A Jain Assayer at the Sulṭān's Mint. Ṭhakkura Pherū and his *Dravyaparīkṣā*

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Abstract

Of the rich contributions made by the Jains to the intellectual history of India, an important but not so well explored aspect is their role as mediators between the Islamic and Sanskrit traditions of learning. One such mediator is Ṭhakkura Pherū who held a high office at the court of the Khaljī Sulṭāns of Delhi in the first quarter of the fourteenth century. Pherū composed several works on different scientific subjects in Apabhraṃśa verse. The most significant of these is the *Dravyaparīkṣā*, which deals with the techniques of refining precious metals and of determining their fineness, and provides the name, provenance, weight, metal content, and exchange value in terms of the Khaljī currency, of some 260 coin types issued by various kingdoms of north India from the twelfth to the early fourteenth centuries. The present paper discusses the contents of this work and explains its importance for the monetary history of the period.

Keywords: ᶜAlā' al-Dīn Muḥammad Khaljī, assay, currency exchange, *Dravyaparīkṣā, Gaṇitasārakaumudī,* Jains, Kannāṇā, Khaljī Sulṭāns, Pherū, Quṭb al-Dīn Mubārak Shāh, test sticks, touchstone, *varṇa*

1.0 Pherū's Life

Of the rich contributions made by the Jains to the intellectual history of India, an important but not so well explored aspect is their role as mediators between the Islamic and Sanskrit traditions of learning. I have discussed elsewhere how the Jains were in the forefront of preparing manuals in Sanskrit to teach the Persian language[1] and how the Jain monk Mahendra Sūri wrote the very first Sanskrit manual on the construction and use of the astrolabe, the Islamic astronomical instrument *par excellence*.[2] Ṭhakkura Pherū, who held a high office at the treasury of the Khaljī Sulṭāns of Delhi in the first quarter of the fourteenth century and who wrote on diverse scientific

[1] Sarma 1996 and 2002.

[2] Impressed by the versatile functions of the astrolabe, Mahendra Sūri, a pupil of Madana Sūri of Bhṛgupura, gave the astrolabe a Sanskrit name *yantra-rāja* and composed under this title a manual at the Delhi court of Fīrūz Shāh Tughluq in 1370; cf. Sūri 1936. About the end of the fifteenth century, another Jain scholar, Muni Megharatna, pupil of Vinayasundara of the Vaṭagaccha, wrote a small manual entitled *Usturalāva-yantra* in 38 stanzas. See Sarma 1999 and 2000.

and technical subjects in Apabhraṃśa verse is a mediator in several respects: mediator between Sanskrit and Islamic traditions of learning, mediator between the elite Sanskrit and popular Apabhraṃśa, and also mediator between the *śāstra* and commerce.

Pherū is known to the academic world though seven works: *Kharataragaccha-yugapradhāna-catuḥpadikā* (composed in AD 1291) which contains a eulogy of the pontiffs of the Kharatara sect, *Jyotiṣasāra* on astronomy and astrology (1315), *Vāstusāra* on architecture and iconography (1315), *Ratnaparīkṣā* on gemmology (1315), *Dhātūtpatti* (n.d.) on metals and perfumery articles, *Gaṇitasārakaumudī* (n.d., but before 1318) on mathematics, and *Dravyaparīkṣā* (1318) on assay and exchange of coins.[3] Pherū mentions frequently that he is from a town called Kannāṇā or Kannāṇa-pura, which survives today as Kaliyana at 28°33′ N; 76°12′ E in the Bhiwani district of the Haryana state.[4]

Pherū was born in the Śrīmāla caste and was a member of the Kharatara sect of the Śvetāmbara Jains. His father was Ṭhakkura Candra, and his grandfather Kalaśa had the title *siṭṭhi* (Sanskrit: *śreṣṭhin*), "merchant-banker". Pherū mentions a son Hemapāla and a younger brother without name. It is probable that Pherū was born sometime in the second half of the thirteenth century, perhaps around 1270, and was brought up and educated at Kannāṇā. His education was wide-ranging. Besides the Jain religious texts, he also studied several Sanskrit and Prakrit texts on astronomy, astrology, mathematics and architecture. His writings, moreover, reveal his practical experience in the trade of gems and perfumery articles, and in assay and money exchange.

[3] The well known Jain savants Agar Chand Nahata (Bikaner) and his nephew Bhanwar Lal Nahata (Kolkata) discovered, around the year 1946, a manuscript containing all the seven works in a Jain Library in Kolkata. The manuscript was copied in 1347, i.e., during Pherū's lifetime or immediately thereafter. The Nahatas published the seven works in 1961; cf. Nahata in the bibliography. Later some of these works were published separately, the details of which will be given below at the appropriate places.

[4] For a detailed account of Pherū's life and works, see Sarma 1984, pp. 1–20.

When the Delhi Sultanate was established towards the end of the twelfth century, the Sulṭāns did not begin fresh coinage with Arabic legends. Instead, they adapted the fabric of existing Chauhan coinage and added their respective names in Nāgarī script. Because banking and minting in the Gujarat-Rajasthan-Delhi region was largely controlled by the Jains,[5] their cooperation was sought by the Sulṭāns for conducting banking and minting operations. Especially the Jains of the Śrīmāla clan, to which Pherū belonged, were known for their expertise in minting and banking.

In the *Lekhapaddhati,* a collection of model documents from the early medieval Gujarat, the coins used in various public and private transactions are often described as *śrī-śrīmālīya-khara-ṭaṃkaśālā-hata-triparīkṣita*, implying that the coins were struck (*hata*) in a mint (*ṭaṃkaśālā*) belonging either to the city of Śrīmāla (modern Bhinmal, 25° 0′ N; 72° 15′ E, in the state of Rajasthan) or to persons belonging to the Śrīmāla clan, and that these coins were tested three times (*triparīkṣita*) for their metal content, or more precisely for the content of silver or gold. It is not clear what *khara* in this expression denotes. It is possible that it refers to the *kharatara-gaccha* of Śvetāmbara Jains. Then the expression would mean that coins were produced at a mint maintained by Śrīmāla Jains of the Kharatara sect, to which Pherū also belonged. After minting the coins, these were tested three times to ensure that they had the correct weight and contained the correct amount of gold or silver, which determines the intrinsic value of the coin. The fact that this expression occurs in as many as twelve documents shows that this must have been a standard formula in early medieval Gujarat to express the genuineness of a particular coin.[6] Owing to these commercial and monetary reasons, the Jains had good relations at the Delhi court. Several of them were also employed there.

Coming from a family of merchant-bankers, Pherū found a ready appointment at the treasury of the Khaljī Sulṭāns of Delhi. It is not known precisely when he entered the services of the Sulṭāns, but it must have been several years before 1315,

[5] See Deyell 1990, p. 247.

[6] See Strauch 2002, pp. 139, 171, 174, 177, 180 et passim.

because in this year he completed the *Ratnaparīkṣā,* where he states that he was employed at the treasury of ᶜAlā' al-Dīn Khalijī. Pherū continued the service under ᶜAlā' al-Dīn's successors, Shihāb al-Dīn ᶜUmar (r. 1316) and Quṭb al-Dīn Mubārak Shāh (r. 1316–1320) and possibly also under Ghiyās al-Dīn Tughluq (r. 1320–1325). In 1318 Pherū occupied a high position at the mint of Quṭb al-Dīn. The *Dravyaparīkṣā,* which Pherū completed in that year, was based on his experience at the Delhi mint.

