, is more unlikely, because contacts between the inhabitants of Asia Minor and those of the Balkans can be traced back to very ancient times. It was probably by accident that humans found out that alloys of copper with other metals (tin, lead), i.e. the various kinds of bronze, were harder and more durable than the copper itself. In such a way, there emerged the bronze weapons and instruments of labor. That was the beginning of the Bronze Age - between the 3rd and the 2nd millennia BC.

It is probable that most of the known ore mining and metallurgical centers in the Balkan region were founded and developed during the period from the 5th to the late 2nd millennium BC.

The period around and after the Trojan War (in the 12th - 11th centuries BC) was characterized by considerable ethno-demographic cataclysms on the Balkan Peninsula. Dorian and Illyrian tribes migrated. A large part of the nations of high culture - the Phrygians (or the Brigs) - left the valleys along

the rivers Vardar and Struma and migrated to Anatolia. It is highly probable that during these displacements some cultural centers disappeared, including the metalproducing centers. Other centers were preserved, and new ones emerged in the course of time. The occurrence and development of the technology for iron production is characteristic for the period considered.

Assessing the many million tons of slag found in the Strandja Mountain region, it can be concluded that the Thracians had been produced many hundred thousand tons of copper there, since very ancient times until the Middle Ages [3]. Old copper slags have been found around Malko Tarnovo, Rossen and Meden Rudnik (in the district of Burgas). It is probable that during that period iron production was also initiated in this region of the Balkans, namely in Demirköy or Malak Samokov, which is known better from the time of the Ottoman Empire. Copper was also produced around Etropole.

For Dacian lands, during this historical period, there were certain data about ore mining and metallurgy in the Parânag Mountain near the river Olt. There were similar metallurgical centers in several other places: Babadag and Dervent in Dobrudja, Cernatul de Sus, etc.

There existed developed ore mining and metallurgy on the island of Thassos [6] and the Halkidiki Peninsula. Silver, gold and copper had been produced on the island of Thassos since the early antiquity. At the beginning, mines were exploited by the local population. Later on, they became property of Phoenician colonialists. Herodotus mentioned the "Phoenician mines" on the island.

Good metallurgists were the Paeonians, also. In the Kratovo-Zletovo region they produced lead, zink, silver, copper, and iron [12]. Around Pehchevo, the village of Mitrashintsi and Radovish they produced iron. Copper was produced in the region of the village of Kosturino near Strumitsa. The Paeonians developed lead and silver mines in the regions of Bosilegrad and Botevgrad [3]. It is very likely that the Paeonians exploited also the mines in Siderokapsa (on the Halkidiki Peninsula), because one of the miners' settlement is called Piyanitsa, and the name of the central part of Paeonia has been Piyanets up to the present day. A reason for this conclusion of ours is given also by the fact that ore mining and metallurgy were strongly developed among the Siropaeonians living in Southern Pirin, Slavyanka and Alibotush.

Titus Livius wrote that the area between Mesta and Struma was "very rich

in fruits and metals". One of the main settlements of the Siropaeonians, Tsiropol (today the village of Gospodintsi in the district of Gotse Delchev), was one of the centers of metallurgy [2]. The high level of metallurgy in the time of Paeonians was also evidenced by the mintage of coins by Paeonian rulers. Prince Teutaos (450 - 425 BC) minted silver coins in his days. According to G. K. Gueorguiev [3], in Southern Pirin - the villages of Tarlis (Trilision), Gorno Brodi (Ano Vrondi), Teshovo, Gospodintsi (Tsiropol), and Kremen - and in the region of Samokov, the metallurgical activities were expanded on the basis of producing iron from magnetite sand.

Several metal-producing centers were also established on the lands inhabited by the Illyrians. On the present-day Albanian territories an old metal-producing region was Pirusta.

It is also known, with certainty, that in the 2nd century AD lead and silver were produced in Kosovo, in the villages of Yanevo and Kishnitsa [12], as well as in the region of Trepcha.

