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THE *PAÑCAVIṂŚATIKĀ* IN ITS TWO RECENSIONS: A Study in the Reformation of a Medieval Sanskrit Mathematical Textbook

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INTRODUCTION

A small mathematical treatise in Sanskrit, the *Pañcaviṃśatikā*, together with Śambhunātha's vernacular commentary, *Gaṇitasāra*, is contained in the manuscript,

A: LD Institute, Ahmedabad, Acc. No. 5325.

The date of Śambhunātha is not known precisely, but he refers to Bhāskara II's *Līlāvatī* (A.D. 1150). In addition, he employs in examples two monetary units called *korī* and *dokaḍā* (28 dokaḍās = 1 korī). The former is most probably a copper coin minted by Sultan Muzaffar Shah III (A.D. 1562-72) [Sircar 1968, 23]. According to the colophon, the manuscript was copied by a Caturavijaya at Bhujanagara (modern Bhuje in Kaccha, about 300 km west of Ahmedabad) in Saṃ 1786 = A.D. 1730. Śambhunātha, therefore, seems to have flourished some time between A.D. 1562 and 1730.

The same work, together with a Gujarātī commentary, *Bālabodhānkavṛtti* is contained in the manuscript,

B: Oriental Library, Baroda, Acc. No. 5283.

According to the last verse and the colophon of the manuscript, the *Bālabodhānkavṛtti* was composed by a *mantrin* (a wise man or a minister?), Śambhudāsa by name, at Ahmedabad in Saṃ 1485 = A.D. 1428/29. It follows that the *Pañcaviṃśatikā* was written before A.D. 1429. But neither of the two manuscripts mentions the name of its author.

The manuscripts

A: LD Institute, Ahmedabad, Acc. No. 5325.

Title: *Gaṇitasāra*. Script: Devanāgarī, Ff. 1-5. Complete. 17 lines to a page. About 55 to 60 letters (*akṣaras*) to a line. Paper. The *Gaṇitasāra* ends at the middle of fol. 5a, and on the rest of the same page is written a *naṣṭajanmapatrī* ("a leaf for a lost horoscope"). On fol. 5b are written several rules concerning *horās* ("hours"), and a table of 28 (not 27) *nakṣatras* which lists the number of stars and their formation (with an illustration) of each *nakṣatra*.

B: Oriental Library, Baroda, Acc. No. 5283.

Title: *Gaṇitapañcaviṃśatikābālāvabodha*. Script: Devanāgarī. Ff. 1-10. Complete. 12 lines to a page. About 40 to 45 letters (*akṣaras*) to a line. Paper.

The languages of the commentaries

The language used in Śambhudāsa's *Bālabodhānkavṛtti* is basically Old Gujarātī, but it often comes very near to Sanskrit, and sometimes it may be regarded as almost

regular Sanskrit, although several phonetic peculiarities, probably due to the author's native tongue, are observed.

Śambhunātha's *Gaṇitasāra* is written throughout in a vernacular, which too is perhaps Old Gujarātī, but which is slightly different from that of Śambhudāsa.

Reconstruction of a common ancestor

The title of the work, *Pañcaviṃśatikā* ('[the work] of twenty-five [verses]), suggests that the work in its original form consisted of 25 verses. Manuscript A, however, contains 40 verses, among which 39 are numbered 1, 1-3, 1-6, 6-33, and 1; another unnumbered verse is embedded in the commentary on (A 22). Manuscript B, on the other hand, contains 27 numbered verses plus several that are unnumbered. Many verses, with or without variants, are naturally found in both manuscripts, but some are only in A, and others only in B. These facts indicate that Śambhunātha and Śambhudāsa separately commented on an enlarged recension of the *Pañcaviṃśatikā*, although it is not easy to differentiate their own additions from their predecessors'.

I have tried to reconstruct an ancestor (designated X) common to both recensions (A and B) according to the following working hypotheses (cf. the Concordance below).

1) Those verses which occur in only one of the two recensions are later additions.
   Verses found only in A:
   1', 2', 3', 3ab, 4, 5, 21cd, 22, 22U, 23, 24, 29, 30, 31, 32, 1°.
   Verses found only in B:
   9U, 19, 21U, 25, 26, 27.

2) The other verses, which occur in both recensions, existed in the ancestor.

The first three verses in the above list, (A 1'), (A 2'), and (A 3'), which are found only in A, are numbered separately from the rest in the manuscript. Moreover, Śambhunātha introduces the next stanza, (A 1) = (X 2), as "the *śloka* stanza of the original work" (mūlagraṃtha no ślokaḥ). This means that the three verses at least were added by Śambhunātha himself. (A 22U) occurs in the solution of an example under (A 22), and is not numbered in the manuscript. It is, therefore, most probably a quotation by him. (A 1°) occurs in the commentary on the last verse, (A 33), and is numbered "1" separately from the rest. So, it also appears to be an addition by him.

As for recension B, the last verse, (B 27), which is a colophon to the commentary, is no doubt an addition by Śambhudāsa himself. The two unnumbered verses, (B 9U) and (B 21U), which are a quarter verse and a half verse respectively, are also most probably additions by him.

Apparent exceptions to the second hypothesis are (A 3cd) ≃ (B 2U), and (A 21ab) ≃ (B 18U). Although each pair has the same content, I have excluded them for the following reasons. First, the sentences are not the same; (A 3) and (A 21) are written in

normal *āryā* and *śloka* meters respectively, while (B 2U) is not quite metrical and (B 18U) is poorly worded in *śloka*. Second, both (B 2U) and (B 18U) are unnumbered in recension B, and correspond to only part of a full verse, (A 3) and (A 21) respectively, of recension A. Moreover, (A 3) is identical with *Triśatikā* 1 = *Pātīgaṇita* 14 of Śrīdhara (of the eighth century A.D.). It is, therefore, highly probable that they are later additions. It may also be pointed out in this connection that (A 21) agrees with *Aparājitapṛcchā* 47.22 (in the twelfth century) and Ṭhakkura Pherū's *Gaṇitasāra* 3.45 (ca. A.D. 1315) in contents. See Translation below.

Thus, I have obtained twenty-four *ślokas* of the supposed ancestor; they are numbered 1-24 in the third column (designated X) of the Concordance given below. This is quite reasonable because we get exactly 25 *ślokas* by supposing another one for the lost colophon of the original *Pañcaviṃśatikā*. It is, therefore, very likely that these twenty-four verses constituted the original *Pañcaviṃśatikā* too, but it is sometimes difficult to determine the original purports of those verses precisely, since the two commentaries differ from each other sometimes in the expressions of the verses, and sometimes in their interpretations. We shall examine these differences next.

Differences between the two commentaries

I shall give below a list of the differences between the two commentaries with brief comments. See the Translation with Mathematical Commentary below for more information.

(X 1) Benediction.
A: *svīyasūtrair* (with my own versified rules).
B: *pañcasūtrair* (with five *sūtras*).

In recension B, the word *sūtra* is used in an unusual sense, i.e., "a section" of the text,and in fact Śambhudāsa divides the text into five sections.

Sūtra 1. Addition (1 ½ verses): (B 2)-(B 2U).
Sūtra 2. Subtraction (1 verse): (B 3).
Sūtra 3. Multiplication (6 verses): (B 4)-(B 8U).
Sūtra 4. Division (1 ¼ verses): (B 9)-(B 9U).
Sūtra 5. The rest (19 verses): (B 10)-(B 27).

It is, however, noteworthy that nothing in the ancestor reconstructed above suggests such a division into sections. Recension A has no explicit division into sections, as is usual with small mathematical works like this.

(X 2) Sum of the natural series.
A: Śambhunātha reads only two methods in the verses.
B: Śambhudāsa reads four methods.

As the verse actually contains at least three methods, Śambhunātha seems to have missed at least one method. Śambhudāsa, on the other hand, reads four methods, but his reading of the verse contains an irregular hiatus.

(X 3) Difference of the natural series.

A: According to Śambhunātha, *vyavakalita* ("difference") is,

$$S_n - n = S_{n-1}$$

B: According to Śambhudāsa, it is,

$$V_{n.m} = S_n - S_m.$$

Śambhunātha's interpretation of *vyavakalita* is unique, while Śambhudāsa agrees with Śrīdhara (Tr and PG) and Ṭhakkura Pherū (GS).

(X 5) *Kapāṭasandhi*.

(X 6) *Gomūtrikā*.

(X 7) *Tatstha*.

(X 8) *Hīnādhikabhāga* of *khaṇḍaguṇana*.

These are the names of multiplication methods, but the nomenclature is hopelessly confused in the two commentaries.

(X 9) Multiplication of zero and unity

A: Śambhunātha reads only two rules in the verse.

B: Śambhudāsa reads three rules.

Śambhudāsa's second rule, which Śambhunātha misses, is a rather unusual one, prescribing the writing-down of the zero symbol at a certain step of the multiplication procedure.

(X 14) Fractions

A: Multiplication and division of fractions of the ordinary type, b/a.

B: Multiplication of numbers whose fractional portions are expressed according to a place-value system, $p;q$.

Recension A is traditional.

(X 15) Rule of three

A: (the first, the middle, the last).

B: (the last, the middle, the first).

The order of the three terms in the terminology of recension B is unusual. Recension A is traditional.

(X 16) Investments

A: One method.

B: Two methods, according to Śambhudāsa.

It is difficult to see Śambhudāsa's second method even in his own wording of the verse.

(X 17) Second rule, which is meant for the purification of gold.
A: Rule for the purity.
B: Rule for the weight.
Perhaps the rule itself is meant for the weight as in B, but Śambhudāsa wrongly applies the rule to an example of simple mixture of gold.

(X 23) Second rule, which is meant for the volume of a cone-like heap of grain.
A: Śambhunātha wrongly takes the rule to give a formula for the volume of a sphere.
B: Śambhudāsa's interpretation is correct.

(X 24) Telling time from a shadow
A: Correct and exact expression of a rule.
B: Ambiguous expression of the rule.
(A 1°) in A and (B 26) in B give a table of twelve noon-shadows, which are to be employed in (X 24), but the numerical values in the two tables differ from each other. It is of special interest that the values given in (A 1°) do not satisfy a simple linear zig-zag function. Those of (B 26), on the other hand, satisfy as usual a linear zig-zag function. The maximum and minimum values of both functions are six and zero respectively, but in A they take place at Sagittarius and Gemini respectively; in other words, the entire graph of A has been shifted to the left by one zodiacal sign.

THE ORIGINAL *Pañcaviṃśatikā* AND THE TWO RECENSIONS

Although Śambhunātha does not always understand the verses correctly (X 3 and 23), recension A itself seems to preserve more traditional elements than recension B, which contains several new elemetns (X 1, 14, and 15) that do not completely tally with traditional Indian mathematics. Śambhudāsa employs in his commentary a linear standard of non-Sanskrit origin, namely, *gaja*, which called *gaz*, was in vogue under the Mughul Empire. Abu-l Fazl (ca. A.D. 1600) has recorded seven types of *gaz* [Srinivasan 1979, 15]. The inverse order of terminology for the rule of three (X 15), adopted in recension B, may also be explained by the right-to-left order of Arabic writing. At the same time, however, it should be noted that Śambhudāsa has borrowed many examples from Śrīdhara's works, *Triśatikā* and (or) *Pāṭīgaṇita*.

The reconstructed ancestor (X) begins with the sum of the natural series *(saṅkalita)*. This is in the style of Śrīdhara (both in the *Triśatikā* and the *Pāṭīgaṇita*) and of Ṭhakkura Pherū (in the *Gaṇitasāra*). Śambhunātha supplies a verse for the addition and subtraction of numbers expressed in the decimal place-value system, following probably the style of Bhāskara II's *Līlāvatī*, which is in fact the only work Śambhunātha mentions by name. See under (A 28) = (X 23).