V. S. Agrawala wrote that Pherū was the mint master at Delhi,[7] and since then everybody has been repeating it. However, there is no clear evidence to support this view. At the beginning of the *Dravyaparīkṣā*, Pherū merely states that he was "employed at the Delhi mint" (*siri ḍhilliya ṭaṃkasāla kajjaṭhiye*). He does not say that he was the head of the Delhi mint, as Agrawala supposes. As we shall see below, the coinage of ᶜAlā' al-Dīn Khaljī and his successors whom Pherū had served contain several imperial and religious titles in Arabic which the monarchs assumed. In the reign of Quṭb al-Dīn Mubārak, the range of coinage was substantially increased; in addition to the circular fabric of coins, a new square fabric was introduced. More important still, in his coinage Quṭb al-Dīn dispensed with the nominal allegiance shown to the Caliph depicted in the coinage of his predecessors (e.g., *yamīn al-khilāfa,* "the right hand of the Caliphate) and assumed himself the titles of "Caliph, the Lord of the two Worlds" (*khalīfa rabb al-'alamīn*), the "Most High Imām" (*al-imām al-a'zam*) and similar grandiloquent titles. It is naturally the responsibility of the mint master to see that these religious titles in Arabic are correctly reproduced on the coinage. Such responsibility would certainly not have been conferred upon a non-Muslim.

Moreover, had Pherū been the mint master, the *Dravyaparīkṣā* would have contained some information on the process of minting which is totally absent in the *Dravyaparīkṣā*. What this work contains are brief descriptions of the techniques of assay and purification of precious metals and a detailed account of exchange of coins. These, as Pherū himself says,

[7] See Agrawala, 1951–1952, p. 321: *ṭhakkura pherū alāuddīn khaljī ke dillī kī taṃkasāl ke adhyakṣa the*; this is repeated in his subsequent publications.

were written down for the sake of his brother and son, who may have been embarking on a career as assayers and money-exchangers. Thus, the *Dravyaparīkṣā* is primarily a manual on assay and money exchange. It would be safer, therefore, to assume that Pherū was the assayer or the assay master at the Delhi mint under Sulṭān Quṭb al-Dīn Mubārak.

1.1 Pherū's Writings

Pherū's scientific writings in Apabhraṃśa differ from the earlier or contemporary Sanskrit scientific texts, not merely in language, but in several other respects. Sanskrit scientific writings, like other Sanskrit writings, are normative in nature, and avoid any spatial or temporal reference.

This will be clear, for example, from the metrology, or the units of measurement, employed in mathematical texts. Whether it is Āryabhaṭa writing in Kusumapura in Bihar towards the end of the fifth century, or Bhāskara I in Valabhī in Gujarat in the first half of the seventh century, or Bhāskara II in Maharashtra in the middle of the twelfth century, they all use what is called the Māgadha-māna, "the [units of] measurement of Magadha". Not so in the case of Pherū's writings, which allow us to reconstruct the metrology employed in the Delhi-Haryana region in the first half of the fourteenth century.

Moreover, Sanskrit writers generally state that they had studied all the works of the *purvācāryas*, and are giving merely a summary of their past writings. Thus, they lay greater emphasis on their *śāstra-jñāna*. Pherū also mentions the *śāstras* he has read, but lays stress on his practical experience, stating often *niyadiṭṭhiye daṭṭhuṃ,* "having seen with own eyes" or *paccakkhaṃ aṇubhūyaṃ,* "having experienced directly".

Four of Pherū's works show valuable traces of Pherū's direct experience and thus are rich in contemporary data. The *Dhātūtpatti*[8] deals briefly with the extraction and purification of metals like brass (*pittali*), copper (*tambaya*) and lead (*sīsaya*); and in greater detail with perfumery articles like camphor, aloe-wood, sandal, musk, saffron, their places of occurrence,

[8] See Nahata 1961, III, pp. 39–44 (text only) and Nahata 1976 (text with Hindi translation).

properties, varieties and, most importantly, their prices. It is possible that Pherū's family was engaged in the trade of metals and perfumery articles, along with gems.[9]

On gems Pherū wrote a small work with the title *Ratna-parīkṣā*[10] on the basis of the Sanskrit works by Buddhabhaṭṭa, Bṛhaspati and others, and more importantly on the basis of his practical knowledge. He states that he has "directly experienced the examination of gems by experts" (*paccakkhaṃ aṇubhūyaṃ maṃḍaliya-parikkiyaṃ*) "during the victorious reign of ᶜAlā' al-Dīn, ... after having seen with his own eyes the vast ocean-like collection of gems in his treasury" (*allāvadīṇa-kalikāla-cakkavaṭṭissa kosamajjhatthaṃ / rayaṇāyaru-vva rayaṇuc-cayaṃ ca niyadiṭṭhiye daṭṭhuṃ*). His family must have been in the gem trade, and Pherū may have been trained by the senior members of the family. Above all, he had the opportunity to see in the treasury of ᶜAlā' al-Dīn Khaljī a vast collection of gems. Pherū must have been an expert gemmologist and a high official in the treasury; otherwise, he would not have had access to ᶜAlā' al-Dīn's gem collection.

His book on gemmology follows the traditional pattern of the Sanskrit texts. What is new here is a very detailed tariff of prices of different kinds of gems, which increases exponentially according as the weight increases. It is certain that this tariff of prices is contemporary, that is, valid for the Delhi region in the first quarter of the fourteenth century.

The *Gaṇitasārakaumudī*[11] is not dated, but there are reasons to believe that it must have been composed much earlier than 1318 when Pherū wrote the last known work *Dravyaparīkṣā*. With 311 stanzas distributed in five chapters, it is the largest of his seven works. It is not only the first full-fledged mathematical text in Apabhraṃśa, but it also extends the range of mathematics beyond the traditional framework of the earlier

[9] On the perfumery trade, cf. McHugh 2008, pp. 306 ff.

[10] See Nahata 1961, III, pp. 1–16 (text only) and Nahata n.d. (text with Hindi translation); Sarma 1984.

[11] Nahata 1961, IV, pp. 41-74; SaKHYa 2009.

Sanskrit texts, and includes diverse topics from the daily life where numbers play a role.

The first three chapters are structured like the Sanskrit mathematical texts and treat traditional topics like fundamental operations, fractions, series, proportion, plane and solid geometry and so on. What Pherū had learnt from his own experience and from that of his contemporaries is presented as supplementary material in the fourth and fifth chapters. The supplementary material includes mechanical shortcuts in commercial arithmetic, mathematical riddles, rules for converting dates from the Vikrama era to Hijrī era and vice versa, and classification and construction of magic squares. These topics were not touched upon in any mathematical text before.

The section of solid geometry provides rules for calculating the volumes of domes (*gomaṃṭa,* from Persian *gumbad*), minarets (*munāraya,* from Persian *mīnār*), arches (*tāka,* from Persian *tāq*) and similar innovations in architecture introduced by the Sulṭāns of Delhi. The references to the arch and dome are particularly interesting, because just about the same time when Pherū was composing his *Gaṇitasārakaumudī,* the true arch and the true dome were employed successfully for the first time in the ᶜAlā' ī Darwāza, the gateway erected by ᶜAlā' al-Dīn in 1311 as part of his extension plans to the Quwwāt al-Islām mosque, which contains the Quṭb Mināṛ.

