DOI: 10.31897/PMI.2019.2.201

UDC 671:669(092)

PRODUCTION OF SILVER RUBLE AND PARTICIPATION OF THE SAINT-PETERSBURG MINING UNIVERSITY IN THE DEVELOPMENT OF MONETARY INDUSTRY OF RUSSIA

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The article is a continuation of the research on the production of silver rubles and the development of Russian coinage. Graduates of the Saint-Petersburg Mining University contributed to the reputation and history of the Saint-Petersburg Mint as an advanced and high-tech production.

The article describes the beginning of the development of silver ruble production, the use of ores from the Nerchinskoye deposit in the Transbaikalia to produce the main raw material in the form of concentrates and a silver alloy. The materials for the study used unique exhibits of the Mining Museum of the Saint-Petersburg Mining University, which are associated with the history of coinage and the Saint-Petersburg Mint. Some samples of lead-silver ores cast billets, and stamped coins were studied to determine the technological features of their manufacture. An analytical study of the features of minting and obtaining the first Russian silver coins according to some data of the royal decrees was carried out. The current level of technology and knowledge, as well as the special equipment of the laboratories of the Saint-Petersburg Mining University, made it possible to re-evaluate the characteristic features of the production of silver coins.

***Key words*:** silver ore; coin; Mint; Mining Museum; Saint-Petersburg Mining University; silver ruble; metallurgy; structure; standard

***How to cite this article*:** Bazhin V.Y., Telyakov N.M., Aleksandrova T.A., Gorlenkov D.V. Production of Silver Ruble and Participation of the Saint-Petersburg Mining University in the Development of Monetary Industry of Russia. Journal of Mining Institute. 2019. Vol. 236, p. 201-209. DOI: 10.31897/PMI.2019.2.201

Introduction. The production of the silver ruble in Russia has a long history since the time of Peter the first. From 1701 to 1720 the establishment of mints was entrusted to Peter's associates (the stolnik N.O.Kokovinsky, Senator V.A.Apukhtin, Prince P.I.Prozorovsky, Admiral F.A.Golovin, Admiral F.M.Praksin, etc.). In 1720, the Mining Board started to manage the monetary business, and from 1731 a special monetary office was established, later is was renamed into the Coin's Office. From 1763 all the mints of Russia entered the office of the Mint Department of the Mining Board. In 1811, the management of mints was included in the authority of the Department of Mining and Salt Affairs, which had a close relationship with the Mining Cadet Corps (Mining University). At that time, the Coin Charter, which existed until 1885, was published, when a new and last Coin Charter was introduced.

There are scientific studies and publications devoted to the development of coinage in Russia and abroad [11, 12, 23]. The coin business is a whole complex of issues related to the system of money circulation, which is based on a full-bodied coin, which ensures the value of the metal contained in it. The special literature covers in details the processes and historical features of copper coins production [4, 19] and the technological features of copper-nickel coins production, which are of interest for this study. The problem for studying the history of the silver ruble production, which was originally the main financial unit of Russia, is the fire of 1917, which destroyed the archives of the Mint and many samples. However, private collections and museums (the Hermitage, the Museum-Estate «Ostafyevo», the Mining Museum of the Mining University) preserved the authentic samples and materials about the silver ruble manufacture; this data can be used to restore the production history.

Considering the recommendations of I.G.Spassky [20] about the need to study the cultural heritage in the field of coinage, scientists of the University of Mines investigated some features of the silver coins production technology. The Mining Museum has relevant documents and samples, which help to examine the whole cycle of coin production starting from the development of Ner-

chinsk ore and ending with genuine coins of that time. Of historical importance for the 245-year history of the University of Mines is that prominent graduates of the University of Mines, such as Ya.P.Chernyshev, F.F.Lesnikov, I.K.Zatler, M.Mikhailov and others, who became mintsmeister of the Mint in St. Petersburg [8]. Thanks to the modern scientific and laboratory base of the University of Mines today it is possible to get a clear assessment of ore samples, ingots, rolled strips, checks and test coins of various categories.

