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The Minting of Platinum Roubles

PART IV: PLATINUM ROUBLES AS AN ARCHIVE FOR THE HISTORY OF PLATINUM PRODUCTION

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This paper augments a series of articles on Russian roubles in this Journal (1–3) with a summary of recent research into the manufacturing history and materials characterisation of these coins. The results are not only significant for the identification of genuine roubles issued between 1828 and 1845, 'Novodel' issues produced in the late 19th century, and outright forgeries of the 20th century, but offer a fascinating insight into the difficulties encountered at the time in the large-scale refining and processing of platinum metal. A range of instrumental methods have been used to elucidate the magnetic properties, chemical composition and low density of genuine roubles, and to reveal their complex internal structure. The resulting new insights into the historical practice of platinum metallurgy are unbiased by concerns about industrial espionage, state secrets, and professional rivalry.

The first half of the 19th century was a crucial period in the discovery and metallurgical study of platinum and its allied metals, iridium, osmium, palladium, rhodium and ruthenium. Only platinum was known in 1800, but all six were known by 1844 (4–7). The subsequent development of their refining and production processes is not well known, probably due to commercial secrecy. Contemporary 'best practice' reports, for instance by Sobolevsky's Russian Royal Mint in St. Petersburg (8), are therefore not necessarily comprehensive or reliable in their technical detail.

When significant deposits of platinum were discovered in the Ural mountains, the Russian authorities, and in particular the then Minister of Finance, Count Egor F. Kankrin wanted to use it for coinage along with gold and silver denominations. The value ratio between the three metals was set at 15.6:5.2:1 for gold, platinum and silver, respectively. Large-scale platinum ore processing began following the decision in April 1828 to issue platinum roubles. This was done at the Royal Mint in St. Petersburg, supervised by General Sobolevsky. A technically successful process used about 20 tonnes of platinum ore from 1828 to 1845, striking more than 1.3 million 3 rouble pieces (Figure 1), almost 15 thousand 6 rouble pieces and 3474 12 rouble pieces, with a total platinum weight of 485,505 troy ounces (approximately 15.1 tonnes) (Reference (4), page 247). The monetary side, however, was less successful. In 1845 the Russian government demonetised the entire platinum coinage, which was sold to various European platinum refineries for reworking.



Fig. 1 3 rouble piece, dated 1831, struck by the Royal Mint in St. Petersburg under the supervision of General Sobolevsky (diameter 23 mm)

There was something of an 'afterlife' for the Russian platinum roubles when the Russian Royal Mint produced fresh coins ('Novodels') for collectors in the late 19th century. Officially struck, using the original dies, these are numismatically identical to the original series. It may be difficult to distinguish authentic early to mid-19th century coins from the 'Novodels' by established numismatic criteria, particularly since the latter are typically in mint condition, and more likely to be found in major reference collections. A written provenance is often missing, so a scientific protocol is required to distinguish 'Novodel' issues from monetary

coins. A further complication is the existence of 20th century forgeries, allegedly produced in the Lebanon, and perhaps also elsewhere.

Recent literature (1–3, 9) has drawn attention to a valuable body of technical information. It is the aim of this paper to give an up-to-date, first-hand account of key results from the ongoing research of the author's group into these coins, and to outline the potential of early coins and medals for providing direct and precise information regarding the development of platinum metallurgy over more than a century.

Early 19th Century Platinum Refining

The early metallurgy of platinum was considerably hampered by its chemically and thermally refractory nature, and by the presence in the ore of other, not easily separable elements (typically about 25% in total of varying amounts of the other platinum group elements, plus iron and copper). Most proposed refining methods relied on dissolving the ore in *aqua regia* (mixed concentrated hydrochloric and nitric acids), followed by selective precipitation of platinum as ammonium hexachloroplatinate. Careful washing was needed to remove as much of any coprecipitated iridium and iron salts as possible without excessive loss of platinum. The dried precipitate was brought to red heat, driving off the ammonia and chlorine, and yielding a metallic platinum sponge. The sponge was then ground, forged and hammered, with repeated annealing cycles. The result was a solid metal which was forged into bars and sheets. The density of the metal sponge increased progressively during hammering to a maximum of around 21 g cm^{-3}, close to that of pure platinum at 21.45 g cm^{-3}.