Medieval Indian mathematics consisted of two major fields, namely, *pāṭī* and *bījagaṇita*. The original *Pañcaviṃśatikā* may be classified as a book of *pāṭī*, which

consists mainly of arithmetical operations (*parikarman*) such as addition, subtraction, etc. and eight kinds of "practical mathematics" (*vyavahāra*), and which does not employ algebraic symbolism (*bīja*). The ancestor actually contains most of these topics, but not all of them. It misses "the practical mathematics" of "piling [of bricks]" (*citi*) and "sawing [of timbers]" (*krakaca*), and is very poor in "the practical mathematics" of "series" (*śreḍhī*) and "plane figure" (*kṣetra*). Thus, the ancestor is incomplete as a book of *pāṭī*. This was probably the case also with the original *Pañcaviṃśatikā*, and recension A was perhaps meant to be a more comprehensive book of *pāṭī*, although it still lacks the section on "the practical mathematics of piling", and rules based on the Pythagorian Theorem.

From the viewpoint of the history of Indian mathematics, the importance of our text lies in its historical expansion and reformation rather than in its mathematical contents, as it throws new light upon the history of reformation of other Sanskrit mathematical treatises. For example, the title of our text, *Pañcavimśatikā*, reminds us of the *Ganitapañcavimśī* "Mathematics in twenty-five *ślokas*" "ascribed to Srīdhara (in the eighth century). Although there seems to be no direct relation between the two works, both claim to be a work consisting of twenty-five verses, and both contain more than that in their present form; the number of verses of the latter is estimated at nearly ninety from its unique, incomplete manuscript. This seems to me to suggest that, just like our text, the *Ganitapañcavimśī* also consisted of twenty-five verses in its original form, and was expanded to its present form by the hands of a later interpolator or interpolators. This conjecture is supported by the fact that eight and a half verses of the present *Gaṇitapañcaviṃśi* are found verbatim in Bhāskara's *Lilāvatī* (A.D. 1150).

Gaṇitapañcaviṃśī	*Lilāvatī*
Rule 26	204 : 3/2 Indravajrā stanzas
Ex. 14	205 : 1 Śloka
Rule 27	135 : 1 Āryā
Rule 28	136 : 1 Āryā
Ex. 15	137 : 1 Śloka
Rule 31ab	234 : ½ Vasantatilakā
Ex. 19	235 : 1 Indravajrā
Rule 31cd	236 : ½ Vasantatilakā
Ex. 20	237 : 1 Upajāti

Other works having similar titles

Tejasiṃha, head of the Lunkāgaccha, wrote in the 17th century the *Iṣṭāṅkapañcavimśatikā* ("[A book of] twenty-five [stanzas/rules] on arbitrarily chosen numbers", a manuscript of which is preserved in the LD Institute (Acc. No. 903). It consists of 25 verses (14 *śārdūlavikriḍita* stanzas and 11 *vasantatilakā* stanzas) for mathematical rules and one additional verse (in the *upajāti* meter) for the ending.

All the rules deal with a single type of mathematical game, in which any optional number, when modified by a series of arithmetical operations, turns out to be the number determined in advance. The ninth stanza, for example, reads thus:

> Any optional number is multiplied by 265, increased by unity, multiplied by 500, and divided by 265. The remainder [of the division] is again multiplied by 2. When the years equal in number to the result have elapsed from the Final Liberation (*nirvāna)* of Mahāvīra, King Vikrama was born to the earth.

The arithmetical computations have been so arranged here that number 470 is obtained irrespective of the number chosen by a partner.

The author, Tejasiṃha, is said to have died in A.D. 1686 [Jain & Agrawal 1988, 22]. Photocopies of the manuscript have appeared at the close of *Arhat Vacana,* Vol. 1, nos. 3-4, 1989.

It is probably the same Tejasiṃha that wrote the *Gaṇitapañcaviṃśatikā* (Ms: LD Institute, Acc. No. 3665/5, dated Saṃ 1870 = A.D. 1813). It is a small collection of 25 mathematical problems, each problem being questioned in one *drutavilambita* stanza. Most of the problems are of the type:

$$x - \frac{x}{2} - \frac{x}{3} - \frac{x}{42} - \frac{x}{8} = 18 \text{ (stanza 25)}.$$

The answer 1008 to this problem is a sacred number for the Jainas. Another stanza, numbered 26, in the same meter is appended for the ending.

These two works, devoted for particular topics, may be regarded as a kind of monograph, which is a hitherto neglected field of study in Indian mathematical literature.

Concordance of the Sanskrit verses commented on by *Śambhunātha* (A) and *Sambhudāsa* (B) *with their ancestor (X) reconstructed*

In manuscript A, there are four verses numbered 1, two 2, two 3, and two 6. In order to differentiate them, the marks, '', ', and °, have been attached to the numbers by me. The letter U attached to a verse-number (N) indicates that the verse in unnumbered and located between verses N and $N+1$ in the manuscripts.

A	B	X	Contents
1″	1	1	Benediction to Mahādeva. Calls the work *Pañcaviṃśatikā.*
1′	—	—	Names of 18 decimal places.
2′	—	—	(Continued)
3′	—•	—	Addition & subtraction in the decimal place-value system, with a rule for zero.
1	2	2	Sum of the natural series.
2	3	3	Difference between the sums of two natural series.
3ab	—	—	Sum of the natural series (S_n).

3cd	2U	—	Integral portion of $\sqrt{2S_n} = n$. (A3) = Tr 1 = PG 14
4	—	—	Arithmetical progressions.
5	—	—	Geometrical progressions.
6	4	4	Multiplication: Enumerates the names of 4 methods.
6′	5	5	*Kapāṭasandhi.*
7	6	6	*Gomūtrikā.*
8	7	7	*Tatstha.*
9	8	8	*Khaṇḍa.*
10	8U	9	By zero and unity.
11	9	10	Division.
—	9U	—	Zero for a quotient. (B 9U) is a quarter verse.
12	10	11	Square and cube.
13	11	12	Square-root.
14	12	13	(Continued)
15	13	14	Multiplication and division of fractions. The rules of A and B are different.
16	14	15	Rule of three and inverse rule of three.
17	15	16	Investments.
18	16	17	Mixture of gold (its purity).
19	17	18	Areas of a square and an oblong. Area of a trapezoid.
20	18	19	Areas of a triangle and a circle.
21ab	18U	—	Circumference of a circle.
21cd	—	—	Area of a circle.
22ab	—	—	Area of a circle.
22cd	—	—	Area of a circle.
22U	—	—	Approximation to the square root.
23ab	—	—	Area of a circle (identical with A 22 ab).
23cdef	—	—	Area of a circle.
24	—	—	Area of a segment of a circle.
—	19	—	Heron's formula for the areas of a trilateral and a (cyclic) quadrilateral.
25	20	20	Area of a segment of a circle. Area of "a rim", or of any other irregular figure.
26	21	21	Volume of a rectangular solid.
—	21U	—	Arithmetical mean of different lengths. (B 21U) is a half verse.
27	22	22	Volume of a cylinder.
28	23	23	Volume of a sphere. Volume of a cone-like heap of grain.
29	—	—	Grain heaped up on the ground.
30	—	—	(Continued)
31	—	—	(Continued)
32	—	—	Work for sawing timber.

33	24	24	Telling time from a shadow.
1°	—	—	Length of the noon-shadow.
—	25	—	Length of daylight.
—	26	—	Length of the moon-shadow.
—	27	—	Colophon of the commentary. Gives the name of the author (Śambhudāsa) and the title (*Bālabodhānkavṛtti*) of the commentary.
[—	—	25	Colophon of the *Pañcaviṃśatikā* (?)]

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I wish to express my sincere gratitude to Professor David Pingree of Brown University, who initiated me into the *Pañcaviṃśatikā*, and who kindly secured for me xerox copies of its two manuscripts used for the present study. It is also thanks to him that the manuscripts of the *Gaṇitapañcaviṃśatikā* and the *Iṣṭānkapañcaviṃśatikā* have become available to me. He also took the trouble to go through the first draft, and to give me many valuable suggestions, especially on the section on the gnomon and shadow, but mistakes and shortcomings are my own.

SANSKRIT TEXT OF THE *PAÑCAVIṂŚATIKĀ*

Two recensions (A and B) and their common ancestor (X) reconstructed.

(X 1)>(A 1″, B1)

mahādevaṃ praṇamyādau bālānāṃ buddhivṛddhaye[1]/
svīyasūtrair[2] ahaṃ vakṣye pañcaviṃśatikām imām/ /

[1]-vṛddhāye in B (corr.i.m.). [2]pañcasūtrair in B.

(A 1')

ekaṃ daśa śataṃ tasmāt sahasram ayutaṃ tathā/
lakṣaṃ ca prayutaṃ koṭir arbudaṃ cābjakaṃ tataḥ/ /

(A 2')

kharvanikharvapadmaṃ ca śa[nkur] jaladhir eva ca/
Antyaṃ madhyaṃ parārdhaṃ ca kramād ākhyā daśottarāḥ/ /

(A 3')

yathā sthānakam aṅkānāṃ yutir viyutir āditaḥ/
khenonādhyaḥ sa eva sa na[1] pāte [']ṃtyāṃkasaṃgraha[ḥ]/ /

[1]saḥ/da in ms.

X 2)>(A 1, B 2)

saikādyapadaghātārdhaṃ bhaved[1] ekottareṇa tat[2]/
padavargādyayogārdhaṃ[3] saikādyārdhavadhe[4] phalam/ /

[1]tathā in B. [2]ca in B. [3]-yuktārdhaṃ in B. [4]saikādyardhavadheḥ in A.

(B 2U)

saṃkalitadviguṇān mūlasamo[1] gaccha[ḥ]/ /

[1]mūlūṃ samaṃ is ms.

(X 3)>(A 2, B3)

saṃkalitotpannadyumnād[1] vyayaṃ tyaktvā[2] dhanaṃ bhavet/
taddhanaṃ[3] vyavakalitaṃ munibhiḥ purā/ /
[1]saṃkalitonnatadrarmmā in A, -dyumnāta in B. [2]kṛtvā in B.
[3]tat- in B.

(A 3)

saikapadāhatapadadalam ekādicayena bhavati saṃkalitam/
dyiguṇīkṛtasaṃkalitān[1] mūlaṃ gaccho [']vaśiṣṭasamaḥ/ /
[1]-saṃkalitāt in ms.

(A4)

vyekapadaghnacayaḥ sādyo[1] [']ntya[ṃ] svavaktrayutād[2] dalam/
madhya[ṃ] svapadanighnaṃ tat sarvasvaṃ jāyate caye/ /
[1]-cayogrāhyo is ms. [2]-yutāṃ in ms.

(A 5)

oje gacche nireke syād guṇaḥ same [']rddhite kṛtiḥ/
gacchāntaṃ vyastam antyānkāc cayād guṇāh kṛtiḥ[1] phalam/
vyekaṃ vyekacayacchinnam ādighnaṃ syād guṇottare/ /
[1]kṛtaṃ in ms.

(X 4)>(A 6, B4)

dvidhā kapāṭasandhiś ca tathā gomūtrikā dvidhā|
tastho dvidhā punaḥ proktas tathā khaṇḍas[1] tridhā smṛtaḥ[2]| |
[1]khaṇḍa-in B. [2]mataḥ in A.

(X 5)>(A 6', B5)

praśnopari nyasen mūlyaṃ mūlyena[1] guṇayet kramāt|
anulomavilomābhyāṃ kapāṭākhyam dvidhā bhavet| |
[1]mūlaṃ maulyena in A, mūlaṃ mūlona in B.

(X 6)>(A 7, B 6)

praśnād adho nyasen mūlyaṃ[1] guṇayet sakalaṃ mithaḥ[2]|
anulomavilomābhyāṃ gomūtrākhyaṃ dvidhā bhavet| |
[1]mūlya- in B. [2]tataḥ in A, guṇayeś| |śrīlaṃ mithaḥ in B.