Finally, there is a highly interesting section listing the average yield of several kinds of grains and pulses per *bīghā*, the proportions of different products derived from sugar cane juice, and the amount of ghee that can be obtained from milk. This valuable data has naturally attracted the attention of economic historians.[12]

Thus, Ṭhakkura Pherū's *Gaṇitasārakaumudī* throws valuable light on the development and popularization of mathematics in northern India in the early fourteenth century and also on the economic conditions of that period, especially in the Delhi-Haryana-Rajasthan region, as no other mathematical work does.

[12] Cf. Habib, 1982.

2.0 The *Dravyaparīkṣā*

Chronologically the last and in content the most unique is the *Dravyaparīkṣā* (henceforth DP)[13] which Pherū composed in 1318.[14] It consists of 149 *gāthās.* As in other works, here also the title of the work is in Sanskrit; within the text there are many section headings, colophons and sub-colophons which are in a kind of mixed Sanskrit. Thus, *iti svarṇa vivahāraṃ, vivaraṇaṃ jantreṇāha, iti draṃmamudrāḥ*, etc. There occur also some technical terms taken from the Persian, like *cāsanī* or *cāsanikā,* which will be discussed below.

But it is the main language of the text, Apabhraṃśa, which causes serious problems in understanding. When I came across Pherū's works for the first time many years ago, I was impressed that he wrote on so many scientific topics in the popular Apabhraṃśa, and in my youthful enthusiasm wrote a paper with the title "Popularisation of Science in the fourteenth century".[15] But when one begins to study the texts closely the Apabhraṃśa verses with the elision of many consonants and with the frequent elongation of vowels for metrical

[13] Nahata 1961, III, pp. 17–38 (text only); Nahata 1976 (text with Hindi translation). The Nahatas were keen that the renowned scholar Vasudev Sharan Agrawala should translate and annotate especially the work on numismatics. Agrawala too recognized the uniqueness of the *Dravyaparīkṣā,* but could not fulfill the wishes of the Nahatas completely. He published a partial English translation of *gāthās* 51–139; see Agrawala 1966 (reprint 1969). An English translation of the entire text is still a desideratum; it should clearly explain the chemical and metallurgical processes described in the *gāthās* 1–50 and contain a thorough analysis of the coin catalogue (in *gāthās* 51–149), comparing Pherū's data with the actual specimens and their modern assays.

[14] In the concluding verse of the DP, Pherū mentions that he has expounded the subject briefly for the sake of his son and brother in the year 1375 of the Vikrama era; cf. DP 149: *evvaṃ davvaparikkhaṃ disimittaṃ caṃdataṇaya phereṇa | bhaṇiya suyabaṃdhavatthe teraha paṇhattare varise ||*

[15] Sarma 1986. Curiously enough, this paper turned out to be very popular; it was printed three times in Kolkata! It was reprinted in *Jain Journal*, 21.3 (January 1987) 86–95; and again in Ganesh Lalwani, *Jainanthology: An Anthology of Articles selected from Jain Journal of last 25 Years,* Jain Bhavan, Calcutta 1991, pp. 146–156.

purposes[16] proves to be an inadequate medium for scientific communication. When the subject is somewhat known, one can with some effort restore the consonants and draw some sense out of the text. Even then with undifferentiated case endings it is often difficult to know which is the multiplier and which is the multiplicand. But when the subject is new, it is often difficult to derive any sense out of the brief verses. When my Japanese friends and I were working on the *Gaṇita-sārakaumudī,* the mathematics was not difficult to understand, but when the subject is the calculation of the area of cloth required to cover various types of tents, our collective linguistic and mathematical expertise failed to cope with it. We looked at the pictures of tents in the Mughal miniatures of the seventeenth century; we talked to contemporary tent makers of the twentieth century, but all in vain. Pherū's discussion of tents is certainly valuable for the cultural history of the fourteenth century, but the correct apprehension remains still elusive.[17]

Similar problems occur also in the DP. However, there is a useful innovation in this book. Since the data provided in the metrical *gāthās* is numerical, Pherū adds after each block of text a table where he presents the same material in numerals in a visually more appealing manner.

As stated earlier, Pherū was the assay master at the mint of Quṭb al-Dīn Mubārak Shāh, and he composed the DP for his younger brother and son on the basis of his direct experience at the Delhi mint (*siriḍhilliya taṃkasāla kajjaṭhie / aṇubhūya karivi...*).[18] The term *dravya-parīkṣā* means the examination of

[16] Pherū even modifies his own name for metrical reasons as "phira" in 4ab: *taṃ bhaṇaï kalasanaṃdaṇa caṃdasuo phira [a]ṇubhāya taṇayatthe* and as "phera" in 149ab: *evvaṃ davvaparikkhaṃ disimittaṃ caṃdataṇaya phereṇa*.

[17] SaKHYa 2009, pp. 28–29, 36, 77–78, 86, 189.

[18] DP 2–3*: je nāṇā muddāiṃ siri ḍhilliya ṭaṃkasāla kajjaṭhiye | aṇubhūya karivi pattiu vanhi muhe jaha payāu ghiyaṃ || taṃ bhaṇaï kalasanaṃdaṇa caṃdasuo phira 'ṇubhāya taṇayatthe | tiha mullu tullu davvo nāmaṃ ṭhāmaṃ muṇaṃti jahā ||* "[Pherū] who is employed (*kajjaṭhiye*) in the mint (*ṭaṃkasālā*) at the glorious Delhi and thus has direct experience of various types of coins (*muddā*), just as clarified butter [is obtained] after melting [the butter] on the fire, even so after having [melted the coins and] understood (*karivi pattitu*) [their metal content]; Pherū, son of Canda, son of Kalasa, describes them (i.e., the coins)

the metal content (*dravya*) in the coins. As there was no official rate of exchange at that time for different currencies, the official or private money exchangers priced a coin on the basis of its metal content, for example, by ascertaining the amount of pure gold or pure silver in a particular coin. Such a determination of the metal content in artefacts is called assay.

Since the coins issued by several kingdoms in different periods of time continued to be in circulation, it was necessary to determine their intrinsic value by assay and to fix their exchange rate in terms of the local currency. Pherū calls this money exchange *nāṇavaṭṭa* (Sanskrit: *nāṇaka-vartana*). From this is derived the term *nāṇavaṭī* in the sense of money exchangers. The word survives still as a surname in Gujarat. How important this profession was can be seen by the number of related surnames like Parekh/Parikh (from Sanskrit *parīkṣaka*) or Potdar/Poddar[19] (from the Persian *fotah-dār*).[20]

The DP can be divided into two parts. The first part, consisting of 50 stanzas, deals with the techniques of assaying and thus provides the necessary technical background for currency exchange, while the second part, in 99 verses, offers valuable data on 260 coin types, which include not only the coins issued by the Khaljī Sulṭāns, but also by various kingdoms in northern India in the twelfth, thirteenth and early fourteenth centuries. This detailed listing of coins greatly adds to our numismatic knowledge, which is based on the limited number of extant coins preserved in museums and private collections. The uniqueness of this text cannot be overemphasized; there has not been such a text before or afterwards in India, in fact anywhere else in the medieval world. In this respect, Pherū's DP is comparable to the equally unique *De Re Metallica* of Georgius Agricola (1494–1555).[21]

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for the sake of his brother and son so that they know the price (*mullu*), weight (*tullu*), metal content (*davvo*), name (*nāma*) and the place of issue (*ṭhāma*)".