Over twenty years, Wollaston perfected the refining and working of platinum at a laboratory scale to economic success (6). The Royal Mint in St. Petersburg, on the other hand, pioneered industrial use of the early powder metallurgy, reportedly with several refining variants along the way (4, 7, 9, 10). The relative merits and efficacy of the variants in terms of finished metal quality cannot be judged from these publications alone.

Investigation of Russian Platinum Coins

Bachmann and Renner's (11) were the first analytical results, based on scanning electron microscopy and X-ray fluorescence analysis on an 1829 3 rouble piece. There was a significant degree of porosity at the surface, as expected for material produced by powder metallurgy, and with 0.5 wt.% iron and about 0.1 wt.% each of palladium, rhodium and chromium present. The density of the material was 20.7 g cm^{-3}. The authors record a visible improvement of the surface quality of the coins over the production period. There has been no metallographic study, or discussion of the range and origins of impurities, until recently.

The present study used a series of 3 rouble coins from 1828 to 1842. It was prompted by the observation of a magnetic moment and substandard density for most of them. Only the 1828 coin was in mint condition; the other eight showed clear signs of wear and circulation. A Russian Olympic commemorative platinum coin struck in 1977 was included to represent more recent metallurgical standards. Analysis was largely non-sampling and non-destructive. Only one of the coins was sampled for metallographic study. Full analytical details and results have been published elsewhere (9, 12–14 and literature cited therein). This paper summarises the results and addresses the coins' potential significance for the history of platinum metallurgy.

Material Characterisation

The 3 rouble coins are inscribed with their nominal weight of 2 zolotnik (zol.) 41 dolya (dol.), or 10.35 g, pure Ural platinum; the measured weights vary from 10.35 g for the 1828 issue to less than 10.1 g for the 1837 coin (Table I). Density values were scattered in the range 20.0 to 20.7 g cm^{-3}; the 1828 issue had a density of 21.3 g cm^{-3}. This agrees with contemporary values from the early 19th century literature of about 20 to 21 g cm^{-3}, while placing the 1828 issue close to the theoretical value for pure platinum. Three of the coins showed a considerable response to an ordinary hand-held magnet; a fourth could be lifted bodily; the other three showed no perceptible response,

Table I

Physical Properties of Seven 3 Rouble Platinum Coins

Year	Weight, g	Density, g cm^{-3}	*Magnetic value	Theoretical Fe content (XRD), wt.%	Impurities (XRF), wt.%
1828**	10.351	21.32	0	0	0.7
1832	10.281	20.25	35	2.5	3.5
1835	10.165	20.15	8	0.4	1.8
1836	10.251	20.42	22	1.9	3.5
1837	10.076	20.03	21	1.2	4.1
1838	10.279	20.12	13	0.4	4.1
1842	10.311	20.69	17	1.2	3.1

*Density determined by immersion in water. *Magnetic value is the dimensionless reading from the Förster deflectometer calibrated to zero on the 1828 issue. Weight per cent impurities are taken from Table II. ** 'Novodel' issue*

among them the 1828 coin. It became evident that the uncirculated coin dated 1828 was probably a late-19th century 'Novodel' issue. This was used thereafter as an internal standard for technically pure platinum; its chemical characteristics are given below, together with those of the 1977 commemorative issue.

Where coins showed a magnetic moment, this was quantified using a Förster deflectometer. The instrument was calibrated on the 1828 coin rather than on a sheet of pure platinum, so that the geometry of the reference piece would be identical to that of the samples. The six other coins gave values between 8 and 35 units – results of little significance in themselves, but clearly not random in the light of other observations (Table I).