(X 7)>(A 8, B 7)

ekaikaguṇanād rāśeḥ śīrṣabhedo[1] nigadyate[2]|
pṛṣṭhabheda[ḥ][3] punaḥ proktaḥ tastho [']pi dvividhaḥ[4] smṛtaḥ[5]| |
[1]śīrṣā- in B (corr.i.m.). [2]nigadyataḥ in B. [3]pṛṣṭabhede in A,
koṣṭābheda in B (corr.i.m.). [4]dvidheḥ in B (corr.i.m).
[5]tasthepidvividhāpunaḥ in A.

(X 8)>(A 9, B 8)

kvacid[1] rūpavibhāgaś ca sthānabhāgaḥ kvacid bhavet|
kvacid dhīnādhiko[2] bhāgaḥ khaṇḍo [']pi trividhaḥ[3] smṛtaḥ| |
[1]kvacit in B. [2]kvacit hīnādhiko in B. [3]dvividhaḥ in A.

(X 9)>(A10, B 8U)

śūnyena guṇitaṃ[1] śūnyaṃ śūnyam agre[2] niyojayet|
tad evaikena[3] guṇitaṃ bhaved evaṃ[4] hi sarvataḥ| |
[1]guṇe taṃ in A. [2]śūnyamārge in A.
[3]tadvadekena in A, tadaivaikena in B. [4] eva in A.

(X 10)>(A 11, B9)

praśnād adho haraṃ nyasya praśnaṃ chitvā[1] hareṇa ca|
bhāgo hāryaḥ kramān nūnaṃ bhāgāhāravidhiḥ smṛtaḥ| |
[1]bitvā in A.

(B 9U)

bhāgo nāsti labdhaṃ śūnyaṃ| |

(X 11)>(A 12, B 10)

tulyarāśidvayor[1] ghāte vargo bhavati kevalaṃ|
padatrayāṇāṃ[2] tulyānāṃ vadhe nūnaṃ ghano bhavet| |
[1]-rāśyodvayor in A. [2]-triyāṇāṃ in B.

(X 12)>(A 13, B 11)

vargaṃ saṃtyajya viṣamād dviguṇena[1] paraṃ ghajet|
labdhaṃ niveśayet[2] paṅktyāṃ tadvargaṃ paratas tyajet[3]|
[1] viṣamāt dviduṇana in B. [2]viniveśayet in A. [3]pariśodhayet in B.

(X 13)>(A 14, B 12)

pūrvavad[1] dviguṇīkṛtya[2] tad utsārya[3] paraṃ bhajet[4]|
evaṃ pare[5] [']pi kartavyaṃ dalayed[6] dviguṇīkṛtaṃ| |
[1]pūrvava- in A, pūrvavat in B. [2]dviguṇaṃkṛtya in A.
[3]ucchārtha in B. [4]bhavet in A. [5]paro in B. [6]dalaye in A,
dalayet in B.

(X 14)>(A 15)

aṃśahati[ś] chedaghātabhaktā bhinne guṇe phalaṃ|
paravarttyāṃśakacchedau guṇavad bhāgake phalaṃ| |

>(B 13)

rūpaṃ rūpaiḥ samaṃ guṇyaṃ chedāṃśāv[1] api taiḥ[2] sama[m]|
paraspara [ṃ] tadaṃśau ca bhinnotpannaṃ phalaṃ labhet| |
[1]cchidāṃśāv in ms. [2]teḥ in ms.

(X 15)> (A 16)

madhyāntyayor vadhaḥ pūrvam ādibhāgas trirāśike|
madhyādyayor vadho[1] vyaste prāntyabhaktaḥ phalaṃ bhavet| |
[1]madhyādayor vyadho in ms.

>(B 14)

madhyādyayor vadhaḥ pūrvam antyabhāgas trirāśike|
madhyāntyayor vadho vyaste ādibhāga [ḥ] phalaṃ labhet| |

(X 16)>(A 17)

nānāprakṣeparūpāṇāṃ utpannena phalena te|
guṇyāḥ svayogabhaktās te khaṇḍāni syuḥ pṛthak pṛthak| |

>(B 15)

nānāprakṣeparūpāṇām utpannena vadhaḥ kramāt|
yutibhāgā[d] dyayau[1] labdhī phalaṃ syāt tat pṛthak[2] pṛthak| |
[1]dvayā in ms. [2]prathak in ms.

(X 17)>(A 18)

suvarṇavarṇaghātyaikyaṃ svarṇayogena bhājayet|
labdhānke varṇakā jñeyā svarṇoddhṛte[1] sa varṇakaḥ||
[1]varṇoddhṛtte in ms.

>(B 16)

nānāsuvarṇavarṇānām aikyaṃ svarṇena[1] bhājyate|
labdhāṅke varṇikā jñeyā[2] suvarṇaṃ varṇikāhṛtam| |
[1]svarṇyena in ms. [2]carṇikā jñaiyā in ms.

(X 18)>(A 19, B 17)

caturasre[1] same dīrghe bhujakoṭivadhaḥ phalam|
vasudhāmukhayogārdhaṃ lambaghnaṃ viṣame phalam| |
[1]caturaśre in B.

(X 19)>(A 20, B 18)

vasudhārdhaṃ lambanighnaṃ[1] phalam kṣetre[2] trikoṇake|
vyāsasya turyabhāgena[3] vadho[4] vṛtteś ca vartule[5]| |
[1]vasudhārdhalambaghātaḥ in B. [2]kṣetri in B. [3]-bhāgana in B.
[4]vadhoḥ in A. [5]vartuleḥ in A.

(A 21)

vyāsas triguṇito[1] vṛttir vyāsaṣaḍbhāgasaṃyuthaḥ[2]|
vyāsārdhaṃ ca paridhyardham anyonyaṃ paritāḍayet| |
[1]vyāsattriguñitā in ms. [2]-yuto in ms.

(B 18 U)

vyāsasya triguṇā paridhiḥ ṣaḍbhāgasamanvitā[1]||
[1]ṣaṭ- in ms.

(A 22)

vyāsavarge phalaṃ sthūlaṃ pañcamāṃśanipātanāt|
vyāsārdhavargavargaṃ ca daśaghnaṃ mūlataḥ phalam||

(A 22U)

mūlāvaśeṣakaṃ saikaṃ ṣaṣṭighnaṃ vikalānvitam|
dviguṇena dviyuktena[1] mūlenāptaṃ sphuṭaṃ bhavet| |
[1]dviguṇā- in ms.

(A 23)

vyāsavarge phalaṃ jñeyaṃ pañcamāṃśanipātanāt|
vyāsavargasya yo rāśir hīnas turyeṇa kārayet|
svadhṛter bhāgasaṃyuktaṃ phalaṃ jñeyam athāpi vā| |

(A 24)

jyāśaraikyadalaṃ bāṇanighnaṃ tadvargadigghateḥ|
navabhaktasya mūlaṃ taddhanurbāṇaphalaṃ smṛtam| |

(B 19)

(bhujaikyārdhaṃ[1] caturdhā ca bhujahīnaṃ ca tadvadhāt[2]|
mūlaṃ phalaṃ bhaven nūnaṃ tryasre[2] vāpi caturmukhe| |

[1]bhujekyārdhaṃ in ms. [2]taghāt in ms. [3]tisre in ms.

(X 20)>(A 25, B 20)

jyāśaraikyadaleṣughnaṃ[1] bhāgāṣṭādaśasaṃyutam[2]|
nemyākṛtau ca viṣame vyāsadīrghavadhaḥ[3] phalam| |

[1]yyāśaraikyadaleyyughnaṃ in B. [2]sāgāṣṭā- in A, bhāgāṣṭaḥ daśa- in B. [3]vyosaṃbavadhaḥ in B.

(X 21)>(A 26, B 21)

khāte kāṣṭhe[1] ca[2] pāṣāṇe koṣṭhāgāre[3] citau tathā|
vyāsadīrghavadhas[4] tatra piṇḍaghātaḥ same[5] phalam| |

[1]kāṣṭe in A. [2]B om. ca. [3]koṣṭhāre in B. [4]-dīrdhavadhās in B. [5]piṇḍaghātavadhaḥ in A, piṇḍaghāte samaṃ in B.

(B 21U) tathā vakram|
viṣamaṃ yadi cet [tena] viṣamayuti[bhāgakaḥ][1]| |

[1]tathā cal kraṃ biṣamaṃ yade ceta viṣamayuti caitataḥ kuryāt in ms.

(X 22)>(A 27, B 22)

kāṣṭhapāṣāṇayo[ḥ] stambhe kūpe ca sadṛśaṃ[2] phalam|
vṛttakṣetre[3] phalaṃ tatra tena piṇḍavadhaḥ[4] phalam| |

[1]kāṣṭa- in A. [2]kūpe va sadraśaṃ in B. [3]-kṣetra- in B. [4]piṇḍasamaṃ in A (cf. note 5 for (X 21)), -vādhaḥ in B.

(X 23)>(A 28, B 23)

golavyāsaghanārdhaṃ[1] ca bhāgāṣṭādaśasaṃyutam|
vṛtteḥ ṣaḍaṃśas tadvarga[2] udayena hataḥ phalam| |

[1]-vyāsanārdhaṃ in B. [2]vṛttaṣaḍaṃśavargas tad- in B. [3]hattaḥ in B.

(A 29)

aṇuṣv ekādaśāṃśaḥ syād vedho [']naṇuṣu diglavaḥ|
śūkidhānye ['n]kabhāgaḥ syāt paridheś ca ṣaḍaṃśakaḥ| |

(A 30)

vargito vedhaguṇito ghanahastamitir bhavet|
madhyāntarbāhyaparidhir dvyabdhisatryaṃśarūpakaiḥ| |

(A 31)

guṇitā svīyahāreṇāptaṃ phalaṃ bhittimadhyathaḥ|
antarbāhyasthakoṇeṣu phalaṃ ghanakarāḥ smṛtāḥ| |

(A 32)

bāhukoṭivadhārddhaṃ ca tryasrakṣetre phalaṃ smṛtam|
mūlāgrapiṇḍayogārddhaṃ dairghyaghnaṃ dārujaṃ phalam| |

(X 24)>(A 33, B 24)

chāyā saptayutā kāryā madhyacchāyāṃ[1] tatas tyajet|
dinārddhaṃ saptabhir guṇyaṃ tenāptaṃ ghaṭikādikam[2]| |
[1]-cchāyā in A. [2]Second line in B: dinārdhāt saptabhir guṇyād bhāgān nāḍyo gatā [ḥ] sthitāḥ ("tatas...guṇyā" in margin).

(A 1°)

dvyekakhaikaikasārddhadvivipādvedāś[1] ca paṃcakam|
ṣaṭ [ca] paṃca vipātpaṃca trayaṃ sārddhaṃ ca madhyabhā| |
[1]dvyekakhabhaikasārddhaddhivipādvedāś in ms.

(B 25)

makarādidinās trighnāḥ[1] khatripañcaikasaṃyuktā[ḥ]|
ṣaṣ[ṭ] er bhāgāt kalā labdhi[ḥ] karkād rātris tathaiva hi| |
[1]-dināḥ|tri- in ms.

(B 26)

tridvyekakhendupakṣāgniyugeṣuṣaṭśarā[1] yugā[ḥ]|
kramān meṣādisaṃkrāntau madhyapādāḥ prakīrttitāḥ[2]| |
[1]-yugeyyu- for yugeṣu in ms. [2]-pādapra- in ms.

(Colophon of A)

iti śrīśambhunāthaviracitaṃ gaṇitasāraṃ samāptam|| saṃ 1786 varṣe māha vadi 13 dine likhitam| ga[ṇi]| caturavijayena|| śrībhujanagare|| svavācanārtham|| ||śrīr astu|| kalyāṇam astu|| śreyo [']stu|| iti bhadraṃ syāl lekhakapāṭhakayoś ca||

(B 27)

bāṇāhivedacandrābde[1] [']hammadāvādapattane|
bālabodhāṅkavṛttiś[2] ca śambhudāsena[3] nirmitā||
[1]vānāhideva- in ms. [2]-pṛstiś in ms. [3]śuṃbhu- in ms.