[19] Wilson 1855, s.v.

[20] Assayers and money-exchangers were also designated by the Persian term ṣarrāf which was anglicized as "shroff". On the importance of this profession, cf. Mehta 1991, pp. 66–67 et passim.

[21] The original Latin version was published posthumously in Basel in 1556. For an excellent English translation, cf. Hoover 1912. It may be noted

John S. Deyell evaluates the DP in these words: "It [sc. the DP] concerns the contemporary coinage issued under his direction, discussing denominations, metrology and metal content. In addition, Pheru undertook a thorough survey of the various Indian and foreign coins which were tendered at the mint for melting and re-minting. The author, being well informed, was able to supplement the usual banker's nick-names for different coins with his observations on the political and geographic origin of the coins encountered. In this the *Dravya Parīkshā* provides the key to many obscure early medieval coinage series."[22]

2.1 Assay by Touchstone (*Varṇamālikā*)

The metallurgical process of assay or measuring the degree of fineness of precious metals was mainly of two types: with the touchstone (*nikaṣa* or *kaṣa*)[23] or by fire assay. Gold or any other metal, when rubbed against the rough surface of the touchstone, leaves on it a streak of very fine powder which shows a more consistent colouration than the same mineral in a massive form. Thus, the colour of the streak is a more accurate index of the quality of the mineral than its surface colour. There are reports of skilled jewellers being able to estimate the fineness of gold just by the feel of the piece between the fingers[24] or just by one look at the streak on the touchstone. However, the general practice is to prepare a series of gold pieces with descending degrees of fineness for the sake of comparison. The gold to be tested is rubbed on the touchstone and the streak thus produced is compared with the streaks of reference gold pieces.

I have discussed elsewhere the history of testing gold by the touchstone in India.[25] Kauṭilya was the first to mention

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that Herbert Clark Hoover became subsequently the 31st President of the United States (1929–1933). For a German translation, see Schiffner 1928.

[22] Deyell 1990, p. 253.

[23] Sanskrit lexica list *śāṇa* as a synonym of *kaṣa* (*Amarakośa,* p. 348: *śāṇas tu nikaṣaḥ kaṣaḥ,* comm. *tṛīṇi suvarṇaparīkṣā-pāṣāṇasya*), but the actual usage shows that the former is a grinding stone and not a touchstone.

[24] See Thomas 1891, pp. 181–182.

[25] On the history of the assay by touchstone in India, see Sarma 1983.

this method of testing the purity of gold in the *Suvarṇādhyakṣa-prakaraṇa* of his *Arthaśāstra*, where he measures the gold in a scale of 1 to 16 *varṇas*.[26] The term *varṇa* denotes the colour of streak as well as the degree of purity or fineness. For easy handling, the reference gold pieces were cast in an elongated shape like pencils.[27] Such test sticks are called *varṇa-śalākās, suvarṇa-śalākās, parīkṣā-śalākās* or just *śalākās.* The series of gold pieces with regularly descending degree of fineness is known as *varṇamālikā.*

The preparation of the reference or test sticks involves the calculation of the proportions of gold and base metals in each stick. Starting from Śrīdhara's *Pāṭīgaṇita* of the ninth century, Sanskrit mathematical texts contain a small section called the "Mathematics of Gold" (*suvarṇa-gaṇita*) where they teach how to calculate the proportions of gold and base metal in an alloy of a certain degree of fineness or how to exchange certain amount of gold of fineness *x* against gold of fineness *y,* and similar problems.[28] These texts show the prevalence of gold assay by the touchstone. They also show that the fineness of gold was measured in a scale of 1 to 16 at least up to the twelfth century.

But in Pherū's time, the purity of gold was not measured any more on the scale 1 to 16, but on a new scale of 1 to 12. This new scale is akin to the modern scale of 1 to 24 carats, but it has not been possible to find out why this change occurred. It does not seem to have been borrowed from Persia because, according to Abū al-Faḍl, there they used a decimal scale of 1 to 10. And this new scale of 1 to 12 prevailed later on at the court of Akbar also, as Abū al-Faḍl reports.[29] In Pherū's

[26] *Arthaśāstra* 2.13.15–16.

[27] According to Abū al-Faḍl, in the Mughal period, the standard gold pieces were made in the shape of small balls and mounted on brass needles; cf. Blochmann 1873, pp. 18–38.

[28] The DP also has a small section (*gāthās* 38–41) dealing with the "mathematics of gold" (*svarṇa-vivahāra*); a mathematical problem of gold occurs also in Pherū's *Gaṇitasārakaumudī* 1.69; cf. SaKHYa 2009, pp. 14 (text) and 55 (translation).

[29] Blochmann 1873, p. 18: "The highest degree of purity is called in Persia *dahdahí,* but they do not know above ten degrees of fineness; whilst in India it is called *bárahabání,* as they have *twelve* degrees."

Apabhraṃśa, the term *varṇa* became *vannī,* and the purest gold was described as *vārahi vannī,* "that which has twelve *varṇas*".[30]

Pherū envisages a series of 48 test sticks, each less by a quarter *vannī* than the previous stick. For producing these, a mixture of 23 parts silver and 77 parts copper, which is called *rīsa,* is added to pure gold in different proportions.[31] Thus,

47 parts pure gold + 1 part mixture produces gold of 11 ¾ *vannī*

46 parts pure gold + 2 parts mixture produces gold of 11 ½ *vannī* and so on. [32]

It is not known how silver was graded before Pherū's time, but Pherū grades it on a scale of 1 to 20, purest silver being called 20-*visuvā* silver. For producing the reference sticks to test the purity of silver, the pure silver is degraded by the addition of a mixture (*rīsa*) consisting of 4 parts pure copper and 16 parts pure brass.[33] Pherū does not say how many test sticks are prepared for testing the fineness of silver, but it is reasonable to presume that at least one stick is made for each *visuvā.* Thus, a series of 20 sticks may have been prepared for measuring the fineness of silver on the scale of 1–20.[34]

2.2 Assay by Fire (*cāsaṇiya*)

The second method of assaying the purity of gold or silver is by melting it by fire. This is also known as the loss of weight method. One takes a sample of the gold or silver, weighs it, melts it at a high temperature to remove the impurities, and then weighs again. Pherū calls this process of assay by melting

[30] DP 38.

[31] DP 36–37.

[32] In his *De Re Metallica* Agricola describes the process of assay by the test sticks and even provides a woodcut depicting these test sticks. He grades the fineness in the scale of 1 to 24 and therefore his illustration shows a series of 24 sticks or needles, containing gradually increasing quantities of gold and regularly decreasing quantities of silver. Cf. Hoover 1912, pp. 253–256.

[33] DP 31–32.