From an initial qualitative chemical analysis by scanning electron microscopy with microanalysis by energy-dispersive X-ray spectroscopy (SEM-EDS), the only readily detectable impurities (chlorine and calcium among others) were probably surface contaminants. Of likely primary contaminants from the ore, only iron was detected. However, due to the extremely dense matrix, the detection limits for this and other elements were rather high, precluding reliable quantification and interpretation of the results. The peaks for other elements such as gold and iridium were too close to the dominant platinum peaks to be properly resolved at low concentrations. Two series of X-ray fluorescence (XRF) analyses were performed, both measuring approximately two thirds of the coins' surfaces. Iridium, gold and iron were detected in most coins, followed by minor signals for copper, nickel and occasionally zinc. The second series of analyses by energy-dispersive spectroscopy identified iron and iridium as the main contaminants, both at around 1% by weight, followed by copper and gold in the range 0.1–1%. Rhodium, palladium and nickel were typically present at around 0.1% or less. Elements such as titanium, zinc and tin rarely exceeded a few hundred parts per million (Table II).

The results for the obverse and reverse of each coin are typically very similar, but several coins showed much higher readings for some elements on one side only – for instance, copper and gold at around 1% each on the reverse of the 1838 issue. This was consistent with macroscopically visible gold specks on the coin's surface. One of these particles proved to be a high-copper gold alloy with a low silver content, unlike natural gold nuggets which have a rather lower copper content and a higher silver content. The 1844 3 rouble piece analysed by Lupton (2) gave a similar result. The 1837 coin studied here shows abnormally high levels of nickel, silver and tin on its reverse, together with an elevated copper level.

Both the magnetic and chemical analyses indicated a significant presence of iron in these coins, but did not distinguish between mechanically incorporated iron-rich particles (either oxide or

Table II

XRF Analyses of 3 Rouble Platinum Coins

Coin	Ti	Mn	Fe	Ni	Cu	Rh	Pd	Ag	Sn	Ir	Au	Sum, %
1829	110	< 20	12,300	60	2800	1100	1350	680	10	3500	1100	2.3
	100	< 20	12,500	80	3000	1150	1270	900	< 5	3700	1050	
1831	40	< 20	6700	250	1600	790	540	220	< 5	9400	1100	2.1
	300	< 20	6900	230	1850	770	530	160	10	9200	850	
1832	60	< 20	15,800	680	4200	1100	760	220	10	13,200	510	3.5
	180	180	14,300	600	5100	1050	710	140	10	12,100	280	
1835	140	< 20	5700	125	1200	520	210	240	30	9200	630	1.8
	240	620	5200	140	1050	610	260	200	30	8400	1000	
1836	140	100	13,800	470	3100	1400	610	215	60	14,100	220	3.5
	280	480	14,500	410	4200	1400	590	475	20	13,300	190	
1837	50	190	10,600	440	5900	870	570	195	15	14,100	550	3.6
	25	180	13,700	1540	7300	890	550	1180	850	10,800	430	
1838*	530	< 20	11,800	340	2850	760	290	100	60	12,200	1100	4.1
	280	< 20	11,300	440	10,300	760	280	825	80	15,100	13,200	
1842	50	< 20	7000	340	2900	1500	1380	220	30	16,700	950	3.1
	160	70	5100	230	2250	1650	2000	190	75	18,700	1050	
1828**	520	90	6100	50	290	90	140	50	10	2250	< 300	0.7
	< 20	< 20	130	< 20	260	85	140	50	5	2300	< 300	
1977	< 20	< 20	480	< 20	110	60	140	< 5	< 5	< 300	< 300	< 0.2
	< 20	< 20	650	< 20	170	50	90	< 5	< 5	< 300	< 300	