(Colophon of B)

iti mantriśambhudāsaviracitā[1] pañcaviṃśatikābālabodhāṅkavṛttiḥ samāptā[2]||cha|| ||cha||
[1]maṃtraśaṃbhudāsaviricitā in ms. [2]samāptaḥ in ms.

A 1'-2'. Names of 18 decimal places

Eka (10^0), daśa (10^1), śata (10^2), sahasra, ayuta, lakṣa, prayuta, koṭi, arbuda, abjaka (10^9), kharva, nikharva, padma (10^{12}), śaṅku, jaladhi, antya, madhya, and parārdha (10^{17}). [These are] named in order according to the decimal system.

These names, except for *padma*, were very popular in Hindu (as against Jaina) mathematical works since the eighth century A.D. The number of places, 18, was also fixed in them. The popular name for the power 10^{12} is *mahāpadma* (a big lotus) or its synonyms (such as *mahābja, mahāpaṅkaja, mahāsaritpati*, etc.); and *padma* (a lotus) without *mahā* (big) is usually taken to indicate the same power as *abja* (a lotus), i.e., 10^9. In the present stanzas and Śambhunātha's commentary, however, *padma* is regarded as different from *abja (ka)*.

Śambhunātha refers to the decimal places greater than *parārdha;* he repeats *daśa, śata, sahasra*, etc. together with *parārdha*. His example is: "eka sahasra eka śo igyāra parārdha" (one thousand one hundred and eleven *parārdha*) for 1111×10^{17}.

Cf. Abh 2.2; Tr 2'-3'; PG 7-8; GP 8-9; GT 2-3; L 10-11; GS 1.12-14; GK Prakīrṇaka 2-3; GM 12-14. For a Jaina table see GSS 1.63-68.

A 3'. Addition and subtraction of numbers expressed in the decimal place-value system

Beginning with the first [numeral], the sum or difference of numerals [is made] according to the places. That [numeral], when decreased or increased by zero, is itself. When there is no subtraction (i.e., when the subtrahend is greater than the minuend), the sum of the last [adjacent] (i.e., next) numeral [and the minuend is taken to be the new minuend].

Ex. 1. Addition	Ex. 2. Subtraction
1 5 6	1 5 6 4 5
1 4	4 7 5 6
2 2 6	"These are subtracted."
1 1 3 5	1 0 8 8 9
1 5 3 1	

Cf. GP 10; L 12; GK Prakīrṇaka 12; GM 14.

X 2. Sum of the natural series ([saṃkalita]).

Half of the product of the first [value] increased by unity and the number of terms will be that [sum which is obtained] by increasing one by one. Half of the sum of the square of the number of terms and the first [value is also the sum]. Multiplying half of the first [or the first] increased by unity [by the other value, one obtains] the [same] result.

Def. $S_n = 1 + 2 + \ldots + n$.

$$Sn = \frac{n(n+1)}{2}.$$

$$Sn = \frac{n^2 + n}{2}.$$

$$Sn = \begin{cases} (n+1).\ \frac{n}{2} \text{ (if } n \text{ is even).} \\ \frac{n+1}{2}.\ n \text{ (if } n \text{ is odd).} \end{cases}$$

Note that the word *ādya* (lit. "the first") in this rule is used in an unusual sense, i.e., "the number of terms", or *n*, which is also called *pada* as usual in the same verse.

A. Śambhunāta explains the first two methods only.

Ex. $n = 10$.

$$S_{10} = \frac{10\,(10+1)}{2} = 55. \qquad S_{10} = \frac{10^2 + 10}{2} = 55.$$

B. Śambhudāsa regards the definition itself as a method for computing *Sn*, reading the second quarter (*pāda*), of the verse, not as "bhaved ekottareṇa tat" (in ms. A), but as "tathā ekottareṇa ca" ([the same result is obtained] also by increasing one by one), which contains irregular hiatus.

Ex. $n = 10$.

$$S_{10} = \frac{10\,(10+1)}{2} = 55. \qquad S_{10} = 1 + 2 + \ldots + 10 = 55.$$

$$S_{10} = \frac{10^2 + 10}{2} = 55. \qquad S_{10}\,(10+1)\,\frac{10}{2} = 55.$$

For $n = 20, 30, \ldots, 100$, Śambhudāsa gives only the results: $S_{20} = 210$, $S_{30} = 465, \ldots, S_{100} = 5050$. This example is identical with Tr Ex. 1 = PG Ex. 1.

Cf. BSS 12.19; Tr. 1-2; PG 14-15; SS 13.21; L 117; GS 1.16-18; GK Śreḍhī 11 (I, p. 114); GM 155.

B 2U. Supplement to (X 2).

The number of terms is equal to [the integer part of] the square-root of twice the sum.

Integer part of $\sqrt{\ 2Sn} = n$.

(B 2U) = (A 3cd) in contents. Cf. GS 1.20.

X 3. *Difference of the sums of two natural series (vyavakalita)*

Having subtracted the expense (*vyaya*) from the property (*dyumna*) produced by addition (*samkalita*), there will be property (*dhana*). This property has been called the difference (*vyavakalita*) by ancient sages.

A. Śambhunātha regards the verse as prescribing the rule:

$Sn - n = S_{n-1}$.

Ex. $n = 10$. $S_{10} - 10 = 55 - 10 = 45 = S_9$.

B. Śambhudāsa, like Śrīdhara and Pherū, regards the verse as giving the difference of the sums of two natural series (S_n and S_m):

$V_{n,m} = S_n - S_m$.

For S_n and S_m see (X2) above.

Ex. $S_{100} - S_{10} = 4995$, $S_{100} - S_{20} = 4840$, $S_{100} - S_{30} = 4585$, ..., $S_{100} - S_{90} = 955$, $S_{100} - S_{100} = 0$.

In the ms. these values are tabulated, and the last result, the zero (0), is expressed as "0000". This example is identical with Tr Ex. 2 = PG Ex. 2.

Cf. Tr 3-4; PG 16-17; GS 1.21-22.

A 3. Sum of the natural series

Half of the product of the number of terms and the same increased by unity is the sum by means of the first term and the common increase which are [both] unity. The [integer part of the] square-root of twice the sum, which is equal to the remainder, is the number of terms.

$$S_n = \frac{n\,(n+1)}{2}.$$

Integer part of $\sqrt{\ }^2 S_n$ = its remainder = n,

(since $2S_n = n^2 + n$).

Ex. $n = 24$. $S_{24} = 300$. $2S_{24} = 600 = 24^2 + 24$.

The meter of (A 3) is *āryā*. Verse (A 3) is identical with Tr 1 = PG 14.

A 4. Arithmetical progressions

The common increase, multiplied by the number of terms less one and increased by the first term, is the last term. Half of the sum of [the result and] the first term is the middle (or the mean) term. This, when multiplied by the number of terms, becomes the total sum in piling (i.e., of an arithmetical progression).

$a_n = a + (n - 1)\,d$, $\overline{m} = (a + a_n)/2$, $S_n = \overline{nm}$,

where a, d, and n are the first term (*ādya/vaktra*), the common difference (*caya*), and the number of terms (*pada*) of an arithmetical progression, and a_n, $\overline{m}$, and S_n are the last term (*antya*), the middle term (*madhya*) or the arithmetical mean, and the total sum (*sarvasva*) of the series.

Ex. On the first Dvādaśī festival four Brāmaṇas are invited, and on the succeeding occasions of the same festival the number of Brāmaṇas invited is increased each time by three. How many are invited in total for twenty-five occasions of the Dvādaśī festival?

Given, $a = 4$, $d = 3$, $n = 25$. $a_{25} = 76$, $\overline{m} = 40$; $S_{25} = 1000$.

Cf. Abh 2.19; BSS 12.17; Tr 39; PG 85,95; GSS 2.64; MS 15.47; L 121; GS 3.26; GK Śreḍhī 1; GM 161.

A 5. Geometrical progressions

If the number of terms is odd, then [it is] decreased by one and there will be [the designation] "multiplication"; if even, then halved and "squaring". [This procedure is repeated until] the number of terms ends (i.e., is exhausted). In the inverse order from the last figure, which is the common increase (i.e., the multiplier), multiplication [by the common increase] and squaring [are made according to the designations]. The result [thus obtained], increased by one, divided by the common increase less one, and multiplied by the first term, will be [the sum of the geometrical series] of which the succeeding terms are multiples [of the preceding ones].

$$S_n = a. \frac{r^n - 1}{r - 1} \text{ (A 5ef),}$$

where a, r, and n are the first term, the common ratio, and the number of terms of a geometrical progression. (A 5abcd) gives an algorithm for computing r^n.

Ex. $a = 2$, $r = 3$, $n = 7$. (m = multiplication, s = squaring.)

$n = 7$

↓m 2187 (= 729.3) = $3^7 = r^n$.

6 ↑

↓s 729 (= 27^2)

3 ↑

↓m 27 (= 9.3)

2 ↑

↓s 9 (= 3^2)

1 ↑

↓m 3 = r.

0

$$S_7 = 2. \frac{2187 - 1}{3 - 1} = 2186.$$

Cf. *Chandaḥsūtra* 8.32; PG 94-95; GSS 2.94; Pṛthūdakasvāmin on BSS 12.17; MS 15.50-53; SS 13.25; L 130; GK Śreḍhī 21 (I, p.127); GM 169-170.

X4. Multiplication

Kapātasandhi (a door junction) is of two kinds, and ***Gomūtrikā*** (A cow's urine) is also of two kinds. In addition, ***Tatstha*** (being there) is said to be of two kinds, and ***Khaṇḍa*** (separation) is regarded as of three kinds.

The verse enumerates the names of four methods of multiplication, which are being described in the next four verses. Due to the laconic expressions of the versified rules and the sketchy descriptions of the commentaries, there remains much ambiguity about the details of the procedures. Moreover, the two commentaries (or recensions) do not agree with each other in nomenclature. For example, *Kapāṭasandhi* of Śambhunātha (in A) is called the *koṣṭhabheda* of *Tatstha* by Śambhudāsa (in B), while *Kapāṭasandhi* of the latter is called *Tatstha* by the former. Śambhunātha in the present verse regards *Khaṇḍa* as of two kinds, *rūpavibhāga* and *sthānavibhāga*, but under (A 9) = (X 8) he admits three kinds. On the contrary, stanza (A 9) itself reads *dvividhaḥ* (two kinds) instead of *trividaḥ* (three kinds), although (A 6) = (X 4) reads *tridhā* (three kinds).

Cf. Tr 7.

X 5. Kapāṭasandhi ("a door junction")

One should place the price above the question, and multiply with the price in order. There will be two varieties [of the method] called *kapāṭa* according to whether the order [of procedure] is natural *(anuloma)* or inverse *(viloma)*.

In the present and the following verses, the multiplier and multiplicand are called "the [quantity in] question" *(praśna)* and "the price" *(mūlya)*.

A.

Ex. A horse costs two hundred and thirty-five *korīs*. How much do fifteen horses cost?

0	2	3	5
1	0 2	0 3	0 5
5	1 0	1 5	2 5
3	5	2	5

235 korīs × 15 = 3525 korīs.

B. Śambhudāsa first explains the four methods for multiplication (X 5-8) and an auxiliary rule concerning zero and unity (X 9), and then gives eleven examples with working processes for only the first example. The first eight examples require the price of a certain thing when its quantity (Q) and the unit price (U) are given. The rest are purely numerical examples which have been devised for a special form (*rūpa*) of the result.