Metallurgy was on a high level at the time of the Macedonians. Alexander the 1st took advantage of the migration of the Bisalts, who had not submitted to Xerxes and fled away into the Rhodope Mountains, and invaded their lands [9]. In such a way he laid his hands on the silver mines in the Disor Mountain, which would supply him with one talent of silver daily. Later on, by occupying also the mines in the region of Pangaei-Philippi, the Macedonians acquired the opportunity of producing high-quality coins. These two ore-mining centers for noble metals were considered the most important ones in the Eastern Mediterranean lands.

We can assess the technological level of Macedonians on the basis of the false silver coins minted in the time of Alexander the Great: their external layer was made of silver, whereas the core was of copper.

Having conquered the Balkans, the Romans intensified the production of metals at the already developed metal-producing centers. They also started the exploitation of new ore deposits. Quite a few authors wrote that, coming to the Balkans, the Romans had brought along new equipment and technologies, also [12]. There are serious reasons to think that they acquired and disseminated techniques and equipment that had already been in use on the Balkans. The technical level in Macedonia and Hellas was higher than that in Rome, in the 2nd century BC, when Rome conquered their territories.

A metallurgical center was the area around Chiprovtsi [8]. Although it is very probable that the production of metals was carried out there even before the coming of Romans, the most certain evidences for such activities are from the Roman times and the Middle Ages. Gold, silver, lead and iron were produced in that region [16]. At the site of Gorno Yazovo, more than 50 so called 'rupas' (pits from which ore was taken out) have been uncovered. Some of them are more than 100 m long and nearly 120 m deep [9].

2. Equipment and technology of ore mining and metallurgy

The production equipment, which was used by miners in the antiquity and was preserved until the 19th century, and as auxiliary instrumentation even to our days, included picks, hoes, shovels, hammers, wedges, rakes, and axes. This equipment evolved with time, mainly in connection with the emergence of new materials used for making the tools mentioned above. Initially, these tools were made of stone, wood, or bone. Later on their material (of some of them) would be changed to copper, or to bronze at a later stage. A qualitative leap was achieved by making them of iron. Since a long time ago tools were manufactured of meteoritic iron (more correctly of an alloy of iron and nickel) [3], but making mining tools of iron in large numbers started not earlier than 1500 BC.

Taking out the ore began at the surface and gradually, following the orebody, was continued in the depth. At the surface and downward underground, where rocks were soft, excavation was carried out with picks and shovels. Hard fissured rocks were dug out by means of picks, bits (wedges) and hammers.

To excavate hard massive rocks and ores, the fire-cracking method was applied. It is not known how long ago it was introduced for the first time. This technique consisted in making a fire on the head face. Its burning was maintained for a long time until the rocks were heated to a high temperature. Then cold water was poured over the strongly heated rock. As a result of sharp temperature changes the rock and ore was cracked and could be easily excavated.

Ore transportation was performed manually by means of a shovel, baskets and pans, or with bags made of leather, which were called djacks in our lands.

When the orebody was situated along the vertical or steeply downward or the mine was exploited through a shift, the vertical transportation of the ore was carried out with the aid of a winch called chekrak (similar to those used for taking out water from wells). Those winches were driven by hand or by horses. The ore was placed in wooden buckets (or baskets) tied to the rope of the chekrak and in such a way it was pulled up to the surface. Miners went down into the mine and climbed back to the surface using ladders. In the 5th century BC, silver-producing mines in Greece reached down to a depth of 120m [5].

With the penetration into underground depths there occurred problems with the drainage of mining developments and also with the lighting and ventilation. Ancient clay lamps that burned oils of plant or animal origin (tallow) have been found at old mining sites in our country [1]. Wax or tallow candles were used as well. Konyarov [2] thinks that iron lamps burning oil were brought to the Balkans by the Saxes.