*Measured using a "Spectro X-LAB 2000" XRF spectrometer. All data in ppm. The upper row gives values for the obverse, the lower row for the reverse. Other metals were also found in most coins, up to hundreds of ppm, such as zinc. *The 1838 coin has gold specks visible on its reverse. **The 1828 coin is a 'Novodel' issue, probably produced in the late 19th or early 20th century*

metal) and iron alloyed to the platinum matrix. X-ray diffraction (XRD) was used to determine this. The XRD pattern for the 1828 'Novodel' issue exactly matched the indexed peak positions of pure platinum, demonstrating that the surface morphology of the coins had little or no influence on the XRD pattern. The only peaks found were those of metallic platinum, with the peak positions for all coins other than the 'Novodel' issue being shifted to slightly higher 2θ values, that is, smaller lattice spacings. The atomic radius of iron in the metallic bond is about 10% smaller than that of platinum; hence, substituting iron for platinum will decrease the cell parameters of the resulting alloy, as observed in the coins.

After Cabri and Feather (15), the deviation of the measured peak from the ideal was used to calculate a theoretical value for the iron content in the alloy. Cabri and Feather's Figure 3 gives the relationship between iron content and peak shift for chemically analysed binary platinum-iron alloys. The coins, however, are more complex multielement systems with significant amounts of iridium, rhodium, gold, copper, and possibly other elements, as well as iron. All these elements will affect lattice parameters, but the whole effect is here ascribed to iron, that is, a binary system is assumed. Thus the calculated theoretical iron concentrations represent the total effect of all alloying elements rather than that of iron alone. However, one may be confident of the dominance of iron in the peak shift since the atomic radii of other major contaminants are very similar to that of platinum, or they are present in concentrations much lower than that of iron. In particular, the atomic radii for iridium and gold are only slightly lower (iridium)

or higher (gold) than that of platinum; thus, the main contribution to the peak shift is probably due to iron and copper, which are both significantly smaller in radius than platinum.

The copper concentration is known to be about one quarter of the iron concentration. Most of the crystal lattice deformation is therefore due to the iron component, with possibly up to one quarter due to the copper, and much less due to iridium. The maximum theoretical iron content calculated from the XRD pattern is about 2 to 2.5 wt.% Fe, and can be as little as 0.5 wt.% (13). This agrees very well with the iron content measured by XRF of around 0.5 to 1.5 wt.% (see Table I), with up to one quarter of the calculated shift ascribed to copper. In summary, the XRD pattern confirms a significant presence of iron in the platinum lattice, as an alloying component in solid solution rather than as a mechanical impurity.

It is important to recall that, while eddy current and density measurements test the entire coins, both XRF and XRD analyses only characterise the near-surface parts of the coins, as the extremely dense matrix will have prevented any penetration of the X-rays beyond a few tens of μm.

Metallographic Investigation

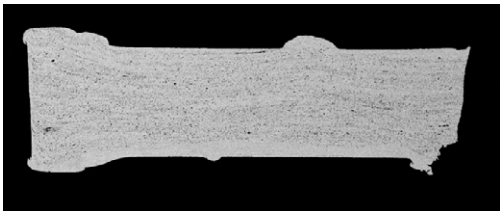
The 1837 coin was chosen for metallographic investigation of its interior, having shown the strongest magnetic response to the hand-held magnet and among the highest impurity content in the XRF analysis. However, its calculated iron content according to XRD and eddy current readings was only moderate. Sampling was done with a slow-moving diamond-impregnated cutting wheel, removing a triangular cross-section from the rim. The sample was mounted in cold-setting resin, perpendicular to the coin's flat surfaces; then ground and polished by standard procedures down to a quarter micron diamond finish for optical and scanning electron microscopy.

Most striking under the optical microscope was the high density of tiny oxide inclusions throughout the body of the coin, but notably absent immediately beneath the two main surfaces (Figures 2(a) and 2(b)). The inclusions consisted mainly of oxides of iron and nickel. Two distinct, adjacent oxide phases were observed, haematite and magnetite, which are described in Table III.