Features of the royal silver rubles production technology. In the classic work of V.V.Uzdennikov [22], there is a list of governmental decisions determining the alloy standard and the monetary unit (or total weight) of coins from 1700-1917. The list begins with the Edicts of His Imperial Majesty dated January 24 and February 14, 1718. However, there are two more edicts issued before 1718. The first one is dated May 18, 1701 [15] and is called «On the redistribution of old money, sending them to the mint and the exchange of old money for new for individuals with extra payment of 10 kopeks per ruble». This edict refers us to 1495: «...the Tsar orders to exchange money».

In 1495, Ioann III Vasilyevich invited foremen from Italy, who began to skillfully mint Russian coins. It is believed that this year is [6] the beginning of the production of rubles in the form of a coin, which confirms the text of the decree of Peter I. In 1701 Peter I made the final decision on conducting large-scale financial reform. Consequently, by this time many components of the enormous state financial mechanism must be ready for the changes. From 1964 to 1701 8592366 silver coins were made. These coins and unaccounted coins from 1495 to 1664 were re-coined.

In the second decree [16] of October 26, 1711 «On the making a small silver coin of 70 zolotniks» the Government Senate ordered the mint to coin fine silver coins out of pure fused silver, foreign silver coins, and talers until the special order from the Merchant Chamber. In these pure silver coins, there should be 70 zolotniks per pound. This order of the Tsar was sent to the Mint (Monetary Silver Yard). From 1701 to 1711 17070063 coins were minted. This decree for the first time sets a standard for a silver coin. By 1711 a technology was developed for producing silver from the ore of the Nerchinskoye deposit and minting the silver ruble.

The main stages that allowed Peter I to carry out a large-scale monetary reform successfully were set. In 1649, Alexei Mikhailovich issued a decree according to which merchants were obliged to sell talers only to the government. Due to this, the state received about 150,000 silver talers per year. It was difficult to turn the accumulated silver into coins of greater value. During this period the state faced the task of developing domestic silver deposits.

The first coinage of the ruble began in May 1649, and on May 8 a decree was issued on recoining 890,000 talers into new silver rubles. This technology used the hammering device. The principle of this hammer was that a load weighing 50 kg fell from a height of 6-7 feet along a directional groove with a stamp attached to it, thereby gaining enough power to stamp a coin [25]. During this process, the stamps often broke, and in September 1649 the coinage practically ceased. The order was not unfulfilled, and Alexei Mikhailovich lost interest in this idea. But they found a way out – they could re-stamp talers with Russian emblems. For our research, it is important that talers did not contain gold, and in Russian silver ores, it contains from 3-10 g per 1 ton. We found gold in various concentrations in all studied samples of coins and billets.

The data of R.Zander [5] show that in the middle of the 17th century it was impossible to implement regular minting of large silver coins, and at that time it was a ruble, but the industry gained the necessary experience for further development. The work of the press should not depend on the coining dies. The die should be prepared in advance and the required quantity. The number of dies necessary to ensure the operation of the mint is shown in [8]. «So, only in one year, 1819, in the Medal Chamber they made two dies, three master stamps and 281 stamps for minting gold coins. The results of the same year for silver processing look even more impressive: they made two dies, 12 master stamps, and 2396 stamps. ...Judging by the reports for 1819-20 the staff of the Medal Chamber officially employed 29-30 people: 10 medalists, 4 artists, 5 apprentices, and 8 students.

DOI: 10.31897/PMI.2019.2.201

But in fact, there were no more than 25 people, since the list of the staff members included the main medalist K.A.Leberekht, who was not working any longer, two nominally present people – F.P.Tolstoy and Y.Y.Reihel, F.Lyalina, who was detached for a long period and long-term ill I.Shilov and P.Skobina» [8].

Analysis of materials and museum archives of the Mining Museum confirmed that approximately 4-5 brigades, each consisting of two or three assistants, apprentices, and students, performed such a tremendous work. The brigade produced two dies per working day.

The Argun ore field, found in 1676 [2], has become an important factor in the future success of coinage in Russia. Further exploration of this deposit ended with the consolidation of the Priargunsky lands for Russia as a result of the conclusion of the first peace treaty between Russia and China in 1689. A sample of Nerchinsk ore, located in the museum of the Mining University, is presented in Figure 1. In the archive, it is registered under the name «lead shine», the analysis confirms the high lead content (7-8%).