Ex. 1. Q = 1196 gadīyāṇas of *rūpa* (silver?), U = 18 drammas/gadīyāṇa.
Ex. 2. Q = 865 tolas of *hema* (gold), U = 32 ṭaṅkas/tola.
Ex. 3. Q = 196 maṇas of *mañjīṭha*, U = 35 ṭaṅkas/maṇa.
Ex. 4. Q = 4865 maṇas of *dānta* (ivory?), U = 36 ṭaṅkas/maṇa.
Ex. 5. Q = 38327 maṇas of *ṣāṇḍa*, U = 81 drammas/maṇa.
Ex. 6. Q = 1767 maṇas of *sūkadi*, U = 64 ṭaṅkas/maṇa
Ex. 7. Q = 3703 maṇas of *ācchī*, U = 188 drammas/maṇa.
Ex. 8. Q = 1859 maṇas of *paḍasūtra*, U = 308 ṭaṅkas/maṇa.
Ex. 9. 152207 × 73 = 11111111 (in the form of a *vallī* or creeper).
Ex. 10. 333333666667 × 33 = 11000011000011 (a *kaṇṭhābharaṇa* or necklace).
Ex. 11. 142857143 × 7 = 1000000001 (a *hāra* or necklace of pearls).

Illustration of Ex. 1 (1196 × 18 = 21528). In the ms. the two varieties, the natural and the inverse orders, are illustrated by the "setting" (*nyāsa*), one of the intermediate steps, and the result (21528), without explanations.
om10t1m10t2m10

	Natural order	Inverse order
Setting	1 1 8	1 8
	1 1 9 6	1 1 9 6
A step	1 8 8 2 8	1 1 9 6 8
	1 9 6	8 7 4
	7 4	8 2
Result	2 1 5 2 8	2 1 5 2 8

These illustrations obviously contain scribal errors. The following are my tentative reconstructions. The underlines indicate the numerals newly written at each step.

(1)	Price	1 8		1 8
	Question	1 1 9 6		1 1 9 6
(2)		1 8		1 8
	18 × 1:	1 8 1 9 6	18 × 6:	1 1 9 6 8
				4
(3)		1 8		1 8
	18 × 1:	1 8 8 9 6	18 × 9:	1 1 9 6 8
		1		7 4
				2
(4)		1 8		1 8
	18 × 9:	1 8 8 2 6	18 × 1:	1 1 9 6 8
		1 9		7 4
		7		8 2
(5)		1 8		1 8
	18 × 6:	1 8 8 2 8	18 × 1:	1 1 9 6 8
		1 9 6		8 7 4
		7 4		8 2
(6)	From (X 9):	1 8		1 8
		1 8 8 2 8		1 1 9 6 8
		1 9 6 0		8 7 4 0
		7 4 0		8 2 0
(7)	Result	2 1 5 2 8		2 1 5 2 8

Steps (1), (5) without the first line, and (7) are given in the ms. At step (6), the empty places are filled with zero according to (X 9).

Cf. Tr 5-6; PG 18-19; GP 10; GSS 2.1; MS 1.3; SS 13.2; GT 15; L 14; GS 1.27; GK Prakīrṇaka 13; GM 17-18.

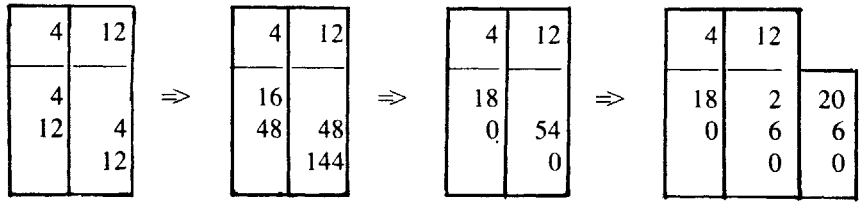
X 6. Gomūtrikā ("a cow's urine").

One should place the price below the question, and multiply the whole mutually. There will be two varieties [of the method] called *gomūtra* according to whether the order [of procedure] is natural or inverse.

A.

Ex. 1. The area of a square figure.

4 hastas 12 aṅgulas × 4 hastas 12 aṅgulas
= 20 sq. hastas 6 sq. aṅgulas.



The ms. shows the first step only.

Ex. 2. A horse costs three hundred fifty-five and a half *korīs*. How much are fifteen horses? (28 *dokaḍās* = 1 *korī)*

355 1/2 korīs × 15 = (355 korīs + 14 dokaḍās) × 15
= 5325 korīs + 210 dokaḍās
= 5325 + 7 1/2 korīs = 5332 korīs.

The main text calculates: 355 × 15 + 7 = 5332, while the enclosed expression is:

15	
355 ko II[a]	5325[b]
dokaḍā 14	210

a 10 in the ms.
b 5321 in the ms.

B.

Ex. 1196 × 18 = 21528. Just as in the case of *Kapāṭasandhi*, the two varieties are illustrated by the first "setting", one of the intermediate steps, and the result.

	Natural order	Inverse order	
Setting	1 1 9 6	1 1 9 6	(question)
	1 x	x 1	(price)
A step	1 9 7 8 8	1 9 7 8 8	
	1 7 4	1 7 4	
Result	2 1 5 2 5	[2 1 5 2 8]	

Evidently, the result of the natural order is wrong, and that of the inverse order is missing. Likewise, the intermediate step of the inverse order and the second line of the setting in both cases appear to suffer from scribal errors.

(1)	Question	1 1 9 6		1 1 9 6
	Price	1 8		1 8
(2)	1 × 18:	1 8	6 × 18:	6 8
				4
(3)	1 × 18:	1 9 8	9 × 18:	9 8 8
				7 4
(4)	9 × 18:	1 9 7 2	1 × 18:	2 7 8 8
		1 7		7 4
(5)	6 × 18:	1 9 7 8 8	1 × 18:	2 0 7 8 8
		1 7 4		7 4
(6)	From (X 9):	1 9 7 8 8		2 0 7 8 8
		1 7 4 0		7 4 0
(7)	Result	2 1 5 2 8	Result	2 1 5 2 8

Cf. BSS 12.55.

X 7. Tatstha ("being there").

A. Śambhunātha's recension reads:

The variety [called] *śīrṣa* (the head) is declared in multiplying the quantity one by one. In addition, the variety [called] *pṛṣṭha* (the back) has been told [in the same category]. [Thus], *tatstha* is also regarded as of two kinds.

Ex. 1. *śīrṣabheda.* 135 × 12 = 1620.

1 2	1 2	1 2	
1 3 5	1 2 3 5	1 5 6 5	1 6 2 0
	(12 × 3)	(12 × 3)	(12 × 5)

Ex. 2. *pṛṣṭhabheda.* 135 × 12 = 1620.

1 3 5	1 3 6 0	1 4 2 0	1 6 2 0
1 2	1 2	1 2	
(12 × 5)	(12 × 3)	(12 × 1)	

B. Śambhudāsa calls the two varieties "the head" and "the box" (*koṣṭha*).

Ex. 1. *śīrṣabheda*. 1196 × 18 = 21528. In the ms. are given the following three steps.

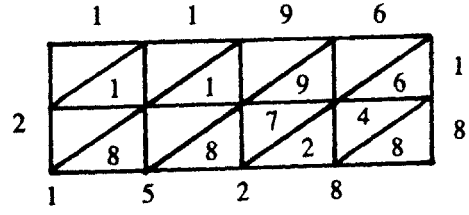
	Setting	A step	Result
Price	1 8	1 1 9 6 8	2 1 5 2 8
Question	1 1 9 6	8 8 7	

My tentative reconstruction is as follows:

(1)	1 × 1196:	1 1 9 6
(2)	8 × 1:	1 1 9 6 8
(3)	8 × 1:	1 1 9 6 8 8
(4)	8 × 9:	1 1 9 6 8 8 2 7
(5)	8 × 6:	1 1 9 6 8 8 8 2 7 4
(6)	From (X 9):	1 1 9 6 8 8 8 2 0 7 4 0
(7)	Result:	2 1 5 2 8

Probably the intermediate step in the ms. is a corrupted form of step (5).

Ex. 2. *koṣṭhabheda*. 1196 × 18 = 21528.



Cf. Tr 6; PG 19; GSS 2.1; GM 16.

X 8. Khaṇḍa ("part")

In some cases the separation by integers (*rūpavibhāga*) will be [employed], in other cases the separation by places (*sthānabhāga*), and still in other cases the separation by decreasing and increasing (*hīnādhikabhāga*). The [method called]

khaṇḍa has also been handed down [to us] in three kinds.

(1) Separation by integers: $ab = ax + ay$, where $b = x + y$.

A.

Ex. Given under (A 6) = (X 4).

$135 \times 12 = 135 \times 6 + 135 \times 6 = 810 + 810 = 1620.$

Expression in the ms.:

6	135	810	sum	multiplier	12	product
6	135	810	1620	multiplicand	135	1620

B.

Ex.

$1196 \times 18 = 1196 \times 9 + 1196 \times 9 = 10764 + 10764 = 21528.$

2) Separation by places:

$ab = ax_1 10^n + ax_2 10^{n-1} + \ldots + ax_{n-1} 10^1 + ax_n 10^0$,

where $b = x_1 10^n + x_2 10^{n-1} + \ldots + x_{n-1} 10^1 + x_n 10^0$.

A.

Ex. $135 \times 12 = 135 \times 10 + 135 \times 2 = 1350 + 270 = 1620.$

B.

Ex. $1196 \times 18 = 1000 \times 18 + 100 \times 18 + 90 \times 18 + 6 \times 18$

$= 18000 + 1800 + 1620 + 108 = 21528.$

Expression in the ms.:

1 8	1 8 0 0 0	
1 0 0 0		
1 8	1 8 0 0	
1 0 0		⇒ 21528
1 8	1 6 2 0	
9 0		
1 8	1 0 8	
6		

3) Separation by decreasing and increasing:

A. According to Śambhunātha, the rule given is:

$ab = a(b \pm k) \mp ak.$

Ex. 1. $997 \times 25 = (1000 - 3) \times 25 = 25000 - 75 = 24925.$

Ex. 2. $293 \times 50 = (290 + 3) \times 50 = 14500 + 150 = 14650.$

B. According to Śambhudāsa, the rule given is:

$ab = (ak)(b/k).$

Ex. $18 \times 1196 = (18 \times 2) \times (1196/2) = 36 \times 598 = 21528.$

Cf. BSS 12.55-56; Tr 7; PG 20; GSS 2.1; GT, p.5; L 14-15; GS 1.29; GK Prakīrṇaka 14-15; GM 16.

X 9. Multiplication by zero and unity

[A number], multiplied by zero, is zero. One should employ zero in front. [A number], multiplied by unity, is the same. This will be so indeed everywhere. Three rules are prescribed here.

1) $a.0 = 0$.
2) Write down zero in front.
3) $a.\ 1 = a$.

A. Śambhunātha differentiates $a.0 = 0$ and $0.a = 0$ in the first rule, and says that "it is the same" in the case of unity (the third rule) as well, but does not refer to the second rule. His reading of the second quarter of the verse itself is quite ambiguous: "One should employ (what?) in the way (?) of zero" (*śūnyamārge niyojayet*).

B. According to Śambhudāsa, the second rule is meant for filling empty places in multiplication. See Exs. for (X5) and (X 6) above.

For zero, cf. BSS 18.32-35; Tr 8 = PG 21; GP 17; GSS 1.49; MS 15.10-11; SS 14.6; GT 45; L 45-46; BG 16-20; BGA 1.11-15; GS 1.31; GK Prakīṇaka 30; GM 46.

X 10. Division

Having put down the divisor below the question (i.e., the dividend), and divided the question by the divisor, the division should be made (lit. part should be taken away) in order. [Thus] the rule for division has been certainly handed down [to us].

This gives the well-known method, which places the divisor (*hara*) under the dividend, which (the latter) is called "the [number in] question" (*praśna*) in our text.

A.

Ex. $1620 \div 12 = 135$.

		1		1 3		1 3 5
1 6 2 0	⇒	4 2 0	⇒	6 0	⇒	0
1 2		1 2		1 2		1 2

The last step and the first line of the second and the third steps are not given in the ms.

B. After having given an auxiliary rule (B 9U), Śambhudāsa assigns ten examples, which all require division of a certain amount of money (the denomination is always the *dramma*).

Ex. 1. 488/4 = 122.
Ex. 2. 327/3 = 109.
Ex. 3. 4096/16 = 256.
Ex. 4. 11664/108 = 108.
Ex. 5. 30276/87 = 348.