[34] In his *Les six voyages,* the French jeweler Jean-Baptiste Tavernier (1605–1689) includes a sketch of 13 test-sticks used for testing the quality of silver in India; the sketch is reproduced in Petit 2008–2009, p. 148.

cāsaṇiya or *cāsanikā*. The word is from the Persian *chāshnī*. One who performs this task is called *chāshnīgīr*.[35]

The process is based on the principle that precious metals do not oxidize or react chemically and that they remain separate while the others form slags or other compounds. The metal to be melted is placed in a small cone-like vessel, which is surrounded by charcoal and heated. The vessel is called "cupel" (Sanskrit *mūṣā*[36]) and the whole process is also known as cupellation. According to Pherū, the cupel is made by moistening bone ashes and molding the moist substance into the desired shape. This is done so that the impurities in the metal to be melted are absorbed by the ashes.[37] Pherū's prescriptions for this are as follows:

> Take one part each of dry *Palāśa* (*Butea frondosa*) wood, wild cow's dung and goat's bones and burn them together. Strain the ashes. With one and a quarter *sers* (= 270 g) [of these ashes] form a cup (*gaha*) [in which place the metal to be melted]. Blowing gently with a blow-pipe (*vaṃkanālī*), melt it with one and a quarter man (= 11kg 3 g) of charcoals of the *Dhava* tree (*Grislea tomentosa* or *Anogeissus latifolia*)."

This basic procedure of assay is followed in the DP by more elaborate processes of the purification of gold and silver and of extracting silver from lead. These are similar to the basic assay, but performed on a larger scale. The metal to be refined is melted with an excess of lead, which becomes oxidized and forms litharge and dissolves any base metals present, thus

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[35] F. Steingass, *A Comprehensive Persian-English Dictionary,* s.v. explains chāshnī as "taste, taste by way of a sample, proof, trial, ... assay" and *chāshnīgīr* as "a taster to a prince, a cup bearer, a carver." In India, however, both the words were associated with the assay of gold and silver in the mint, and they were used in this sense by Abū al-Faḍl in his *Ā'īn-i Akbarī*; cf. Blochmann 1873, p. 23. Since *chāshnī* involves heating and liquefying metals, it came to mean also the treacle formed in the course of producing sugar from sugarcane juice. This is the sense that prevails in modern Hindi today.

[36] In Sanskrit there is extensive literature on the process of cupellation, which has been competently studied by Deshpande 1996.

[37] According to Agricola the best material is the ashes obtained from the burnt horns of a deer; cf. Hoover 1912, pp. 228–229.

separating them from the silver or gold. The litharge soaks into the lining but the precious metal is left on the surface. The more one repeats the process, the purer the metal becomes.[38] Thus, in order to achieve 100% pure gold, one has to melt the gold several times.[39]

The coins of various types which were in circulation were brought to the royal mint where they were melted and cast as pure gold or silver ingots. These ingots were either preserved as such in the treasury or used for minting new coinage. Therefore the knowledge of these processes is essential for officers of the treasury. Pherū's account is the earliest to be found in India. Three hundred years later, Abū al-Faḍl gives a more detailed account in his *Ā'īn-i Akbarī* in connection with the description of the imperial mint.[40]

2.3 The Basic Monetary and Weight Units

Before I discuss the coins and their parameters described by Pherū, it is necessary to briefly explain the monitory and weight units prevalent at Delhi at the time when the DP was written. The standard coin of this period is the silver *Ṭaṃkā* with a weight of one *tolā*. On the basis of the extant specimens, numismatists have estimated that the *tolā* of this period is roughly equal to 11.003 grams.[41] This silver *Ṭaṃkā* was equal in value to 60 *dammas* (Skt. *dramma*). The *damma,* popularly known as *gānī,* was a coin made of billon, i.e. an alloy of silver

[38] Wulff 1966, p. 13**:** "The cupellation process that separates the precious from the base metals with the aid of lead added to the melt and subsequent oxidization of both lead and base metals must have been known for a long time, since most gold and silver objects of antiquity show a high degree of purity."

[39] Abū al-Faḍl boasts that at Akbar's mint the process of refining gold was so highly developed that ʿAlā' al-Dīn's *dīnār* type of coin which was supposed to be purest gold at 12 *vannī,* turned out to be just 10 ½ *vannī* when tested by the advanced methods at Akbar's mint; cf. Blochmann 1873, p. 12.

[40] Blochmann 1873, pp. 18–38. The most detailed description of the processes of assay and purification of not just gold and silver, but a range of other minerals is given by Georgius Agricola in his *De re metallica.* Here he approaches the subject not as treasury official, but as a mining engineer, with elaborate woodcut illustrations. Cf. Hoover 1912, Books VII–XI.

[41] Deyell 1990, p. 261.

and copper, and weighed 1 *māṣā* (1/12 *tolā* = 0.917 g). There were eight different denominations of *damma* or *gānī* coins, viz., of 1, 2, 4, 6, 8, 12, 24 and 48 *gānīs,* which were designated respectively *iggānī, dugānī, caügānī, chagānī, aṭhagānī, bārahgānī, caübīsagānī, aḍtālīsagānī.* Pherū states that "in the treasury and in public transactions everywhere, the basis of accounting was *iggānī* or 1 *gānī.*"[42] The lowest denomination is *visuvā* which has the value of one-twentieth of a *damma*. It is a copper coin, weighing 1 *māṣā* (0.917 g). The scheme of weights in the DP is as follows:

20 *visuvas* = 1 *java* (=0.057 g)
16 *javas* = 1 *māṣa* (=0.917 g)
4 *māṣas* = 1 *ṭaṃka* (=3.667 g)
3 *ṭaṃka* = 1 *tolā* (=11.003 g)

Here the weight unit *ṭaṃka* (approximately 3.667 g) has to be distinguished from the monetary unit *Ṭaṃka,* which weighs 1 *tola* or 11.003 g.

2.4 The Catalogue of Coins

The second part of the DP constitutes a kind of catalogue of coins. Here Pherū provides the name (*nāma*), provenance (*ṭhāma*), weight (*tullu*), metal content (*davvo*), and the exchange value in terms of the Khaljī currency (*mullu*),[43] of some 260 types of coins issued by various kingdoms of northern India in the twelfth, thirteenth and early fourteenth centuries. The data is given first in verses and then in tables (*jantra*).[44] For the sake of the metre, sometimes the proper names of the coins are modified in the verses; sometimes the proper sequence of the denominations is changed. These are, however, correctly reproduced in the tables. Thus, the tables serve as corrective supplements to the verses.

[42] DP 136. The *iggānī* is the standard unit of currency; cf. Gupta 1969, pp. 87–89; Wright 1974, pp. 105–107.

[43] At the very outset, Pherū promises to provide these parameters for all the coins; cf. DP 3, cited in n. 18 above.

[44] These tables are preceded occasionally (e.g., after DP 77) by the prose line: *vivaraṃ jantreṇāha,* "the details are told by means of a table."

The coins described are of five types: gold, silver, gold-silver-copper alloy (*tri-dhātu-miśrita-mudrā*), silver-copper alloy or billon (*dvi-dhātu-mudrā*) and copper. The metal content of each coin type is expressed as follows. In the case of gold and silver coins, the degree of fineness is given in the scale of 1 to 12 for gold and of 1 to 20 for silver. For coins made of alloy, the weight of each metal per 100 specimens is listed. For example, the parameters of a coin named *Paüma* (Sanskrit: *Padma*) minted at Varanasi, presumably under the reign of the Gahaḍavāla kings, are given as follows:

> The coin from Varanasi called *Paüma* is [made] of three metals. One hundred coins weigh thirty-seven *tolas,* and contain forty-one *ṭaṃkas* of eleven *vannī* eleven *java* gold; thirty-six *ṭaṃkas* of pure silver and thirty-four *ṭaṃkas* of copper.
> In each *Paüma,* there are silver, gold and copper one *māṣa* each plus seven, ten and five *javas* and zero, four and fifteen *visuvas* respectively.
> The weight of a single *Paüma* is one *ṭaṃka,* seven *javas,* sixteen *visuvaṃsas.* Know that its price is fifty-nine or sixty *jaithalas.*[45]

That is to say, each coin weighs 1 *ṭaṃka,* 7 *javas* and 16 *visuvas* and consists of 1 *māṣā,* 10 *javas* and 4 *visuvas* of gold; 1 *māṣā,* 7 *javas* of silver; and 1 *māṣā,* 5 *javas* and 15 *visuavas* of copper. The touch of the gold is 11 *vannī* 11 *java,* where *java* is one-sixteenth part of a *vannī;* this translates to 23 3/8 carats. This data is given more clearly in the table.