Draining the mine at small depths and low water quantities was carried out by hand. Water was scooped up with vessels. Later on miners started using bucket wheels (norias).

To pump water out of mines, piston pumps were also applied. Probably, pumps have been used in our region since a long time ago, because the twopiston pump was invented by Ktesibius and used in Roman and Byzantine times. Konyarov wrote that wooden pumps had been found at two places in Bulgaria: in the mines of Plakalnitsa and Sokolets. Pieces of wooden tubes were also found in Plakalnitsa. The engineer B. Enchevich who describes the pumps found in the Plakalnitsa mine supposes that they were used by the Saxes. However, he himself writes that the pumps were found in old Roman mining developments [1].

With penetrating more deeply into the Earth the composition of the atmospheric air was changed as a result of miners' breathing, lamp burning, burning of fires for fire-cracking exploitation, processes of rotting, emission of gases from the rock mass, etc. As long as worked volumes were small, air was set in motion by waving a piece of clothing. Later on, around 3000 BC, when the bellows were invented, they were also implemented for ventilation in mines. However, the capacity of bellows as means of ventilation was not great. Other technical solutions were also conceived. When it was allowed by

the terrain configuration, the miners would realize a horizontal development with slight inward inclination as well as corresponding vertical excavations (rises, shifts). In such a way they used the natural draft resulting from temperature differences. The horizontal working was also used for mine drainage. When the terrain did not permit the realization of such a solution, at least two vertical working were driven in order to organize air motion. If no natural draft could be created, the miners would make a fire in one of the vertical working in order to use the chimney effect.

Irrespective of the good care taken of mining extraction, the ore produced always contained waste rock as well. On the other hand, the ore pieces themselves contained unwanted impurities impeding the realization of the metallurgical processes. The content of quartz disturbed the correct melting of the metal, due to the high point of melting of the quartz. In contrast to this, the

fluorite reduced the temperature of melting but flowed out along with the melted ore [6]. It was namely the presence of pieces of the host rock and detrimental impurities in the ore that was the cause for origination of the processes of separating, crushing, grinding and washing of the ore. A more through analysis indicates that these processes, which nowadays are characteristic for the ore-processing industry, have been differentiated since a long time ago.

The first separation of the ore was carried out with the excavation. The ore separated in the mine was dumped into heaps in sorting rooms. Then workers called pickers sorted it there by removing stones and soil and separating the small pieces of ore from the big ones. The big pieces of ore were crushed with stone hammers. Apart of such a hammer made of porphyry was found at the old mining developments near Etropole. Another one, made of granite, was found at the Plakalnitsa mine. Porphyry hammers were also found at the silver-and-lead mines situated to the south from the railway station of Verino near Ihtiman [6].

The ore was crushed manually. According to the specialized literature, water-driven crushing installations were known as well. They operated with iron hammers. One such installation was mentioned by Irechek in his description of the lead-and-silver mines near the village of Rupie in the district of Vlasotintsi (Serbia) [6]. In later times there were similar installations in the area around Chiprovtsi as well as in the village of Martinovo. It is assumed,

however, that the oldest water-driven crushers on the Balkans were those on the Halkidiki Peninsula. They were known as early as at the time of the Phoenicians. It is likely that it was the Phoenicians who had transferred those crushers to the Balkans [8].

Plates of porphyry were used for grinding the ore. Ore grinding was also carried out in stone mills, the upper stone of which was turned by hand. Probably, after the 2nd century BC people started using water-driven mills as well [2, 5].

The ground ore was washed in pans, filled with water, which were moved to and from. As a result of this handling, the ore particles being heavier fell to the bottom, and the rock fragments, which were lighter, were spilled together with water out of the pan. The tools and devices described were the prototypes of the dressing equipment.

The dressed ore was forwarded for metallurgical processing. The metallurgical production was one of the greatest achievements of humanity. Let us recall to our minds that one of the metals used in the earliest days of the metallurgy, namely copper, melts at 1085 oC. This high point of melting imposes a number of requirements not only with respect to its provision, but also regarding the vessels which should not be melted at such temperatures. These problems were solved by the metallurgists of the ancient times.

