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Refining the Rupee

Pyrotechnical Assaying and Chemical Metallurgy in the Mughal Imperial Mint (c. 1556–1707 CE)

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Abstract

This study examines the applied chemistry, thermal engineering, and specialized metallurgy that sustained the production of high-purity coinage in the central mints of the Mughal Empire between 1556 and 1707 CE. Departing from conventional numismatic scholarship, which tends to read coins chiefly as instruments of dynastic chronology or political messaging, the paper treats the imperial mint as a standardized, pre-industrial laboratory of extractive metallurgy. It reconstructs the pyrotechnical logic of cupellation the controlled oxidation of lead used to draw pure silver out of crude bullion together with the chemical separation of gold and silver alloys through locally generated acid. Reading the technical regulations preserved in Abu'l-Fazl's Ain-i-Akbari against the assay evidence of surviving imperial rupayas, the paper argues that hereditary artisan lineages attained a currency fineness of roughly ninety-six to ninety-nine per cent pure silver without any modern analytical apparatus, relying instead on disciplined sensory judgement and reproducible workflows. The stability of the Mughal tri-metallic monetary order, it concludes, rested ultimately upon the chemical literacy of the empire's minting guilds.

Keywords: *Mughal minting; pyro technology; silver refinement; cupellation; the imperial rupee; applied chemistry.*

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1. Introduction: The Mint as a Pre-Industrial Laboratory

Within the historiography of the Mughal Empire, the mint has most often been studied as an appendage of political and dynastic history. Coins are read as dated documents witnesses to a ruler's titles, to the reach of a sovereign's name across his territories, and to the rhythm of accessions and conquests. The administrative vocabulary of the institution itself, the *Dar-ul-Zarb* or "house of striking," has likewise been treated primarily as a problem of terminology and location rather than of technique.[1] This paper proposes a different point of departure. It asks not what the coin says, but how it was made and in doing so it recovers the mint as a site of sustained chemical and thermal labour.

The daily work of the imperial mint was, in its essentials, the work of a refinery. Crude and heterogeneous metal arrived at its gates; uniform, high-purity currency left them. Between those two states lay a sequence of operations melting, assaying, the oxidative removal of base metals, the acid separation of gold from silver, controlled alloying, and striking that together constituted an industrial chemistry.. The economic historians who first reconstructed the Mughal monetary system established its scale, its tri-metallic structure, and its remarkable stability.[2] Yet their concern was with volume, price, and circulation rather than with the material processes that gave the rupee its physical integrity.[3] It is precisely this material dimension that the present study seeks to supply.

The organizing concept of the analysis is what may be termed empirical reproducibility. The mint possessed balances of genuine precision, capable of weighing a coin to a fraction of a grain; what it did not possess was any instrumental means of chemical analysis. The fineness of a metal could not be read from a dial. Instead, the artisan judged purity through the trained interpretation of physical signs the colour of a flame, the texture of an ash bed, the sudden brightening of a molten bead at the moment its impurities departed. That such sensory knowledge could be standardized, transmitted across hereditary lineages, and reproduced consistently across dozens of mints scattered over an empire is the central technical achievement this paper sets out to explain.

The chronological frame adopted here runs from the accession of Akbar in 1556 to the death of Aurangzeb in 1707. This was the period in which the Mughal silver rupee matured from a regional reform into one of the most widely trusted coins of the early modern world, and in which the chemical disciplines of the mint reached their fullest articulation in surviving administrative record and physical artifact alike.

2. The Rupee and the Mughal Mint Network

The silver rupee that the Mughals inherited was not their own invention. Its decisive form was given during the brief interruption of Mughal rule by Sher Shah Suri, whose currency reforms of the early 1540s imposed order on the debased and multi-standard coinages of the late Delhi Sultanate. Sher Shah fixed a broad silver piece, the *rupiya*, at a weight of roughly one hundred and seventy-

[1] S. H. Hodivala, *Historical Studies in Mughal Numismatics* Calcutta,1923, p. 47.
[2] Irfan Habib, "The Currency System of the Mughal Empire (1556–1707)," *Medieval India Quarterly* 4, no. 1, 1960, p.3.
[3] *Ibid.*, p. 7.

eight grains of high-purity metal, and pegged it within a coherent relation to copper and, later, to gold. The Mughals, on their return, did not discard this settlement; they adopted and perfected it.[4]

Under Akbar the rupee was absorbed into a centralized and deliberately standardized system. The metrology of weight and fineness was specified with administrative exactness, and the physical consistency of the coin was treated as a matter of state. The careful work of standardization that underlay early Mughal coinage—the fixing of weights, the regulation of dies, the supervision of fineness—has been traced in detail by historians of Akbari metrology.[5] The reform was not merely numismatic but fiscal: the revenue settlement associated with Akbar's finance minister, Raja Todar Mal, presupposed a stable unit of account, and the rupee supplied it.[6]

Administratively, the system rested on a wide network of mints. Under Akbar and his successors the number of officially recognized minting centers at various times exceeded forty, distributed across the principal commercial and provincial cities of the empire. The geography of these establishments, their hierarchy, and their operating personnel were already the subject of careful reconstruction in the foundational numismatic literature.[7] That so many dispersed workshops could produce coin of effectively interchangeable quality is itself evidence of a shared and enforced technical standard.