The marked absence of metal oxide inclusions near the surfaces, and within certain layers in the

Fig. 2(a) (Below) Optical micrograph of cross-section of 1837 coin, showing oxide inclusions present throughout its body, but notably absent beneath the two principal surfaces

Fig. 2(b) (Right) As Fig. 2(a), but at higher magnification



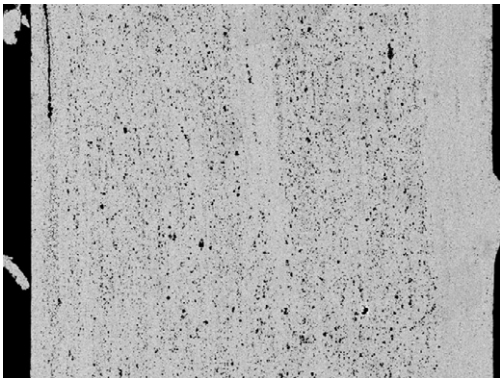


Table III

Oxide Inclusions Throughout Body of 1837 Coin

Oxide inclusion, identified by Raman spectroscopy (12)	Colour	Composition, determined by electron micro-probe analysis
Haematite	Bluish, with intense red internal reflections	Pure iron oxide
Magnetite (iron-deficient)	Greyish	5 wt.% nickel oxide

body, was interpreted as a result of pickling of the hammered sheet metal during the process, before its being folded over for repeated hammering, and then of pickling of the coin blanks after the final annealing. This would have removed any oxide scale from the surface and the immediate sub-surface layer. Notably, there were no voids or pores in the body, nor were any grain boundaries apparent. However, in cross-section the outer surfaces did show some imperfections and irregularities (e.g., Figure 2(a), top part of machined rim), comparable to those observed earlier by Bachmann and Renner (11) using non-destructive SEM imaging

The clean near-surface layers and the inclusion-rich body were analysed separately by a scanning electron microscope fitted with a wavelength-dispersive spectrometer. Results are summarised in Table IV. The iron results were the most interesting, showing a clear tendency to higher concentrations in the body than near the surface. This further corroborates the hypothesis of partial iron depletion of the surface metal by oxidation and leaching.

To elucidate the metallographic structure of the platinum matrix, and to better understand the relationship of the inclusions to the matrix, we turned to the Johnson Matthey Technology Centre for help with etching. This was done in hydrochloric acid saturated with sodium chloride, and applying an alternating current to the sample. Initially, the etching attacked the oxide inclusions only. The metal grain structure which eventually became visible was relatively coarse, with a clear elongation of the individual grains parallel to the flat surfaces of the coin (Figures 3(a) and 3(b)). The cycles of forging and annealing, the latter often at high temperatures and over many hours (4), prior to the striking of the coins, had clearly obliterated the initial structure of the metal sponge. Grains were on average about two orders of magnitude larger than the inclusions. No systematic spatial relationship between the inclusions and the metal grains was apparent.

Table IV
Average Contents of 1837 Coin Regions

Region	Average content, wt.%*			
	Fe	Ni	Ir	Rh
Near-surface layers	0.73	0.03	0.85	0.57
Body of the coin	1.40	0.05	1.06	0.51

*From Ref. (9), p. 85

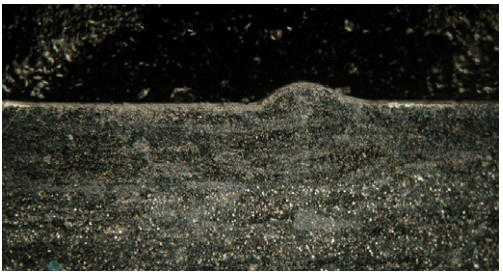


Fig. 3(a) Elongation of individual metal grains parallel to flat surfaces of 1837 coin, apparent after etching