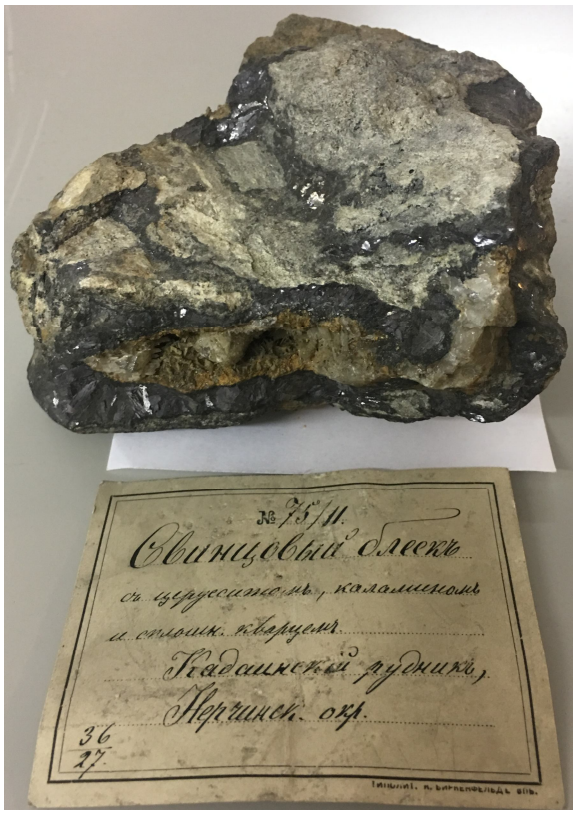

Fig.1. Sample of Nerchinsk lead-silver ore

Already on April 13, 1689, a government decree was issued on the establishment of the Argun silver-smelting plant: «It is ordered to establish in Siberia, in the Nerchenskoye, a silver mining plant and on the Argun River, or where it is meaningful to build a city or a fortress near the ore-smelting sites, it is ordered to found a city according to the decrees and regulations previously sent from Streletsky to okolnichy and voivode Fyodor Alekseevich Golovin and to Nerchinsk to stolnik and voivode Ivan Vlasov» [6].

The analysis of production flowcharts and archive materials showed that the melted material was sent to the metal halides, where they carried out enrichment of lead alloy with silver. The enriched product was purified; now this operation is called refining.

After 15 years of existence, the Argun plant was renamed Nerchinsky. On the plan of the Nerchinsk silver smelting plant (Fig.2), we can see that they used kilns as the main smelting units. The plan Nerchinsk plant refers to the period after 1690. In 1690 «...they built everything required to ensure the full production process...» [14]. The plan shows that at that time a brick ore-smelting kiln with manually operated bellows and a warehouse next to it, one halide (rumbling bunker) was used for mechanical separation of silver and lead, and one refining unit for silver purification.

From the analysis of the documents, it follows that the ore master A.Levandian, a Greek, was the first to begin ore smelting in an old repaired furnace and within a month out of 254 pounds of rock received 45 pounds (737 kg) of lead and 5 pounds 30 zolotniks (2.13 kg) of silver, he carried all operations at his own expense (used «his own ladel»), the treasury provided him with food and two pounds of silver from every 10 produced. In 1707, Levandian was sent to Moscow. By decree of Peter I, he received the right to trade in Russia «unguarded goods» for 2,000 rubles a year as a reward for the construction of the Nerchinsky plant and the training of Russian people.

Since 1708, the operation of Nerchinsk plant was carried out mainly under the guidance of the first Russian engineers. The masters were I.A.Kisilev, A.I.Popov, D.M.Repenskikh, the Tobolsk Cossack son, K.M.Ulfov, and others. In 1724 the started there the mining school for teaching local children. In the future, at each plant and mines, there were such schools that trained personnel for