2.4.1 The Nomenclature of Coins

An interesting feature of the catalogue is the plethora of names of the coins. Today a coin is generally known by its denomination, but in Pherū's time, the nomenclature was formed in several ways, often after the names of ruling monarch. In the DP, the coinage is generally classified according to kingdoms, and under each kingdom, the coins issued by different kings are arranged in a chronological order. Thus,

[45] DP 62–65. No specimen of this coin seems to be extant.

for Gujarat, Pherū lists the billon coins which were issued by the respective kings in the following order.

1. *kumara/kumarapurī* (issued by Kumārapāla Caulukya, r. 1144–1173)
2. *ajayapurī* (Ajayapāla Caulukya, r. 1173–1175)
3. *bhīmapurī* (Bhīma II Caulukya, r. 1178–1241)
4. *lūṇavasā/lavaṇasapurī* (Lāvaṇyaprasāda Vāghela, r. 1242 – 1243)
5. *vīsalapuri* (Vīsaladeva Vāghela, r. 1244–1262)
6. *ajjanapurī / arjunapurī* (Arjunadeva Vāghela, r. 1264–1273).

Because of the metrical constraints, Pherū sometimes gives only an abbreviated form of a name in the verse, but the full form in the table. Thus, what he calls *kumara* is only a short form of the coin named *kumarapurī,* which was issued by the king Kumārapāla Cālukya who ruled from Anhilvad Patan from 1144 to 1173. But what does suffix *˚purī* mean? From the Sanskrit texts and inscriptions we learn that such coins were known as *Kumāra-priya, Bhīma-priya* and so on[46] which became *Kumarapurī, Bhīmapurī,* etc., in Apabhraṃśa. Such a method of naming the coins seems to have prevailed in Gujrarat and Malwa.

In Punjab and Delhi, however, another system of nomenclature prevailed before the advent of the Muslim rule. Among the coins from Jalandhar (*jālaṃdharī mudrāḥ*) are mentioned *Jaïtacaṃdāhe, Rūpacaṃdāhe* and *Tiloyacaṃdāhe* (DP 109–110). These were presumably issued by kings named Jaitracandra, Rūpacandra and Trailokyacandra. Likewise, the coinage issued by the Tomar Rajput king Anaṅgapāla was known as *Aṇaga-palāhe*, by Madanapāla as *Mayaṇapalāhe*, by Pṛthvīpāla as *Piṭhaüpalāhe* and so on (DP 111 and the table that follows). I have not been able to define the linguistic reason for this nomenclature.

Similarly coins issued by Muslim rulers are also designated after their names. Thus, *Kuvāicī* or *Kuvācīya* (DP 116) are the coins issued by Nāṣru-d-dīn Qubācha of Sind (r. 1203–1228) who was appointed Governor of Ūcch by Muḥammad bin Sām

[46] Strauch 2002, pp. 313–314, where several other occurrences are cited.

in 1203 and who assumed independence after the latter's death in 1206. *Samasī* (DP 118) and *Tittimīsī* (DP 120) are the coins of Shams al-Dīn Īltutmish (r. 1210–1235). Some of his coins bear also the Nāgarī legend *samasadīna* or *samasadi.*

Besides these designations based on the names of rulers, there are some which are purely descriptive. Pherū mentions gold coins bearing the figures of Sītā and Rāma. He calls these *Sīyārāma* and adds that they are of two types, *saṃyogī* (Sītā and Rāma together?) and *viyogī* (Sītā and Rāma separately?). It is not known who issued these coins before the time of Pherū. According to Parameshwari Lal Gupta, Akbar also issued a coin with the figures of Rāma and Sītā and with the Nāgarī legend *siyarāma.*[47] Pherū designates a gold coin (DP 58) and a trimetallic coin (DP 62) *Paümā* or *Padamā*; probably these bore the figure of Lakṣmī.

But there are several designations which are either nicknames or trade names for certain coins, such as *Karāriya, Khaṭṭalāga* (DP 55), *Vilāīkora* (DP 67), *Bhaṃbhaï, Egaṭipi* (DP 75) and so on. Further research is needed to interpret these names properly.

2.4.2 The Coinage of the Turkish Sulṭāns

The lion's share of the catalogue goes to coins issued by the various kings at Delhi, from the Tomar king Anaṅgapāla to Pherū's employer, Qutb al-Dīn Mubārak Shāh of the Khaljī dynasty. Before the advent of the Khaljīs, Delhi was ruled by various Sulṭāns from Mu'iz al-Dīn Muḥammad ibn Sām (r. 1193–1206) to Mu'iz al-Dīn Kaiqubād (r. 1287–1290). Of these Sulṭāns, Pherū mentions only their billon coins (DP 112–31), although they are known to have issued silver coins also.

For example, about Raḍīyya Sulṭānā (r. 1236–1240), the only female ruler of this dynasty who ruled under the name of Jalālat al-Dīn Raḍiyya, Pherū states as follows:

> Shams al-Dīn's (*samasadi*) daughter Raḍīyya (*radīyā*). Her *Radī* is twofold: [minted at] Delhi and Badaun. [These contain respectively] sixteen and a half, and twelve and three quarters *ṭaṃkas* [of silver in one hundred pieces].

[47] Gupta 1969, p. 119 and pl. xxvi, no. 281; see also Mitchiner 2000.

> [Their prices are] nineteen and thirty-one [pieces per *Ṭaṃka*].[48]

But according to Stan Goron and J. P. Goenka, there survive also a gold *ṭaṃkā* of Raḍīyya minted at Lakhnautī in Bengal and silver *ṭāṃkas* minted at Delhi, in addition to the billon *jītals* minted at Delhi and Badaun.[49] This is the only occasion when Pherū mentions the names of different mints.

Likewise, of the first rulers of the Khaljī dynasty, namely, Jalāl al-Dīn Fīrūz II Khaljī (r. 1290–1296) and his son Rukn al-Dīn Ibrahīm (r. 1296), Pherū's information is partial and mentions only the billon coins, because they were still in circulation (*vaṭṭaṃti vivahāre*; DP 132).