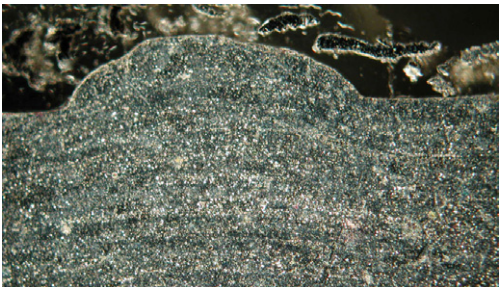


Fig. 3(b) As Fig. 3(a), but at higher magnification

Compositional Characterisation of the 1828 and 1977 Coins

Together with the six coins dated between 1829 and 1842, two later coins not intended for circulation were analysed by XRF: the 'Novodel' issue labelled 1828, but probably made in the late 19th or early 20th century, and the 1977 commemorative issue. Their density and XRD pattern were much closer to the theoretical values for pure platinum (see above). They gave no unusual magnetic response. Their chemical (surface) composition is given in the bottom two rows of Table II. It is obvious that they are made from more highly refined platinum, with much lower levels of all contaminants. Not unexpectedly, the 1977 coin shows the least contaminations, with about 550 ppm iron as the major impurity, whereas the 'Novodel' issue (Figure 4) still has more than 2000 ppm iridium and iron, and a slightly higher copper

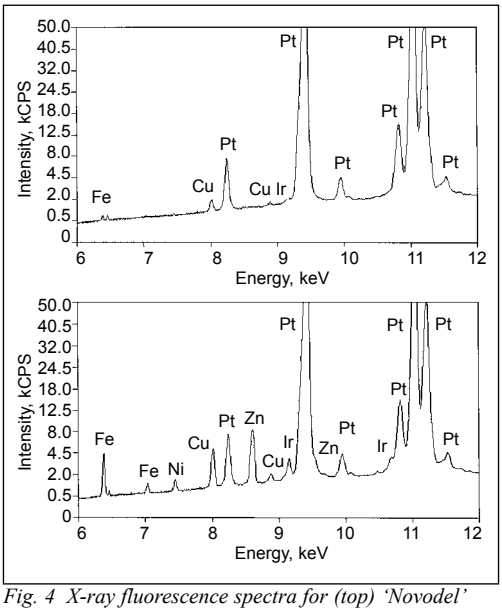


Fig. 4 X-ray fluorescence spectra for (top) 'Novodel' issue and (bottom) 1837 coin

content than the 1977 issue. Notable is the almost complete separation of gold, first witnessed here (Figure 5).

The occurrence of anomalously high levels of certain elements on one surface only is not restricted to the early coins; the 'Novodel' issue has on its obverse much higher readings for titanium, iron and zinc. The origins of these and other similar high readings are not yet known, requiring more research on both manufacture and subsequent treatment.

Interpretation of the Results

The physical, chemical and metallurgical characteristics of the coins relate directly to their manufacture. The considerable contamination, both as discrete inclusion of iron oxide, and as alloying elements in the platinum, such as iron, iridium, copper, rhodium and gold, reflects the limitations of the refining operation based on selective precipitation from *aqua regia*. The practitioners of the time were well aware of the necessity to rinse the precipitate sufficiently to remove as much of the iron as possible, but not so as to lose too much platinum.



Fig. 5 The 1838 coin has a macroscopically visible gold speck on its surface (lower right; adjacent to date)

The methods available to separate iridium and platinum were all laborious and far from quantitative, so it is unsurprising that iron and iridium are the main contaminants in the coins, with concentrations of around 1 wt.% each. Other elements, such as rhodium, palladium, copper and gold, accompany platinum into the precipitate to some extent. Iron was probably the most deleterious contaminant, at higher concentrations rendering the metal too hard and brittle for successful forging and striking. The upper limit of tolerability of iron contamination obviously depended strongly on the intended use of the metal, while the purity attainable depended on the skills and experience of the practitioners as much as on the quality of reagents and tools available.