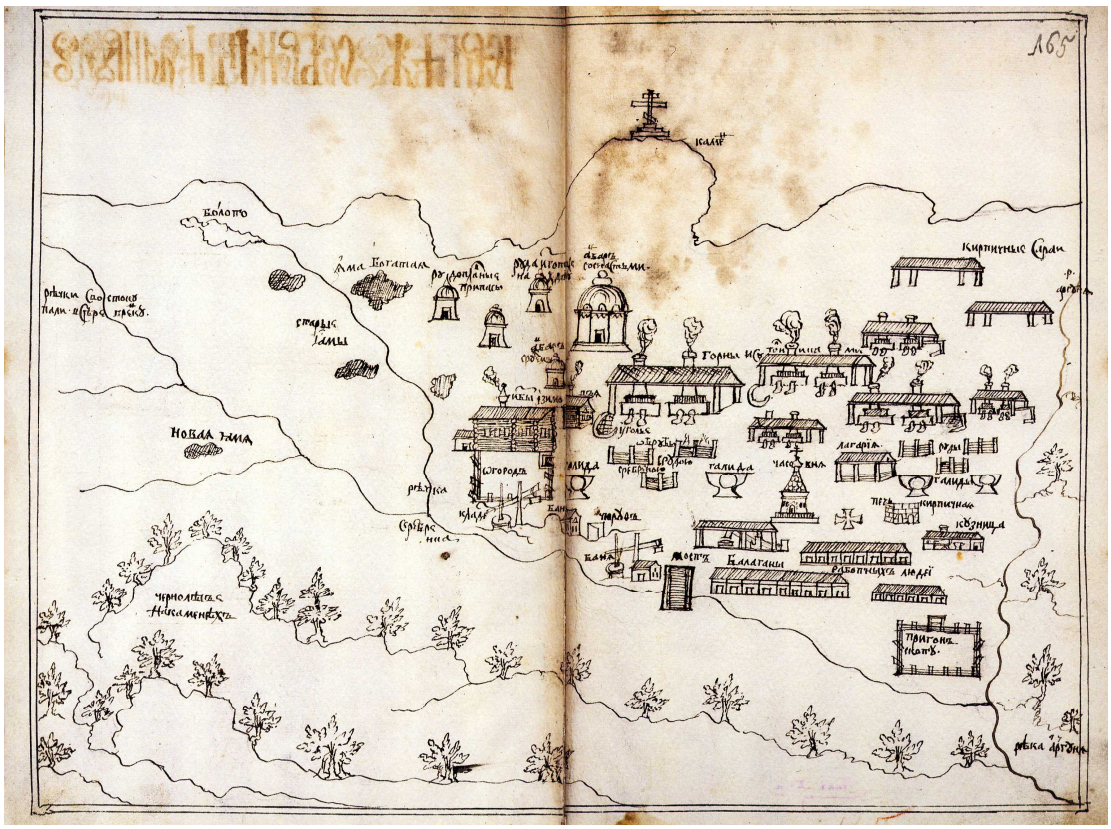

Fig.2. The plan of Nerchinsky silver smelting plant [2]

mining and factory work. In 1823, at the Nerchinsky Plant, they opened a mining and industrial school, after which the prominent students went on to the St. Petersburg Mining Cadet Corps. In 1710, 1183 pounds (19.4 tons) of lead and 8 pounds 3 pounds (132 kg) of silver were smelted [9].

Analysis of the raw material base for the manufacture of silver coins in the period of Peter the Great. During the first 200 years of operation in Transbaikalia, 1523840 tons of lead-silver ore were obtained, of which 470 thousand kg of silver and 43 thousand tons of lead were extracted. Without considering the losses of metals during their production, the lead content in the ore is not less than 2.8%, and the silver content is more than 300 g/t. According to the professor of the Leningrad Mining Institute, I.N. Piskunov, during all this time the Nerchinsky Lead-Silver Plant processed approximately 50 thousand tons of lead and 500 tons of silver. Later, mining of lead and silver originated in Altai, and over 150 years of existence of Altai plants, approximately 150 thousand tons of lead and 1500 tons of silver were produced.