Ex. 6. 156025/395 = 395.
Ex. 7. 1466521/1211 = 1211.
Ex. 8. 19345600/1808 = 10700.
Ex. 9. 10000003/13 = 769231.
Ex. 10. 100001/11 = 9091.

Śambhudāsa only gives the first "setting" (*nyāsa*) and the quotient. Thus, 4 8 8 and 122, for the first example.

Cf. Tr 9; PG 22; GP 11; GSS 2.18-19; MS 15.4; SS 13.3; GT, p.6; L 18; GS 1.33; GK Prakīrṇaka 16; GM 19.

B 9U. Zero for a quotient

[When] there is no division, the quotient is zero.
This rule is no doubt meant for filling empty places in the line of the quotients obtained at each step, but it has been rarely stipulated.

X 11. Square and cube

In the case of the product of two equal quantities, there is a square only. In the case of the product of three equal terms, there will be certainly a cube.

$a^2 = a.a.$ $a^3 = a.a.a.$

A.
Exs. $2^2 = 4$, $3^2 = 9$, ..., $9^2 = 81$, $1^2 = 1$.
$3^3 = (3.3).3 = 9.3 = 27$, $1^3 = 1$, $2^3 = 8$, $4^3 = 64$, ..., $9^3 = 729$.
B.
Exs. $1^2 = 1$, $2^2 = 4$, ..., $5^2 = 25$, $15^2 = 225$, $25^2 = 625$, $235^2 = 55225$.
$1^3 = 1$, $2^3 = 8$, ..., $5^3 = 125$, $15^3 = 3375$, $25^3 = 15625$.

Cf. Abh 2.3; BSS 12.62; Tr 11,15; PG 24,28; GP 11; GSS 2.29,43; MS 15.6; SS 13.4; GT 21,26; L 19,24; GS 1.35,41; GK Prakīrṇaka 17,21; GM 23,27.

X 12-13. Square-root

Having subtracted a square from the [highest] odd [place], one should divide the next [place] by twice [the square-root], put the quotient into the line [of the results], and subtract its square from the next. Having doubled [the square-root] as before, and slid that [divisor to the next place], one should divide the next. This [procedure] should be done at the succeeding [places] also. One should have what has been doubled.

This gives the well-known algorithm. No example in A.

B.

Ex. $\sqrt{1} = 1, \sqrt{4} = 2, \sqrt{9} = 3, \sqrt{16} = 4, \sqrt{25} = 5, \sqrt{225} = 15, \sqrt{625} = 25, \sqrt{55225} = 235$ (without working process).

The working process for the last example may be reconstructed as follows.

o e o e o	(o = odd, e = even)	5 5 2 2 5
5 5 2 2 5		
1 5 2 2 5	$(5 - 2^2 = 1)$	
2		
1 5 2 2 5		
4	$(2.2 = 4)$	
3 2 2 5	$(15 - 4.3 = 3)$	
4 3		
2 3 2 5	$(32 - 3^2 = 23)$	
4 3		
2 3 2 5		
4 6	$(3.2 = 6)$	
2 3 2 5		
4 6	(slide)	
2 5	$(232 - 46.5 = 2)$	
4 6 5		
0	$(25 - 5^2 = 0)$	
4 6 5		
0		
4 7 0	$(5.2 = 10)$	
0		
2 3 5	$(470/2 = 235)$	

Cf. Abh 2.4; Tr 12-13; PG 25-26; GP 12; GSS 2.36; MS 15.6-7; SS 13.5; GT 23; L 22; GS 1.37-38; GK Prakīrṇaka 19-20; GM 25.

X 14. Multiplication and division of fractions

A. Śambhunātha's recension is as follows.

A 15. The product of the numerators, divided by the product of the denominators, is the result in the case of multiplications of fractions. In the case of division, having turned the numerator and the denominator [of the divisor] upside down, [one should obtain] the result just as in the case of multiplications.

$$\frac{b}{a} \cdot \frac{d}{c} = \frac{bd}{ac} .$$

$$\frac{b}{a} \div \frac{d}{c} = \frac{b}{a} \cdot \frac{c}{d} = \frac{bc}{ad} .$$

Ex. 1. $\frac{10}{4} \cdot \frac{10}{4} = \frac{100}{16} = 6\frac{1}{4}$.

Ex. 2. $6\frac{1}{4} \div \frac{10}{4} = \frac{25}{4} \cdot \frac{4}{10} = \frac{100}{40} = 2\frac{1}{2}$.

Ex. 2 is identical with Tr Ex. 10ab.

Cf. BSS 12.3-4, 60; BM Q3, Q4; Tr 20; PG 33; GP 16; GSS 3.2,8; MS 15.15; SS 13.9-10; GT 35-36 (pp.19-21); L 39, 41; GS 1.53,55; GK Prakīrṇaka 28-29; GM 43.

B. The rule in Śambhudāsa's recension is considerably different. It is meant for the multiplication of those numbers which consist of an integer part of a certain measure and its fractional part.

B 13. The integer should be correctly multiplied by the [other] integer, and both fractional parts [produced] from division also correctly by it. Those fractional parts are [multiplied] mutually. One should obtain the result produced from fractions [in this way].
This rule may be expressed thus:

$$(a;b).\ (c;d) = ac + (0;ad) + (0;bc) + (0;0,\ bd),$$

where a and c are integer portions, and b and d are fractional portions, of a certain measure.
Ex. 1. Area of a rectangular field. 10 gajas 12 aṅgulas by 1 gaja 8 aṅgulas, where 24 *jyeṣṭha* (largest) aṅgulas = 1 gaja.

$$10;12.1;8 = 10.1 + 10.0;8 + 1.0;12 + 0;12.0;8$$
$$= 10 + 3;8 + 0;12 + 0;4 = 14 \text{ sq. gajas.}$$

Ex.2. Area of a rectangular field. 25 gajas 14 visās by 16 gajas 10 visās, where 20 visās = 1 gaja.

$$25;14.16;10 = 400 + 0;224 + 0;250 + 0;0,\ 140$$
$$= 400 + 11;4 + 12;10 + 0;7 = 424;1 \text{ sq. gajas.}$$

X 15. Rule of three (trairāśika) and inverse rule of three

A. Śambhunātha's recension can be translated thus:
A 16. The product of the middle and the last [terms] is first [made, and then] divided by the first in the rule of three. In the inverse [rule of three], the product of the middle and the first, divided by the last, will be the result [to be obtained].

When $a_1 : b = a_2 : x$,

$x = ba_2/a_1$ (Rule of three).

When $a_1 : a_2 = x : b$

$x = a_1\, b/a_2$ (Inverse rule of three).

In both cases, the three terms are arranged thus: (a_1, b, a_2), where a_1 and a_2 must be measured by the same unit.

Rule of three.

Ex. 1. One *sera* of ghee (*ghṛta*) is obtained for eight *dokaḍās*. How much is obtained for twenty *dokaḍās?*

(8,1,20) = 20/8 = 2 1/2 *seras*.

Inverse rule of three.

According to Śambhunātha, the inverse rule of three can be applied to the following relationships.

Age: price of living creatures.
Purity: weight of gold.
Shadow: time from a gnomon.
Size: times for filling/emptying measuring cups.

Ex.2. A *baladī* of six *dharas* costs twenty *korīs*. How much does that of ten *dharas* cost?

(6,20,10) = 120/10 = 12 korīs.

Ex.3. A female slave *(dāsī)* who is twenty years old costs a hundred *korīs*. How much is one twelve years old?

(20,100,12) = 2000/12 = 166 2/3 korīs.

According to Gaṇeśa of Nandigrāma (on L 79), a girl sixteen years old is the most expensive, which contradicts the present example. Cf. Tr Ex. 56; PG Ex. 50; GT 109; al-Bīrūnī's India, I, p. 313.

Ex.4. One makes eleven *tolas* of pure gold (where complete purity is sixteen sixteenths) into a piece of gold whose purity is thirteen. What is the weight of the mixture?

(16,11,13) = 176/13 = 13 7/13 tolas.

Cf. Abh 2.26-27; BSS 12.10-11; BM C10, N19,Q11; Tr 29-30; PG 43-44; GP 24; GSS 5,2; MS 15.24-25; SS 13.14; GT 86; L 73; GS 1.63,81; GK Prakīrṇaka 60-61; GM 88.

B. In Śambhudāsa's recension, the three terms, a_1, b, and a_2, are called, in this order, "the last", "th middle", and "the first". This order of naming is the reverse of the usual one, but the right-to-left order itself is popular in the decimal place-value system. Thus, for example, the "2" and the "4" of the number 234 are designated "the last" and "the first" digits respectively.

B 14. The product of the middle and the first is first [made, and then] divided by the last in the rule of three. In the inverse case, the product of the middle and the last, divided by the first, will be the result [to be obtained].

Rule of three.

Ex. 1. Five *maṇas* of rice are obtained for twenty-one *drammas*. How much do ninety *maṇas* of the same cost?

(5,21,90) = 378 drammas.

Ex. 2. Six *maṇas* of *mudga* beans are obtained for twenty-three *drammas*. How much of the same thing is obtained for eighty-one *drammas*?

(23,6,81) = 21 3/23 maṇas = 21 maṇas 5 5/23 seras.

Inverse rule of three.

Ex. 3. A woman *(kamārī)* eighty years old costs forty *taṅkas*. How much does a woman sixteen years old cost?

(80,40,16) = 200 ṭaṅkas.

Ex. 4. A certain pearl is obtained for twenty-five *drammas* of one hundred *caḍatu ṭaṅkas*. For how many *drammas* of sixty *caḍatu ṭaṅkas* is the same pearl obtained?

(100,25,60) = 41 2/3 drammas = 41 drammas 2 jathalas.

X 16. Investments (prakṣepa)

A. Śambhunātha's recension is:

A 17. By the profit produced from various investments, they (i.e., the investments) are multiplied [severally], and divided by their sum. [The result] will be the shares of each [investor].

When a_i is the investment of the i-th investor ($i = 1,2,\ldots, n$), M, the profit obtained from the investments, then the share of the i-th investor is:

$$pi = \frac{a_i . M}{A}, \text{ where } A = a_1 + a_2 + \ldots + a_n.$$

Ex. Three persons invested severally fifty-one, sixty-eight, and eighty-five *korīs*, and obtained three hundred *korīs* in total. How much is the share of each?

Investments (a_i): 51, 68, 85 korīs.
Profit (M): 300 korīs.
$A = 51 + 68 + 85 = 204.$

$$\frac{51.300}{204} = \frac{15300}{204} = 75 \text{ korīs.}$$

$$\frac{68.300}{204} = \frac{20400}{204} = 100 \text{ korīs.}$$

$$\frac{85.300}{204} = \frac{25500}{204} = 125 \text{ korīs.}$$

B. Śambhudāsa's recension is:

B 15. The product of various investments and the profit is [made] severally. From its division by the sum [of the investments will be] two quotients. The result will be that [share] of each [investor].

According to Śambhudāsa, the rule prescribes two kinds of procedures.

$$p_i = \frac{a_i M}{A}, \quad \text{and} \quad p_i = \frac{M}{A} a_i.$$

But it is difficult (if not impossible) to see the latter formula in his wording of the verse.

Ex. 1. Seeds.
Investments *(a_i)*: 2, 3, 4, 5 seīs.
Profit *(M)*: 210 seīs.
Method 1. $A = 2 + 3 + 4 + 5 = 14$ seīs.
$a_i M$: 420, 630, 840, 1050.
p_i: 30, 45, 60, 75 seīs.
Method 2. $A = 2 + 3 + 4 + 5 = 14$ seīs.
$M/A = 210/14 = 15$.
p_i: 30, 45, 60, 75 seīs.

This example is identical with *Triśatikā* Ex. 67, although the latter uses *prastha* instead of *seī*.
Ex. 2. Money.

Investments *(a_i)*: 100, 500, 1000 ṭaṅkas.
Profit *(M)*: 200 ṭaṅkas.