Konyarov's opinion [1] is that the development of copper-melting furnaces followed that of pottery kilns as it is described by Girshman. Initially, small quantities of copper were melted in small pots. Later on people began constructing square-shaped furnaces with thick refractory walls and concave bottom, which were opened from above. A fire was made on the bottom. Ore was placed over it, than a layer of coal was placed over the ore again, and so on in several layers. The melted metal flowed down to the bottom. The slag was drained through an opening or was hammered out after the metal was cooled down. Metal would be re-melted several times, which allowed obtaining copper of high purity. A fragment of such a furnace was found near Etropole [2].

A technical innovation was the inventing of the bellows around 3000 BC and their use for introducing air into the furnaces, which improved the process of melting of copper ores. Bellows were driven by hand. However, this operation was very wearisome. People began building furnaces near rivers and

there bellows driving was carried out by means of water energy. It is supposed that bellows used at Siderokapsa (on the Halkidiki Peninsula) were driven by wind energy [1].

A novelty in metal casting was the inventing of clay-covered wax models in the 3rd millennium BC.

A bold step forward in mining and metallurgical production was made around 1500 BC, when the production and processing of iron ores into iron began. This happened for the first time in Armenia (Transcaucasus) and Asia Minor. Some researchers think that iron was obtained for the first time in China. From Asia the technology of iron production was transferred to Southern Italy, the Balkan Peninsula and Central Europe during the period from 1000 to 700 BC.

Processing was carried out through the reduction of ore in furnaces. Charcoal was used as fuel. As a result of the reduction of iron ore oxides, which was realized at relatively low temperatures (around 900 °C), a doughlike product of iron and slag was obtained. The slag was removed by forging and high-quality iron was produced [4].

Forging of metals was an ancient technology. Respective tools, too, were invented in connection with this technology: hammers, anvils, tongs, joint pincers, vices, etc. On this basis there also emerged other technological techniques as riveting, hammer welding, etc. It is assumed that the hammer welding of iron was applied for the first time by Glaukos from the island of Chios in the second half of the 6th century BC.

Gradually, the craftsmen learned finer techniques for enriching the iron with carbon (its transformation into steel), with nitrogen, etc. To increase its carbon content they rubbed the heated iron on bacon, and for its nitriding they dipped the iron into urine. It was conveyed between masters that for that purpose it would be most appropriate to use the urine of a cow, red-haired girl, goat fed with fern for three days, etc.

In the period from the 3rd to the 7th centuries AD peoples on a lower level of cultural development (Slavic, Turkic, Sarmatian, and other tribes) came to the Balkan. In some regions they displaced the old population renowned for its metal-producing traditions. The metallurgy declined. It was preserved only in places where there were compact masses of the old population. Gradually, the newly-arrived settlers learned how to practice ore mining and metallurgy,

but a new peak in the development of these technologies was reached around the 13th century after the arrival of the Saxes (Saxons) who were famous oreminers. They brought along progressive equipment and possessed broader knowledge regarding the extraction of ore and metallurgical processing.

3.Conclusion

In conclusion it may be said that the ore mining and metallurgy on our territories were at the head of the world development in the antiquity. There was a certain decline in the production of metals during the period between the 3rd and the 7th centuries, when peoples on a lower level of development settled in our territories.

There are serious reasons to think that some technological techniques, like the hammer welding and technical facilities like water-driven mills, crushers, bellows, etc., can be considered as the Balkan-people contribution to the equipment and technology. There is still the disputable issue whether it was in this region that piston pumps were used for the first time for the needs of ore mining or this happened elsewhere. Future investigations should find out the answers of all these questions.

In many cases, it is not clear during which historical period a given metallurgical center was founded and developed; this is an issue waiting for further solution.

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