At the beginning of the 18th century, a possible method of extracting silver from lead-silver ore was smelting of pre-burnt ore in air furnaces and kilns, which were used for smelting metals, which was not a secret for domestic metallurgists of that time. The technology of baking ores of different composition as far back as 1556 was mentioned in Agricol's textbook [1]. The result of smelting is to obtain crude lead, in which gold and silver are concentrated for subsequent separation in refining production. Thus, the first refining was carried out precisely in those times. At present, this best-known method for extracting silver and gold from crude lead is determined by the ability of lead to form a carrier compound with the litharge (PbO) transition to an oxidizing atmosphere, while noble metals do not react with oxygen to form Dore bead [21]. The remaining surface litharge melts at a temperature of 883 °C, and the boiling point of PbO is 1,470 °C.

There are two types of slag processes – in amorphous and crystalline form. Amorphous litharge is produced at temperatures below its melting point; it is a strong oxidizing agent, transporting oxygen to other elements with transitions to stronger compounds. It is known [3] that it easily oxidizes S, Fe, As, Sb, Sn, Bi, Cu, Zn. The resulting oxides evaporate upon sudden heating, such as SO_2, Sb_2O_3, or

DOI: 10.31897/PMI.2019.2.201

slag with the transition of FeO, ZnO, etc. Thus, with this method of processing, a silver-lead alloy is obtained, it is refined from the main amount of impurities.

When using this well-known method, lead can turn into oxide forms, and in a small-size air furnace (with a capacity of about 1 ton), the resulting litharge (slag) is released from the furnace through a hole. After analyzing the historical, technical reports, we proved that the lead obtained with a silver content of 2.5 % was the basis for the production of silver coins.

The assay analysis carried out in modern laboratories of the Saint-Petersburg Mining University showed that the technology developed by domestic metallurgists for producing silver coins made of silver with a low concentration of copper was that the coin was preheated to 700 °C and received additional energy through stamping. According to the calculations, the friction energy at impact increases the temperature of the coin circle by 150-200 °C, therefore the resulting total temperature provides a partial melting of the contours of the coin, while the fusible heavy silver melt goes to the periphery of the coin.

It was this type of coinage used in the manufacture of the first Peter ruble. The validity of the assumptions is confirmed by the decrees of Catherine I, which are the last decrees of Peter I about the production of standardized coins for minting rubles.

The development of geological research and the associated strengthening of the mining industry based in Transbaikalia and Russia were important in providing raw materials for coinage and eliminating dependence on taler. It is confirmed, for example, by the decree of Peter I on the establishment of the «Order of Mining Affairs» dated August 19, 1700, for the development of the first Russian deposits of silver, gold, tin, tungsten, molybdenum, and fluorite.

In the 18th century, the so-called Nerchinskaya Dauria was the main source of silver and lead, mined from the ores of the Priargunya deposits. The Nerchinskoye deposit can be attributed to the medium type, and in terms of composition (in modern views of the mining and processing industry) – to polymetallic lead-zinc ores with a high silver content (0.87 g/t) with gold inclusions (0.46 g/t) and rare elements [13].

We analyzed samples (exhibits from the Mining Museum) of smelted ore from the Nerchinskoye deposit (Table 1, Fig.3).

Chemical analysis of the ore composition and metallographic analysis were carried out on optical and scanning electron microscopes and other analytical equipment (Axio Lab.A1 and Vega3 LM, Tescan, XRF-1800 spectrometer). The results of the analysis of ore and ingots for the main elements are presented in Table 1 and are consistent with the data of existing fields of arbitration control: «Maximum permissible errors by grade classes».

Table 1

The content of main chemical elements in ore and silver alloy (partial standards, %)

Material	Ag	Pb	Zn	Cu	Cd	Vi	Ni	Au	Others	Total
Alloy 1	28.25	8.95	7.85	2.36	1.25	2.22	0.72	0.16	48.24	100
Alloy 2	69.35	7.45	6.45	3.85	0.25	0.06	0.62	0.04	11.93	100

It should be noted that in our study of a sample from the Mining Museum, only the site with the maximum silver content was selected (Fig.4).

The results of the analysis showed that the site with a relatively low silver content (28.25 %) has a high gold content (0.16 %). In alloy 2, the silver content reaches 69.35 %, and gold is 0.04 %. And the contents of lead, zinc, copper, and nickel in both alloys have similar values, %: 7.45-8.95 Pb; 6.45-7.85 Zn, 2.36-3.85 Cu; 0.62-0.72 Ni; metal has slag inclusions as well.