The research and development which eventually made platinum workable centred on mechanical treatment as much as on the refining procedure (4). Even Wollaston, the undisputed authority on refining and working platinum in the first decades of the 19th century, was not able to obtain platinum metal free of iron; after each forging and annealing cycle he found iron scales which had to be removed by pickling before resuming the treatment (16). Analysis of platinum wire made by Wollaston, and now held in the Science Museum, London, found about 0.35 wt.% iron and 0.2 wt.% iridium in the metal (10).

Metallographic investigation of one of the coins demonstrated that the iron is partly present as iron oxide particles within the body of the coin, and partly as an alloying element in the platinum matrix. For wire drawing, both oxide inclusions and the hardening effect of the iron and iridium alloy component would have been detrimental, requiring purer platinum than for coin minting.

This observation is borne out in the different levels of residual contamination in the metal of Wollaston's wire and the Russian coins.

The degree of contamination in the eight genuine coins analysed here falls in the range 2 to 4 wt.% of combined impurities near the surface; there is a further impurity contribution from the oxide inclusions within the coin matrix. The three coins with the lowest impurity levels are those minted in 1829, 1831 and 1835, that is, during the first half of the period of coin production. Iron, the element most critical to the malleability of refined platinum, shows no decrease during these years. Iridium levels apparently increase slightly. This absence of a consistent trend suggests that refining practice remained basically largely unchanged, resulting in a platinum content of probably only around 95 to 97 wt.% for the genuine coins.

Looking at the data reveals a positive correlation in the concentrations of the three platinum group metals (pgms): iridium, rhodium and palladium, with the highest value for all three elements found in the 1842 coin, and generally low values in the 1835 issue. Iron, on the other hand, follows a different pattern, reasonably well correlated with copper. This probably reflects the different behaviour of these elements during refining and manufacture; we may assume that they all co-varied throughout the precipitation of the platinum sponge and the subsequent washing steps. Only copper and iron are likely to burn out as oxides during the hot forging and pickling. The nature of the oxide inclusions – haematite and oxidised magnetite – clearly indicates aggressively oxidising conditions during metal processing. This is conducive to the further removal of metallic iron from the alloy during hot forging.

It is known that the platinum ore was processed in batches of around 10 to 15 kg per day (8). One may assume that the observed variability in coin composition reflects variability between batches rather than systematic changes in practice. On the other hand, Sobolevsky (8) mentions improvements in the refining procedure followed at the Royal Mint in St. Petersburg, so a reduction of overall impurity levels among the coins over the production period would thus not be unexpected. Schneider (17) reports that at some point the procedure to separate iridium from platinum changed from using an initial excess of hydrochloric acid in the solution, with selective precipitation of the platinum, to selective precipitation of all pgms other than platinum by adding limewater in darkness. It is plausible that the generally higher and more constant levels of iridium in the second half of the production period reflect this change. The quality achieved early on was evidently fit for the purpose, while the slight increase in impurities over time might even indicate that the mint masters learned to cope with them. However, to further explore the issue of variability and trends in composition, a much more comprehensive series of analyses is required, covering multiple coins for each year, as well as more archival research in Russia.

A clearer distinction emerges between the genuine and the later coins, which have total impurity levels of less than one per cent (Table II, bottom two rows). Not unexpectedly, the 1977 coin shows the least contaminations, with about 550 ppm iron as the major impurity. In contrast, the 1828 'Novodel' issue still has more than 2000 ppm each of iridium and iron, although most contaminants are present in significantly lower concentrations than previously. The platinum content is better than 995/1000, if one ignores the possibly erratically high iron content on the coin's obverse. The 'Novodel' and 1977 issues demonstrate major progress in refining and manufacturing practices over more than a century, first following the introduction of hydrogen-oxygen burners in 1847 and then, in the 20th century, the introduction of electrochemical refining. The almost complete separation of platinum and iridium, evident from the 1977 coin, leaves iron as the last major impurity – present at more than just a couple of hundred ppm – thus qualifying the platinum for "999" fineness.