The economic logic that fed these mints was the system of free minting. The imperial Dar-ul-Zarb did not, in the main, draw upon state-owned reserves of bullion. Rather, it stood open to merchants Indian and foreign alike who brought metal of every provenance to be converted, for a fee, into current coin. Spanish-American silver reales arriving through maritime trade, Persian larine, older or worn indigenous pieces, and miscellaneous plate were melted down, refined to the imperial standard, and rest ruck as uniform rupees. The mint thus functioned as the great chemical solvent of a plural metallic world, dissolving the heterogeneity of incoming bullion into a single trusted currency. It is this refining function, rather than the act of striking alone, that the following chapters examine.

3. The Pyro technology of the Assay: The Chemistry of Cupellation

Before any bullion could be refined or struck, its quality had to be known. The determination of fineness the operation captured in the technical sense of *ayar*, the standard or assay of a metal was the foundational act of the mint, and the assay master who performed it occupied a position of exceptional trust. A preliminary judgment could be made by the touchstone, on which a streak of the metal was compared against streaks of known needles; but for silver the definitive test, and the principal refining process, was cupellation.[8]

Cupellation exploited a simple but powerful chemical asymmetry: under heat and a supply of air, base metals such as lead and copper oxidize readily, whereas silver and gold do not. The artisan first combined the impure silver with metallic lead, then placed the charge upon a small, porous cup

[4]Shireen Moosvi, *The Economy of the Mughal Empire c. 1595: A Statistical Study* ,Delhi 1987,, pp. 311–312
[5]John S. Deyell, "The Development of Akbari Coinage," in *The Imperial Mints of Akbar*, ed. Michael Mitchiner ,London:, 1987, p. 86.
[6]*Ibid.*, pp. 88–89.
[7]Hodivala, *op. cit.*, p. 52.
[8]Habib, *op. cit.*, p. 11.

formed of calcined bone ash or finely sifted plant ash. This vessel the cupel was set within a fierce mud furnace and brought to a high temperature while leather bellows forced a steady draught of air across its surface. The bellows supplied no isolated gas, of course, but the oxygen carried in ordinary air was sufficient for the reaction.

As the charge melted, the lead oxidized to litharge, a molten lead oxide that carried the other base impurities with it. Because litharge is readily absorbed by a porous calcareous surface, it soaked into the walls and floor of the bone-ash cupel, drawing the dissolved impurities out of the metal and into the vessel. What remained at the centre, when the operation was complete, was a glowing bead of nearly pure silver. The closing moment of the process was itself the assayer's instrument of judgment: as the last film of oxide cleared, the bead suddenly brightened—a flash long recognized by refiners as the sign that purification was complete. The proportion of silver recovered against the weight of crude metal charged gave a direct measure of the original fineness, and the wastage involved in refining was a recognized and recorded cost of mint operation.[9]

It is tempting to dismiss such practice as mere craft, but to do so would be to misread it. The discipline of medieval and early modern Indian metallurgy its capacity to control composition, temperature, and reaction with reproducible results deserves to be analyzed as a coherent, if non-theoretical, body of knowledge. The same methodological insistence that has been applied to the celebrated corrosion-resistant ironwork of early India may be extended to the refining of precious metals: in both cases a sophisticated mastery of materials was achieved and transmitted without the conceptual apparatus of modern chemistry.[10] The cupellation hearth of the Mughal mint was, on this reading, a laboratory whose theory was embodied in practice and whose instruments were the trained senses of its operators.[11]

4. Chemical Partitioning: Separating Gold from Silver

Cupellation removed base metals, but it could not separate the two noble metals from one another. Much imported bullion arrived as a natural or artificial alloy of gold and silver, and because the two metals are mutually soluble and chemically unreactive under ordinary melting, no amount of heating alone would divide them. To strike pure silver rupees and pure gold *mohurs* from such material, the mint required a genuinely chemical separation the operation known to later metallurgy as parting.[12]

The regulations preserved in the Ain-i-Akbari describe a parting carried out by acid. The alloy was first hammered into thin sheets or reduced to fine grains, so as to expose the greatest possible surface to chemical attack. It was then treated with corrosive liquor generated from saltpetre together with an aluminous or vitriolic salt; the reaction of these substances yielded, in effect, nitric acid within the sealed clay vessels of the refinery. Here again the artisan worked by controlled empirical procedure rather than by formula, judging the progress of the reaction by the fumes evolved and the changing appearance of the charge.