The results of the study and analysis of the literature data show [18, 24] that the alloys contain up to 12 % of slag in the form of a litharge, in which bismuth, cadmium, and nickel are concentrated as oxides. We should note the alloys [10] containing silver and crystallized under non-equilibrium conditions and having a significant discrepancy of silver concentrations at various points of the alloy.

Fig.3. Cast sample of silver alloy from Nerchinsk ore

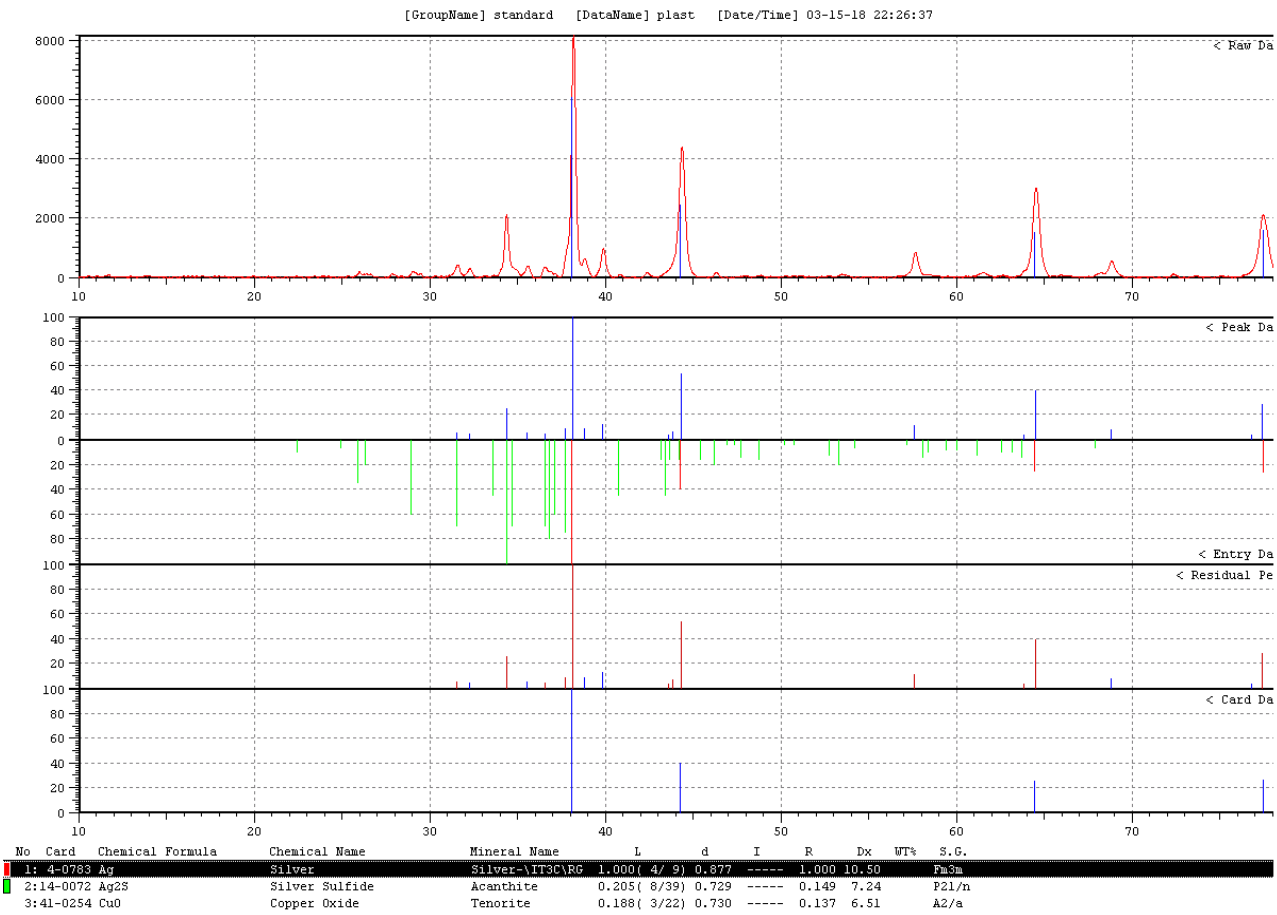

Fig.4. The results of electron microscopic studies of the elemental composition of the sample Nerchinsk ore

The productivity of the Nerchinsk enterprise was small. The plant was intended only for estimating silver reserves, but on the other hand, it was the first state development of the largest silver deposit with the participation of specialists and students of the Saint-Petersburg Mining University (the Mining Cadet Corps at that time).