2.4.3 The Coinage of ᶜAlā' al-Dīn Muḥammad Khaljī

When Pherū was composing the DP in 1318, the coinage of ᶜAlā' al-Dīn and Quṭb al-Dīn was legal tender at the time of writing (*saṃpaï pavaṭṭamāṇā*) and therefore his account of this coinage is naturally very detailed and comprehensive.[50]

ᶜAlā' al-Dīn Muḥammad Khaljī (r. 1296–1316) overthrew his uncle Jalāl al-Dīn Fīrūz and ascended the throne. During his reign of two decades, a large variety of coins were issued. Pherū informs us that ᶜAlā' al-Dīn issued two varieties of *dugānī,* two varieties of *chagānī,* one variety of *igānī,* gold *Ṭaṃkās* of five denominations and weights, one silver *Ṭaṃkā* of 1 *tolā* weight, and 1 gold *dīnār*. The five kinds of gold *Taṃkas* weighed 1, 5, 10, 50 and 100 *tolās.* The 100 *tolā* coin would weigh almost 1.1 kg. Such huge pieces naturally were not used for monitory transactions but as royal gifts to foreign ambassadors or as tokens of royal favour to high nobility. This custom continued into the Mughal times.[51]

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[48] DP 122: *samasadi suyā radīyā tassa radī dunni ḍhillīya budaüvā | saḍha sola paüṇa teraha ṭaṃkaka uṇavīsa igatīsā ||*

[49] Goron and Goenka 2001, pp. 26–27, where all the extant coins of Raḍīyyā are illustrated and excellently catalogued.

[50] DP 134–148; cf. also Gupta 1957, pp. 35–47; Moin 1999.

[51] Cf. Gupta 1957, pp. 37–38 (Gigantic coins). See also Najm-Ul-Hasan, "Making Big Money," *Hindustan Times,* 1 May 1998, for an account of a gold coin issued by the Mughal Emperor Jahāngīr. It weighed a little short of 12 kg, had a diameter of 20.3 cm (i.e., almost the width of A-4 size paper) and

Besides these gold, silver and billon coins there survive also several varieties of copper coins issued by ᶜAlā' al-Dīn which are not mentioned by Pherū.[52] He refers to ᶜAlā' al-Dīn as *Aśvapati Mahānarendra Pātisāhi Alāvadī,* but does not inform us about his titles which were incorporated on coins, such as *sikandar al-thānī,* "the second Alexander," *yamīn al-khilāfa,* "the right hand of the Caliphate," and *nāṣir amīr al-mū'minīn,* "helper of the Commander of the Faithful."[53] Nor does he inform us about the different mints, the names of which were generally available on the coins.

2.4.4 The Coinage of Shihāb al-Dīn ᶜUmar

When ᶜAlā' al-Dīn Khaljī died in 1316 after a long reign, his powerful general Mālik Kafur installed ᶜAlā' al-Dīn's six year old son Shihāb al-Dīn ᶜUmar as the Sulṭān and proclaimed himself as the Regent. This poor child ruled just for two months, during which time the royal mint carried on its work as usual and issued coins under the ruler's name. Pherū lists gold and silver *Ṭaṃkās* of 1 *tolā* each and five types of *gānī* coins. Pherū mentions their weights, silver content and so on, but, unlike modern numismatists, he does not mention the inscriptions on the coins. The long Arabic titles of the Sulṭāns would not have fitted in his Apabhraṃśa metres in any case. Modern numismatic catalogues record these inscriptions also and inform us that on his gold coins the child king was referred to as the "Second Alexander" (*sikandar al-thānī*).[54]

2.4.5 The Coinage of Quṭb al-Dīn Mubārak Shāh

Within two months of his coronation, Shihāb al-Dīn was killed by his elder brother Quṭb al-Dīn Mubārak Shāh who escaped from prison and ascended the throne. Pherū refers to him as *Rāyabandichoḍa,* "he who released himself from the prison and became king" or "he who freed the prisoners on becoming the

was supposed to be the largest gold coin in the world. In 1987 it was estimated to be worth ten million US dollars.

[52] Goron and Goenka 2001, pp. 37–39.

[53] Ibid, p. 37.

[54] Ibid, pp. 39–40.

king".[55] His short rule of four years has nothing to record but his dissolute life. The only achievement was the wide range of his coinage produced by the royal mints at Delhi and in Quṭbābad (Devagiri). According to Pherū, these mints produced as many as sixty-three different types of coins: 32 varieties of gold, 20 types of silver coins, 7 kinds of *dammas* and 4 varieties of copper pieces.[56] In the first two years, the gold and silver *Ṭaṃkās* were of circular shape. These were changed to square shape in 1318, just before Pherū wrote his book. Thus, the mints issued circular and square gold *Ṭaṃkās* of different denominations up to 200 *tolas*. There were also silver coins of 20 different types, and diverse kinds of billon and copper coins. Pherū lists these meticulously with their weights and metal content. What he does not mention are Quṭb al-Dīn's grandiloquent titles, which are mentioned in the modern numismatic catalogues.

Until this time, the Sulṭāns expressed a nominal allegiance to the Caliph and mentioned his name in their coinage. Quṭb al-Dīn discarded the Caliph's name from his coins, and called himself the *khalīfa rabb al-ᶜalamīn,* "Caliph, the lord of the two Worlds," *al-imām al-aʿzam*, "Most High Imām," and *sikandar al-zamān,* "the Alexander of the Age". [57]

Leaving these epithets aside, the coins themselves are said to be of a very high quality. The numismatist Nelson Wright remarks: "The coinage of Qutbuddin Mubarak stands out for its boldness of design and variety of its inscriptions. ... There is perhaps no finer coin in the whole pre-Mughal series than the broad square gold tankah of high relief struck at Qutbabad Fort."[58]

2.4.6 Accuracy of Pherū's Assays

It is to Pherū's credit that he prepared a comprehensive catalogue of Quṭb al-Dīn's coinage. An important element in

[55] DP 139: *itto bhaṇāmi saṃpaï kudubuddī rāyabaṃdichoḍassa | caürasa vaṭṭa muddā nāṇāviha tulla mullo ya ||*

[56] DP 140: *battīsaṃ kaṇayamayā ruppamayā vīsa damma sattavihā | caüviha taṃbaya sāhā muddā savvevi tesaṭṭhī ||*

[57] Goron and Goenka 2001, pp. 40–44.

[58] Wright 1936, pp. 107–108.

his data are the results of his assays. Today these can be compared with the modern assays to ascertain their accuracy. The first major study of the coins of the Delhi Sultanate was undertaken by H. Nelson Wright in his classic work *The Coinage and Metrology of the Sultans of Delhi*. Here he included also the results of the matellographic analyses of the coinage which were done by the assayers of the British Museum and of the Royal Mint. After the *Dravyaparīkṣā* was published, numismatists compared Pherū's statements with modern assay results published by Nelson Wright and found excellent agreement between them.

In particular, John S. Deyell compared the silver content in a series of *gānī* coins according to the analysis of the British Museum and according Pherū's assay and found that the percentage of agreement between the two assays ranges between 96.56 and 101.36 and that the percentage of variance between the two lies between 3.44 and 1.36.[59] It is indeed remarkable that there is a near-perfect agreement between Pherū's assays made in the medieval mint of Delhi and the modern analyses of the British Museum.

Of course, this degree of accuracy pertains specially to the coinage of ʿAlā' al-Dīn and his successors Shihāb al-Dīn and Quṭb al-Dīn, the coinage which Pherū directly dealt with. With regard to the coinage of other Sulṭāns and other kingdoms, the accuracy varies, depending on the number of specimens which were available to him for examination. Some parts of the data may also have been derived by Pherū from old mint records or other trade sources and not by direct examination. Even so, preserving all these records—his own and of others—for posterity in the form of the *Dravyaparīkṣā* was indeed a remarkable achievement.

Bibliography

Agrawala, Vasudeva Sharan, 1951–1952, "Dhātūtpatti," *The Journal of the Uttar Pradesh Historical Society,* 24–25, pp. 321–335.