[9]Moosvi, *op. cit.*, p. 315.
[10]T. R. Anantharaman, *The Rustless Wonder: A Study of the Iron Pillar at Delhi* Delhi, 1996, p. 21.
[11]*Ibid.*, p. 34.
[12]Hodivala, *op. cit.*, p. 60.

The chemistry of the separation turned on a single difference: silver is readily dissolved by nitric acid, whereas gold is not. As the acid acted, the silver passed into solution as silver nitrate, leaving the gold behind as a dark, heavy residue settled at the bottom of the vessel. This sediment was washed, gathered, and melted into pure gold suitable for the imperial mohur, while the silver was recovered from solution and returned to the refining cycle. The recovery of metal from every stage of the process pent acid, swept floors, absorbed cupels was treated with great seriousness, for the quantitative accounting of precious metal was inseparable from the integrity of the mint, and the proportions of loss and yield in refining were matters of careful record.[13]

Considered together, cupellation and acid parting gave the Mughal mint a complete chemical toolkit for the resolution of bullion. The first stripped away the base, the second divided the noble; between them they reduced the disordered metallic intake of a continental economy into two streams of near-perfect purity. The artisans who managed these reactions were, in the most exact sense, practicing industrial chemists.

5. Die Mechanics, Dynamic Symmetry, and Calligraphic Inscription

Refined silver of the highest purity is, paradoxically, ill-suited to circulation: soft metal wears, deforms, and disappears under the friction of daily exchange. The final task of the mint was therefore to restore, by controlled alloying, exactly enough hardness to give the coin a working life without compromising its reputation for fineness. A small and legally regulated proportion of copper of the order of three to four per cent was returned to the purified silver, yielding a metal hard enough to endure the marketplace yet still recognizably of the imperial standard.[14]

From chemistry the work passed to precise mechanical engineering. The alloyed metal was cast and then cut into blank discs, or flans, each weighed individually against the standard so that the finished rupee would answer exactly to its prescribed weight. The blanks were annealed over charcoal heated and allowed to soften so that their internal structure would yield to the die rather than crack under the blow. Each flan was then placed between a pair of hand-engraved steel dies and struck with a heavy hammer, the force of a single accurate blow transferring the full design to both faces at once. The exacting metrology of weight and striking that governed this stage has been reconstructed from the surviving coins themselves.[15]

The dies that delivered the design were themselves works of considerable art. Master calligraphers cut the legends in reverse and in negative into the face of the steel, so that the raised letters of the struck coin would read correctly. The Persian inscriptions the ruler's name and titles, the mint, the regnal year, pious formulae had to be composed within a circular field with such balance that the script, its ornament, and its enclosing border resolved into a unified whole without crowding the edge or breaking the margin. This disciplined organization of the field, a kind of dynamic symmetry in which every element was proportioned to the circle that contained it, gave the Mughal rupee an aesthetic authority that reinforced its economic one.

Here the mechanical and the metallurgical converged. A coin that was at once chemically pure, exactly weighed, mechanically durable, and beautifully struck advertised, in every particular, the

[13]Moosvi, *op. cit.*, pp. 318–319.
[14]Deyell, *op. cit.*, p. 91.
[15]Habib, *op. cit.*, p. 15.

competence of the institution that produced it. The capacity of refined metal to be worked, hammered, annealed, and impressed without failure was the visible end of the long chemical labour that had preceded it.[16]

6. Conclusion: Metallurgical Literacy and Monetary Trust

The purity of the Mughal rupee was not a gift of geology but an achievement of method. Behind every high-fineness coin stood a sequence of demanding chemical and thermal operations—assay, cupellation, parting, controlled alloying each governed by exacting standards and executed by artisans whose knowledge was disciplined, reproducible, and transmitted within hereditary guilds. The mint was, in the terms proposed at the outset of this study, a pre-industrial laboratory, and its products were the most rigorously quality-controlled artefacts the Mughal economy produced.[17]

From this material foundation flowed a larger consequence. The reputation of the rupee as one of the most trusted currencies of early modern world trade accepted far beyond the political frontiers of the empire rested ultimately on confidence in its metal, and that confidence was manufactured daily within the walls of the Dar-ul-Zarb. The chemical literacy of the refiner and the precision of the assayer were therefore not technical curiosities at the margin of monetary history but it's very centre. Trust in the coin was, in the last analysis; trust in the chemistry that made it.[18]

To recover that chemistry is to recover a neglected dimension of Mughal achievement: an empirical materials science, sustained without modern instruments by the trained judgment of its practitioners, on which the monetary order of one of the great early modern states was silently built.

[16]Anantharaman, *op. cit.*, p. 40.
[17]Hodivala, *op. cit.*, p. 73.
[18]Moosvi, *op. cit.*, p. 320.