Thanks to the participation of the Mining Cadet Corps graduates in a relatively short time, the average silver production in Russia was established: during the reign of Anna Ioannovna – 3 tons/year, Elizaveta Petrovna – 8.6 tons/year, Catherine II – about 12 tons/year.

Analysis of decrees and comparison of the physical characteristics of silver coins. Let us study the materials from the archives of government decrees. From Decree No. 4890 of May 25, 1726 [15]: «On the production of rubles, fifty kopeks, and 3 kopeks coins according to submitted standards from foremen. In the Supreme Secret Council, General Field Marshal, Prince A. Menshikov announced the sampling results of 50 kopeks coins and gave evidence from the Shlatter's probing masters (chief mentor of miners students), Levkin, Rybakov, and moreover, provided standards

DOI: 10.31897/PMI.2019.2.201

of three 50 kopeks coins: the first standard 1/2, the second standard 1/3, the third standard 2/3; he also stated ... that Her Imperial Majesty ordered ... the Supreme Privy Council to test these coins and set the standards for new coins – the first standard is used as a standard for 50 kopeks, the third – for rubles and 50 kopeks, the second – for 50 kopeks and 10 kopeks; at the same reason it is argued that in order to improve accuracy in the future, those standards should be given to the Supreme Privy Council and General Field Marshal, Prince, the sample coins must be punctured, a thread must be run through them and sealed with Her Imperial Majesty's seal, the third standard must be given to the Cabinet».

In Decree No. 4909 of June 15, 1726, from the Supreme Privy Council «On making 10 kopeks instead of 3 kopeks» Her Imperial Majesty out that «a new coin from the standard set as a standard for 3 kopeks must be used now as a standard for making 10 kopeks, but not 3 kopeks» [16].

The edict of August 5, 1741, issued in the Office of the Monetary Board, «On the withdrawal of silver 10 kopeks, 5 kopek, 3 kopek, and 1 kopek coins from circulation» [17].

The decrees of May 25 and June 15, 1726, regulate the rules for making proof standards of rubles, and according to the decree of May 25, Catherine I «ordered that new coins must be made in the following mode: the first standard is used for production of 3 kopeks, the third – for rubles and 50 kopeks, the second – for 25 kopeks and 50 kopeks», i.e., 1/2 83 1/3 of the standard, 1/3 of the 83 1/3 of the standard and 1/4 of the 83 1/3 of the standard [16,17].

Consequently, it is obvious from the data from the assay analysis and decrees that 17.26 g of the «quality silver» is put into the ruble, so 1/4 of the standard will be 17.26/4 = 4.315 g of silver. The results of calculations according to the decree of May 25 are given in Table 2.

Table 2

Production parameters of proof coins by decree of May 25, 1726

Coin	Stated standard	Coin diameter, cm	Coin weight, g	Coin area, cm^2	Ag, % (quality)
Ruble	1/4	4.00	28.44	12.56	15.16
3 kopeks	1/2	1.60	1.7	2.26	30.45
25 kopeks	1/3	2.70	7.0	5.72	32.85
10 kopeks	1/3	2.00	2.84	3.14	20.24

The assay analysis restored by us showed that a 10-kopek coin of 1/3 standard turned out to be of poor quality, since on the one hand, the weight of the coin is small (2.84 g), and the workpiece was cooled so quickly that the blow of the press did not get thermal energy from a small height in order to provide a partial smoothing of silver on the surface and contour of the coin. It was impossible to increase the height of the fall of the load (forging and punching pressures), which led to flattening and defects in the coin. A way out of this situation was found in the replacement of silver 1/3 standard for silver 1/2 standard. It became possible to increase the amount of the low-melting phase in the billet and ensured good coin quality. The same situation arose with a 3 kopek coin, although it was made of 1/2 silver standard, the low mass of the coin (1.7 g) did not allow the heat to be concentrated to partially melt the coin over the surface. Therefore, after 20 days, a second decree is issued, according to which the production of 10 kopek coins is canceled, and the standard 3 kopek coins are made according to 1/2 standard (Table 3)