Method 1. $A = 100 + 500 + 1000 = 16000$ ṭaṅkas.
$a_i M$: 20000, 100000, 200000.
p_i: 12 1/2, 62 1/2, 125 ṭaṅkas.

Method 2. $A = 100 + 500 + 1000 = 16000$ ṭaṅkas.
M/A = 200/1600 ṭaṅkas/ṭaṅkas
= 200.48/1600 jayasthalas/ṭaṅkas.
= 6 jayasthalas/ṭaṅkas.
p_i: 600, 3000, 6000 jayasthalas, or
12 1/2, 62 1/2, 125 ṭaṅkas.
(48 jayasthalas = 1 ṭaṅka.)

This example is identical with *Triśatikā* Ex. 68-69, although the latter does not specify the denomination.

Cf. BSS 12.16; BM N1; Tr 38; PG 59; GSS 6.79; MS 15.36; SS 13.19; L 94; GS 3.7; GK Miśraka 1; GM 111.

X 17. Mixture of gold (miśraka)

A. Śambhunātha's recension reads:
A 18. One should divide the sum of the products of the colours (i.e., the purities)

and [the weights of] the gold [pieces] by the sum of [the weights of] the gold [pieces]. The colour [of the mixture] should be known in the numerical figure obtained. When [the first sum is] divided by [the weight of] the gold [obtained], the colour [of the purified gold is obtained].

When v_i and w_i are, respectively, the purity (*varṇa*) and the weight (*suvarṇa*) of the i-th piece of gold ($i = 1,2,...n$), then the purity of the mixture of them is:

$$V = \frac{v_1w_1 + v_2w_2 + \ldots + v_nw_n,}{W}, \text{ where } W < w_1 + w_2 + \ldots + w_n.$$

$$V = \frac{v_1w_1 + v_2w_2 + \ldots + v_nw_n,}{W}, \text{ where } W < w_1 + w_2 + \ldots + w_n.$$

Śambhunātha's example (see below) suggests that the second formula is meant for the case where the weight (*W*) of the mixture decreases due to purification (otherwise the rule is superfluous), but this condition is not stated in the verse.

Ex. Purity (v_i): 13, 12, 11, 10 varṇas.

Weight (w_i): 10, 4, 2, 4 māsas.

$$V = \frac{13.10 + 12.4 + 11.2 + 10.4}{10+4+2+4} = \frac{240}{20} = 12 \text{ varṇas.}$$

When the mixture has lost its weight by purification, and becomes 16 *māṣas*,

$$V = \frac{240}{16} = 15 \text{ varṇas.}$$

B. Śambhudāsa's recension lacks words for the "products" (v_iw_i) and the "sum" (*W*), which are indispensable for the rule.

B 16. The sum of [the products of] various colours and [the weights of] the gold [pieces] is divided by [the sum of the weights of] the gold [pieces]. The colour [of the mixture] should be known in the numerical figure obtained. When [the first sum is] divided by the colour [of the mixture], the weight [of the mixture is obtained.]

Here the second rule is:

$$W = \frac{v_1w_1 + v_2w_2 + \ldots + v_nw_n}{V}.$$

This rule is useful only for the case of purification (otherwise the weight of the mixture is simply the sum of the weights of the gold pieces given), but Śambhudāsa applies it to the case of a simple mixture in his example.

Ex. Purity (v_i): 12, 14 varṇas.

Weight (W_i): 8, 4 gadīyāṇas.

$$V = \frac{12.8 + 14.4}{8 + 4} = \frac{152}{12} = 12\frac{2}{3} \text{ varṇṇas.}$$

$$W = \frac{152}{12\ 2/3} \simeq \frac{152}{13} = 11\frac{9}{13} \text{ gadīyāṇas.}$$

The decrease of weight, 4/13 *gadīyāna,* is due, of course, to the approximation of the denominator, 12 2/3, by 13, and not to the purification of the gold.

Cf. BM 27-29; Tr 36-37; PG 52-53; GSS 6.169, 172; MS 15.38-39; L 103; GS 3.15, 18; GK Miśraka 18; GM 138.

X 18. Areas of a square, an oblong, and a trapezoid.

In the case of a quadrilateral, equal-[sided] (square) or oblong, the product of the side and the upright is the area. Half of the sum of the base and the face, multiplied by the perpendicular, is the area in the case of an odd [quadrilateral] (i.e., a trapezoid).

$A = ab,$

where *a and b* are, respectively, the side and the upright of a square (*sama-caturasra)* or an oblong (*dīrgha-caturasra).*

$$A = \frac{a + b}{2} \cdot h,$$

where *a,b,* and *h* are the mouth or face (*mukha),* the earth (*vasudhā),* and the perpendicular (*lamba*) of a trapezoid (*viṣama-caturasra,* lit. an irregular quadrilateral).

A.

Ex. 1. A Square. $a = b = 4$. $A = 16$.
Ex. 2. An oblong. $a = 8$, $b = 3$. $A = 24$.
Ex. 3. A trapezoid. $a = 8$, $b = 20$, $(c = 5, d = 6,)$ $h = 4$. $A = 56$.

The unit of measurement is not explicitly given in most of Śambhunātha's geometrical examples, but it is probably the *aṅgula* unless otherwise indicated. See under (X 20). Ex. 1 is identical with Tr Ex. 75ab.

B.

Ex. 1. A square. $a = b = 4$ gajas. $A = 16$ sq. gajas.
Ex. 2. A square. $a = b = 4$ 1/2 gajas. $A = 20$ 1/4 sq. gajas.
Ex. 3. An oblong. $a = 4$, $b = 2$ gajas. $A = 8$ sq. gajas.
Ex. 4. An oblong. $a = 4$ 1/2, $b = 2$ 1/2 gajas. $A = 11$ 1/4 sq. gajas.
Ex. 5. A trapezoid. $a = 4$, $b = 14$, $(c = d = 13,)$ $h = 12$ gajas.
$A = 108$ sq. gajas.

Ex. 1 is identical with Tr Ex. 75ab, and Ex. 5 with Tr Ex. 78.

Cf. Abh 2.8; Tr 42; PG 115; GSS 7.50; MS 15.78; SS 13.30; L 173; GS 3.35,39; GK Kṣetra 34,45; GM 231, 240.

X 19. Areas of a triangle and a circle

Half of the base, multiplied by the perpendicular, is the area of a triangular field. The product of a quarter of the diameter and of the circumference is [the area] of a circle.

$$A = \frac{a}{2}.h \text{ (X 19ab)},$$

where a and h are, respectively, the earth *(vasudhā)* or the base and the perpendicular *(lamba)* of a triangle *(trikoṇaka)*.

$$A = \frac{d}{4}.c \text{ (X 19cd)},$$

where c and d are, respectively, the circumference *(vṛtti)* and the diameter *(vyāsa)* of a circle *(vartula)*.

The reconstructed ancestor (X 20 and 23) and Śambhudāsa (B 18U), and most probably the original *Pañcaviṃśatikā* as well, employ 19/6 for π, while Śambhunātha uses $\sqrt{10}$ (A 22 and 24) in addition to 19/6 (A 21 and 23). Ṭhakkura Pherū also uses both $\sqrt{10}$ and 19/6 side by side (GS 3.43 and 45). It is likely that the fraction, 19/6, was obtained from $\sqrt{10}$ by means of the well-known approximation formula:
$\sqrt{a^2 + r} \simeq a + r/2a$.

A.

Ex. 1. An isosceles triangle. $a = 6$, $(b = c = 5,)$ $h = 4$. $A = 12$.

Ex. 2. A circle. $d = 7$.

c. [$= (19/6).7 = 22\ 1/6$] $\simeq 22$, $A = (7/4).22 = 38\ 1/2$.

Here Śambhunātha does not give the computation of the circumference *(c)*, which has been reconstructed according to (A 21). It is difficult to tell why Śambhunātha did not choose 6, instead of 7, for the diameter *(d)*, just as Śambhudāsa did (see below). He uses the same diameter in (A 21, 22, and 23). The diameter and the circumference, 7 and 22, suggest that he simply borrowed the present example from a book which employed the famous approximation to π, 22/7; this value was known to Bhāskara II and Āryabhaṭa II, and perhaps to Śrīdhara as well.

B.

Ex. 1. An isosceles triangle. $a = 14$, $(b = c = 13)$, $h = 12$ gajas.
$A = 60$ sq. gajas.

Ex. 2 A circle. $d = 6$ gajas.

$c = 19$ gajas (according to (B 18U), $A = 28\ 1/2$ sq. gajas.

For (X 19ab), cf. L 166; GS 3.39; GK Kṣetra 39; GM 219. For (X 19cd), cf. Abh 2.7; GSS 7.60; L 201; GS 3.43,45; GK Kṣetra 9.

A 21. Circumference and area of a circle

The diameter, multiplied by three and increased by one sixth of the diameter, is the circumference [of a circle]. One should multiply mutually half of the diameter and half of the circumference. [The result is the area of the circle.]

$$c = 3d + \frac{d}{6} \left[= \frac{19}{6} d \right] \quad \text{(A 21ab)}.$$

$$A = \frac{d}{2} \cdot \frac{c}{2} \text{(A 21cd)}.$$

Ex. $d = 7$. $c = 3.7 + 7/6 = 22\ 1/6 \simeq 22$.
$A = (7/2).\ (22/2) = 38\ 1/2$.
(A 21) = AP 47.22 = GS 3.45 in contents.
AP 47.22:

vyāse triguṇe paridhiḥ ṣaṣṭhabhāgavimiśite/
vyāsārdhaṃ ca paridhyardhaṃ guṇe vṛttaphalaṃ bhavet//

GS 3.45:

vaṭṭassa ya vikkhaṃbhaṃ tiuṇaṃ taha chaṭṭhamaṃsajuya parihī/
vikkhaṃbhaddhe guṇiyā parihi dalaṃ tassa khittiphalaṃ//

Cf. GS Uddeśapañcaka 22:

vaṭṭassa ya vikkhaṃbhaṃ tiuṇaṃ taha chaṭṭhamaṃsajuya parihī/
sā pāya vitthare guṇi jaṃ jāyaī taṃ ji khittaphalaṃ//

Cf. also (B 18U) below. For (A 21cd), see (X 19) above.

A 22. Area of a circle

When the square of the diameter is decreased by one fifth [of itself], [the result is] roughly the area. The square of the square of half the diameter is multiplied by ten. From its square-root the area [of the circle is obtained].

$$A = d^2 - \frac{d^2}{5} \left[= \frac{16}{5} \cdot \frac{d^2}{4} \right] \quad \text{(A 22ab)}.$$

$$A = \sqrt{10}\,(d/2)^4 \left[= \sqrt{10} \cdot \frac{d^2}{4} \right] \quad \text{(A 22cd)}.$$

Ex. A circle. $d = 7$.
Method 1. $d^2 = 49$, $d^2/5 = 9\ 4/5 \simeq 9\ 3/4$,
$A = 49 - (9\ 3/4) = 39\ 1/4$.

Method 2. $A^2 = 10\ (7/2)\ 4 = 24010/16 = 1500\ 5/8 \simeq 1500.$

A rule (A 22U) is quoted here in order to compute the square root of 1500.

$1500 = 38^2 + 56,$

$$\frac{60\ (56 + 1)}{2.38 + 2} = \frac{3420}{78} = 43\ \frac{11}{13} \simeq 44.$$

$A \simeq \sqrt{\ } 1500 \simeq 38 + 44/60 \simeq 38\ 3/4.$

For (A 22cd), cf. BSS 12.40; GSS 6.60; Tr 45; MS 15.88; SS 13.35.

A 22U. Approximation to the square-root

The remainder of the square-root is increased by unity, multiplied by sixty, increased by the fractional portion (*vikalās*), and divided by twice the square root plus two. The quotient will be accurate [approximation to the fractional portion of the square root].