The content of most impurities is below the detection limit for typical EDS systems attached to scanning electron microscopes, and iron levels alone are no reliable discriminator for genuine coins versus 'Novodel' issues. Willey and Pratt (3),

for instance, report very low levels of iron in their 1834 coin and use this to interpret this coin as a forgery. However, the EDS spectrum of that coin shows in addition to the iron peak a significant rhodium peak (*cf.* their figure on page 137 of (3)), unknown in other 'Novodel' issues but appearing in other genuine coins; also, its weight is only 10.16 g, very much in line with the genuine coins studied here. This coin may have been made from a particularly iron-poor batch of metal, but still within the period of genuine coin production. Lupton (2, p. 78) found even lower iron levels in the two 3 rouble pieces analysed, of 0.3 and 0.4 wt.%, respectively; these coins had densities of around 20.8 and 20.4 g cm^{-3} and sufficient other impurities to suggest that they were indeed genuine.

Conclusions

Russian platinum coins have been analysed to characterise their physical and chemical properties. In conjunction with published information on the refining and working of platinum in general, and of these coins in particular, criteria have been established to distinguish authentic coins, issued between 1828 and 1845, from later official reissues, known as 'Novodels'. The density of the authentic coins generally falls between 20 and 21 g cm^{-3}, while later coins seem to have a density comfortably above 21 g cm^{-3}. Similarly, weights below the nominal 10.35 g seem to be common among genuine coins (Table I). A recognisable magnetism appears to be an indicator, though not a prerequisite, for authenticity, as is a complex pattern of specific chemical impurities in the metal (14).

A full understanding of most of the observed physical and chemical characteristics of the nine coins studied here was only possible through the metallographic investigation of one of them (the 1837 issue). Even allowing that one sample may be misleading, we feel that the metallography rendered much more reliable the interpretation of results obtained by non-sampling and non-destructive methods for all these coins.

Platinum refining during the 19th century relied primarily on a complex and then only partially understood sequence of dissolution and precipitation. The main criteria for the purposes of the Royal Mint in St. Petersburg were the malleability of the resulting metal, to be balanced against the overall costs of the operation, and manageability at an industrial scale. The analysis of the genuine coinage of the first half of the century suggests that impurity levels were tolerable, particularly as regards iron and iridium. For both elements, typical concentrations were found to be in the one per cent range, clearly worse than in Wollaston's contemporary metal, refined at a laboratory scale (10). The relatively wide scatter in impurity concentrations found among the coins analysed so far indicates a degree of flexibility in refining practice at St. Petersburg. The 'Novodel' issues are of a considerably higher purity than even the best genuine coins in terms of several critical elements, including gold, iridium, copper, nickel and iron. The present analysis uses only a single 'Novodel' issue, so quantitative characterisation must be cautious. A marked increase in refining quality is, however, to be expected over the fifty years between the production of the original and the 'Novodel' issues, and apparent in all four major contaminants, iron, iridium, copper and gold. The Russian 1977 issue, analysed as an example of a modern use of platinum for commemorative coins and medals, is almost pure platinum, with only minute transition metal concentrations. It is very obviously different from the 19th century metal.

Future work should concentrate on characterising the 'Novodel' issues more fully, both in their chemical composition and physical properties such as magnetic response, density and possibly microstructure. This would greatly improve our discrimination between the two series, which are otherwise almost indistinguishable. It would be of interest to study the homogeneity within and variability between individual metal batches of the genuine coinage on a year-to-year basis. This could show whether any of the indicated changes in St. Petersburg's refining procedures resulted in systematic shifts in composition, if not in improvements in platinum fineness, or whether the observed variability of the composition simply reflects the variability of ore batches or individual batch preparations, without a specific chronological trend in quality.

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