Measurements of the thickness of the samples from the fusible silver-copper-lead billet carried out within the framework of the reconstructed assay in the laboratories of the University of Mining have values of 0.5-5.0 microns. This is explained by the fact that a thin film is necessary to ensure that the silver coin is checked for authenticity, since the most important finishing operation for making a coin is to apply special G signs (in the Russian interpretation of St. George), which are melted by a silver alloy crystallization at the end of the embossing, and have already been discovered and confirmed by modern microscopic examination of the surface [7].

Table 3

Production parameters of standard coins by Decree of June 15, 1726.

Coin	Stated standard	Coin diameter, cm	Coin weight, g	Coin area, cm^2	Ag, % (quality)
Ruble	1/4	4.00	28.44	12.56	15.16
3 kopeks	Out of production				
25 kopeks	1/3	2.70	7.0	5.72	32.85
10 kopeks	1/2	2.00	2.84	3.14	29.44

Figures 5-10 present the analyzed standard coins from the private and archival collections. It was found that with the knowledge of the process of special signs application, it is possible to reliably distinguish fake coins from real ones. The final part of the Decree of May 25, 1726 ends with the distribution of the duty of cross-checking of coins «…those standards should be given to the Supreme Privy Council and General Field Marshal, Prince, the sample coins must be punctured, a thread must be run through them and sealed with Her Imperial Majesty's seal, the third standard must be given to the Cabinet». The analysis showed that starting in 1726, three depositories of the «designated coins» appear on the territory of the Mint. It is revealed that the «coin of the order» is a test coin (with a reduced amount of silver), which has passed the whole technical, administrative procedure and examination. We have standard rubles with a mass of 26-27 g, related to the rule of Peter I, Catherine I, Anna Ioannovna, Ioann IV, Elizabeth Petrovna, and Peter III. The main distinguishing features of such rubles are dented inscriptions on the milling «4 zol...» or «7 zol...», as well as easily observed G-signs, which form specific areas. The same marks are present on the regular rubles, but they can be seen with multiple zooming during heating and cooling.

The analysis of standard coins and technical reports showed that at the beginning of the 18th century there were no express methods for determining the silver content in the original product (silver alloy), the quality of the silver in the 1/4 standard was determined solely by the presence of a G-sign. In the current production conditions, the preparation of the coin blank and the coinage of the test coin with the available stamps was not a difficult operation if there was already an existing production.

Conclusion. Summing up this part of the study, we can conclude the processing of ore into the silver alloy. A complex of research works was conducted with the involvement of specialists from

Reverse side Head side

Fig.5. Silver ruble of Peter I, 1722

Reverse side Head side

Fig.6. Silver ruble of Catherine I, 1723

Reverse side Head side

Fig.7. Silver Ruble of Anna Ioannovna, 1736

Reverse side Head side

Fig.8. Silver Ruble of Ioann IV, 1741

Reverse side Head side

Fig.9. Silver ruble of Elizaveta Petrovna, 1750

Reverse side Head side

Fig.10. Silver Ruble of Peter III, 1762

DOI: 10.31897/PMI.2019.2.201

JSC Goznak of the St. Petersburg Mint. As a result, it confirmed the historical fact that due to the increase in demand for silver ores, thanks to the Nerchinskoye deposit, Russia entered a regular silver ruble coinage. Starting from May 18, 1701, and ending (after the death of Peter I) by the last decree of June 15, 1726, the main provisions of the «Peter's rules for the silver ruble» were formulated and a successful large-scale and significant monetary reform for Russia was carried out. It has been proven that, due to an increase in the demand for the silver ruble as the currency of the Russian empire, technologies for minting silver coins of various denominations have been developed.

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The paper was received on 20 October, 2018.
The paper was accepted for publication on 21 February, 2019.