———— 1966, "A Unique Treatise on Medieval Indian Coins". In: *Dr. Ghulam Yazdani Commemoration Volume,* Hyderabad:

[59] Deyell 1990, see the table on p. 255.

Maulana Abul Kalam Azad Oriental Research Institute, pp. 81–101. Reprinted as "Dravyaparīkṣā of Ṭhakkura Pherū" in *Indian Numismatic Chronicle,* 8, 1969, 100–114.

Blochmann, H. 1873 (tr), *The Ain i Akbari by Abul Fazl 'Allami,* vol. 1, Calcutta: Asiatic Society of Bengal. Reprint: Frankfurt: Institute for the History of Arabic-Islamic Science at the Johann Wolfgang Goethe University, 1993.

Deshpande, Vijaya Jayant, 1996, "Muṣāvijñāna or the Science of the Crucibles," *Indian Journal of History of Science,* 30.4, 359–373.

Deyell, John S., 1990, *Living without Silver: The Monetary History of Early Medieval North India,* Delhi: Oxford University Press, 1990 (Oxford India Paperbacks, 1999).

Goron, Stan and Goenka, J. P., 2001, *The Coins of the Indian Sultanates: Covering the Area of Present Day India, Pakistan and Bangladesh,* New Delhi: Munshiram Manoharlal.

Gupta, Parameshwari Lal, 1957, "The Coinage of the Khilji Sultans of Delhi," *The Journal of the Numismatic Society of India,* 29, 35–47.

———— 1969, *Coins,* New Delhi: National Book Trust.

Habib, Irfan, 1982, "Agrarian Economy." In: Tapan Roychaudhury & Irfan Habib (eds), *The Cambridge Economic History of India,* Volume I: *c.*1200–*c.*1700, Cambridge: Cambridge University Press, p. 50 ff.

Hoover, Herbert Clark, and Hoover, Lou Henry, 1912 (tr), Georgius Agricola, *De Re Metallica,* translated from the first Latin Edition of 1556, London: The Mining Magazine, available online at http://www.farlang.com/gemstones/agricola-metallica/page_001.

McHugh, James Andrew, 2008, *Sandalwood and Carrion: Smell in South Asian Culture and Civilization,* Ph.D. Dissertation, Harvard University.

Mehta, Makrand, 1991, *Indian Merchants and Entrepreneurs in Historical Perspective,* Delhi: Academic Foundation.

Mitchiner, Michael, 2000, *Ramatankas, Hindu Religious Tokens illustrating Themes from Ramayana,* Nasik: Indian Institute of Research in Numismatic Studies (IIRNS).

Moin, Danish, 1999, *Coins of the Delhi Sultanate,* Nasik: Indian Institute of Research in Numismatic Studies (IIRNS).

Nahata, Agar Chand, and Nahata, Bhanwar Lal (eds), 1961, *Ṭhakkura-Pherū-viracita-Ratnaparīkṣādi-sapta-grantha-saṃgraha,* Jodhpur: Rajasthan Oriental Series.

———— n.d. *Ratnaparīkṣā,* (text with Hindi trans.), Calcutta.

Nahata, Bhanwar Lal, 1976, *Ṭhakkura Pherū viracitā Dravya-parīkṣā aur Dhātūtpatti* (text with Hindi trans.), Vaishali: Research Institute of Prakrit, Jainology and Ahimsa.

Petit, Jérôme, 2008–2009, "Banārasīdās et Jean-Baptiste Tavernier: Feux croises sur l'histoire économique de l'Inde au XVII[e] siècle," *Bulletin d'Études Indiennes,* 26–27, 141-152.

SaKHYa, 2009 (= Sreeramula Rajeswara Sarma, Takanori Kusuba, Takao Hayashi and Michio Yano), *Gaṇitasāra-kaumudī, the Moonlight of the Essence of Mathematics, by Ṭhakkura Pherū,* edited with Introduction, Translation and Mathematical Commentary, New Delhi: Manohar.

Sarma, Sreeramula Rajeswara, 1983 "*Varṇamālikā* System of Determining the Fineness of Gold in Ancient and Medieval India". In: B. Datta et al. (eds), *Aruṇa-Bhāratī: Professor A. N. Jani Felicitation Volume,* Baroda: Professor A. N. Jani Felicitation Volume Committee, pp. 369–389.

———— 1984, *Ṭhakkura Pherū's Rayaṇaparikkhā. A Medieval Prakrit Text on Gemmology,* with an Introduction, Sanskrit *chāyā*, Translation into English and Commentary, Aligarh: Viveka Publications.

———— 1986 "Thakkura Pheru and the Popularisation of Science in India in the Fourteenth Century" in: *Sri Bhanwar Lal Nahata Abhinandana Grantha*, Calcutta: Shri Bhanwar Lal Nahata Abhinandan Samaroh Samiti, pt 4, pp. 63–72.

———— 1996, "Sanskrit Manuals for Learning Persian" in: Azarmi Dukht Safavi (ed), *Adab Shenasi,* Aligarh: Department of Persian, Aligarh Muslim University, pp. 1–12.

———— 1999, "Yantrarāja: the Astrolabe in Sanskrit," *Indian Journal of History of Science,* 34, 145–158. Reprinted in, idem, *The Archaic and the Exotic: Studies in the History of Indian Astronomical Instruments*, New Delhi: Manohar, 2008, pp. 240–256.

———— 2000, "Sultān, Sūri and the Astrolabe," *Indian Journal of History of Science,* 35.2, 29–147. Reprinted in, idem, *The Archaic and the Exotic: Studies in the History of Indian Astronomical Instruments*, New Delhi: Manohar, 2008, pp. 179–198.

———— 2002, "From Yāvanī to Saṃskṛtam: Sanskrit Writings inspired by Persian Works," *Studies in the History of Indian Thought,* Kyoto, 14, 71–88.

Schiffner, Carl, 1928 (tr), Georg Agricola, *Zwölf Bücher vom Berg- und Hüttenwesen ...,* in neuer Deutscher Übersetzung bearbeitet von Carl Schiffner et al, Berlin: Agricola Gesellschaft beim Deutschen Museum, V.D.I. Verlag, available online at http://www.digitalis.uni-koeln.de/Agricola/agricola_index.html.

Strauch, Ingo, 2002, *Die Lekhapaddhati-Lekhapañcāsikā: Briefe und Urkunden im Mittelalterlichen Gujarat,* Berlin: Dietrich Reimer Verlag.

Sūri, Mahendra, 1936, *Yantrarājaḥ, Mahendraguru-viracitaḥ, Malayendu-sūri-viracita-ṭīkā-sahitaḥ,* ed. Kṛṣṇaśaṃkara Keśavarāma Raikva, Mumbai: Nirnaya Sagar Press.

Thomas, Edward, 1891 *Chronicles of the Pathan Kings of Delhi,* London, reprint 1967: New Delhi: Munshiram Manoharlal.

Wilson, H. H., 1855, *A Glossary of Judicial and Revenue Terms ...,* London: Wm. H. Allen and Co.

Wright, H. Nelson, 1936, *The Coinage and Metrology of the Sultans of Delhi,* Oxford, reprint 1974: New Delhi: Munshiram Manoharlal.

Wulff, Hans E., 1996, *The Traditional Crafts of Persia: Their Development, Technology, and Influence on Eastern and Western Civilizations.* Cambridge, etc.: The M.I.T. Press.