This rule is meant for the case where the fractional portion of the number in question *(n)* is expressed in the sexagesimal system, say,

$$n = k + \frac{v}{60}\ (k \text{ and } v \text{ are positive integers, and } 0 \leqq v < 60).$$

Let a be the nearest square root in integers,

$$k = a^2 + r, \text{ or } n = a^2 + r + \frac{v}{60},$$

then the rule may be expressed thus:

$$\text{The fractional portion of } \sqrt{n} \simeq \frac{60\ (r + 1) + v}{2a + 2}.$$

Or,

$$\sqrt{n} \simeq a + \frac{60\ (r+1) + v}{2a + 2} \cdot \frac{1}{60}\ \left[= a + \frac{r + v/60 + 1}{2\ (a + 1)} \right].$$

Cf. BSS 12.64-65; BM Q2. Cf. also Tr 46, PG 118, MS 15.55, SS 13.36, L 140, and GK Kṣetra 30-31, which all prescribe approximation formulas of the type:

$$\sqrt{n} = \frac{\sqrt{np^2}}{p},$$

where $\sqrt{np^2}$ is obtained by means of the algorithm based on the place-value system. Cf. (X 12-13) above.

A 23. Area of a circle

The square of the diameter, when decreased by one fifth [of itself], is known to be the area. Or, otherwise, to the square quantity of the diameter, decreased by its quarter, one should add one eighteenth of itself. [The result] is known to be the area.

$$A = d^2 - \frac{d^2}{5} \quad [= \frac{16}{5} \cdot \frac{d^2}{4}] \qquad \text{(A 23ab).}$$

$$A = d^2 - \frac{d^2}{4} + (d^2 - \frac{d^2}{4}) \cdot \frac{1}{18} \left[= \frac{19}{6} \cdot \frac{d^2}{4} \right] \qquad \text{(A 23 cdef).}$$

Ex. A circle. $d = 7$.
Method 1. See under (A 22) above.
Method 2. $d^2 - d^2/4 = 49 - (12\ 1/4) = 36\ 3/4$,
$A = 36\ 3/4 + (36\ 3/4)/18 = 36\ 3/4 + 4 + 2\ 1/24 \simeq 38\ 3/4$.

Verse (A 23ab) is identical with (A 22ab) above. (A 23cdef) is identical with AP 47.24 in contents, and AP 47.24 gives another formula equivalent to it.

AP 47.24:

vyāse vargasya guṇite[a] caturthāṃśaṃ tu pātayet/
śeṣe ' ṣṭādaśake bhāge kṣipte vṛttaphalaṃ bhavet//
[a]Read vyāse vargīkṛte tasya.

AP 47.25:

vyāsavargahastaikonapañcāṅgulāni[a] pātayet/
śeṣaṃ yal labhyate tac ca vṛttasyāpi phalaṃ bhavet//
[a]Read — hastaikaśaḥ pañcāṅgulāni.

$$A = d^2 - \frac{5}{24} d^2 \left[= \frac{19}{6} \cdot \frac{d^2}{4} \right].$$

A 24. Area of a segment of a circle.

Half of the sum of the cord and the arrow is multiplied by the arrow. The product of its square and ten is divided by nine. Its square-root is regarded as the area of the bow and arrow (i.e., the segment of a circle).

$$A = \sqrt{10[h(a+h)/2]^2/9} \left[= \sqrt{10} \cdot \frac{h\,(a\ +\ h)}{6} \right].$$

where *a* and *h* are, respectively, the cord (*jyā*) and the arrow (*śara*/*bāṇa*) of a segment of a circle.

Ex. A segment of a circle. $a = 6$, $h = 1$
$A^2 = 10[1.(6+1)/2]/9 = 490/36 = 13\ 11/18 \simeq 13$.
$A = \sqrt{13}$.

Śambhunātha expresses the square-root of 13 as "315", where the vertical stroke (I) means a quarter of the unit of length, which is not specified here as elsewhere, and the "5" is the number of its sub-unit. If the conversion ratio is k, then "315" means "3 units and $(k/4+5)$ sub-units".

If we apply the above rule for root approximation (A 22U), we obtain, $\sqrt{13} \simeq 3+5/8$. From the equation,

$$\frac{k}{4}+5=\frac{5}{8}k,$$

we obtain: $k=40/3=13\ 1/3$. This is, however, impossible not only because k must be an integer but also because the expression "315" in the manuscript implies that $k/4>5$, or $k>20$. Hence we have to admit either that a different method was used for the root-approximation, or that the expression "315" has been corrupted, or both.

For the same formula, cf. Tr 47; MS 15.89; GS 3.46, See also (X 20) below.

B 18U. Circumference of a circle

Three times the diameter, increased by one sixth [of a diameter], is the circumference [of a circle].

$$c=3d+\frac{d}{6}\left[=\frac{19}{6}d\right].$$

This formula is employed in Śambhudāsa's Ex.2 for (X 19) =(B 18).

Cf. (A 21) above.

B 19. Heron's formula for a trilateral and a quadrilateral.

Half of the sum of [all] the sides is [put down] four times, and [severally] decreased by the sides. The square-root of their product will surely be the area of a trilateral or of a four-faced [figure] (i.e., a quadrilateral).

$$A=\sqrt{(s-a)(s-b)(s-c)(s-d)},$$

where a, b, c, and d are the sides of a quadrilateral ($d=0$ in the case of a trilateral), and $s=a+b+c+d$.

Ex.1 (=Ex.5 for (X 18)). $s=22$, $A=108$ sq. gajas.

Ex.2 (=Ex.1 for (X 19)). $s=18$, $A=60$ sq. gajas.

Cf. BSS 12.21; Tr 43; PG 117; GSS 7.50; MS 15.69; SS 13.28; L 169; GK Kṣetra 33-34; GM 224.

X 20. Area of a segment of a circle, and that of "a rim" and of any other irregular figure

The product of the arrow and half the sum of the cord and the arrow is increased by one eighteenth [of itself]. In the case of a rim-like figure and an irregular [figure], the product of the breadth and the length is the area.

$A = h(a+h)/2 + h(a+h)/2.1/18$ [$= 19/6.\ h(a+h)/6$] (X 20 ab).
where a and h are, respectively, the cord (*jyā*) and the arrow (*śara/iṣu*) of a segment of a circle.

$A = ab$ (X 20cd),
where a and b are, respectively, the breadth (*vyāsa*) and the length (*dīrgha*) of 'a rim' (*nemyākṛti*), i.e., an annulus, or of any irregular (*viṣama*) figure.
A. Śambhunātha refers to the relationship,

A sq. angulas $= A/576$ sq. hastas,

where 24 angulas = 1 hasta. He gives no examples. Cf. (A 24) above for a segment of a circle.
B.
Ex.1. A segment of a circle. $a = 14$, $h = 4$ gajas. $A = 38$ sq. gajas.
Ex.2. A rim. $a = 3$, $b = 5$ gajas. $A = 15$ sq. gajas. This is identical with the later half of *Triśatikā* Ex. 82.

Śambhudāsa gives here five examples of irregular figures, which are all mentioned in the *Triśatikā* (under 44 and 48), and some of them are identical in both works. Irregular figures are dealt with also in GSS 7.7-38 and GK 4.13-14.
Ex.3. A drum-like figure (*murajakṣetra*), which consists of one oblong and two segments of a circle. $a = 10$, $b = 2$, $h = 3$ gajas. $A = 61\ 1/6$ sq. gajas = 61;4 sq. gajas.

Ex.4. A barley-corn (*yava*)-like figure, which consists of two segments of a circle. $a = 10$, $h = 4$ gajas. $A = 59\ 1/9$ sq. gajas = 59;2,16 sq. gajas.

Ex.3. A diamond (*vijra*)-like figure, which consists of two trapezoids.
$a = 3$, $b = 5$, $h = 4$ gajas. $A = 32$ sq. gajas.

This is identical with *Triśatikā* Ex. 84

Ex.4. A half-moon (*ardhacandra*)-like figure, which consists of two triangles. $a = 3$, $h = 8$ gajas. $A = 24$ sq. gajas.
This is identical with *Triśatikā* Ex. 83, where the figure is called "the young moon" (*bālendu*).

Ex.5. A pentagon (*pañcabhujakṣetra*), which consists of an oblong and a triangle upon it. $a = 4$, $b = 2$, $h = 3$ gajas. $A = 14$ sq.gajas.

For formulas similar to (X 20 ab), cf. GP 25; MS 15.93-94; Gaṇeśa on L 213. See also (A 24) above. For (X 20cd), cf. Abh 2.9.

X 21. Volume of a rectangular solid

Of a ditch, a timber, a stone, a storehouse, or a pile [of bricks], the volume is the product of the breadth and the length, multiplied by the thickness, if it is even (i.e., a smooth rectangular solid).

$V = abc$,
where a, b and c are the breadth (*vyāsa*), the length (*dīrgha*), and the thickness (*piṇḍa*) of a rectangular solid such as a ditch, a timber, a stone, or a storehouse.
A. Śambhunātha gives no examples.

B.

Ex.1. $a=4$, $b=5$, $c=3$ gajas, $V=60$ cub. gajas.
Ex.2. $a=4$ gajas 5 visās, $b=5$ gajas 10 visās, $c=3$ gajas 8 visās.
$V=$ 79; 9,10 cub. gajas.

Cf. BSS 12.44; Tr 53; GP 29; GSS 8.4; MS 15.104-105; SS 13.43; L 214; GS 3.55; GK Khāta 2.

B 21U. Arithmetical mean of different lengths.

If it is irregular (distorted), the sum of the different lengths is divided by it (i.e. the number of the places measured).
When the rectangular solid to be measured has distorted surfaces, then the mean length is first obtained by:

$$\bar{a}=\frac{a_1+a_2+\ldots+a_n}{n},$$

where a_i is measured at n different places of the solid lying in the same direction.

Ex. $a=6$, $b=10$, $c_1=2$, $c_2=3$, $c_3=4$ gajas. $\bar{c}=(2+3+4)/3=3$ gajas, $V=180$ cub. gajas.

Cf. BSS 12.44; Tr 52; GSS 8.4,9-10; MS 15.105; SS 13.43; L 214; GS 3.54; GK Khāta 1.

X 22. Volume of a cylinder

Of a timber, a stone, a pillar, or a well, the volume is the same. In that case, the area of the circular field [of its base] multiplied by its thickness (i.e., height), is the volume.

$$V=Ah,$$

where A and h are, respectively, the area of the circular base (*vṛttaphala*) and the thickness (*piṇḍa*) of a pillar (*stambha*).
A. Śambhunātha gives no examples.
B.
Ex. $d=3$, $h=20$ gajas, $c=9\frac{1}{2}$ gajas, $A=7\frac{1}{8}$ sq. gajas $=7;3$ sq. gajas, $V=142\frac{1}{2}$ cub. gajas.

Cf. Tr 57; L 214; AP 47.26; GS 3.60.

X 23. Volumes of a sphere and a cone-like heap of grain

Half the cube of the diameter of a sphere is increased by one eighteenth [of itself]. [The result is the volume of the sphere.] The square of one sixth of the circumference, multiplied by the height, is the volume (of a cone-like pile of grain].

$$V=\frac{d^3}{2}+\frac{d^3}{2}\cdot\frac{1}{18}\left[=\frac{19}{6}\cdot\frac{d^3}{6}\right] \qquad \text{(X 23ab)}.$$

where d is the diameter (*vyāsa*) of a sphere.

$$V = (\frac{c}{6})^2 \cdot h \qquad \text{(X 23 cd)}$$

where c and h are, respectively, the circumference (*vṛtta*) of the circular base and the height (*udaya*) of a cone-like heap of grain.

A. Śambhunātha mistakenly regards the latter half of the verse as giving another rule for the volume of a sphere, and replaces in his commentary "the height" (*udaya*) by "the diameter" (*vyāsa*). (Cf. GS. 3.65 and Uddeśapañcaka 25, where Pherū too employs the word *udaya* for the diameter of a sphere.) According to him, therefore, the second rule is:

$$V = (\frac{c}{6})^2 \cdot d \; [\; = (\frac{\pi}{6})^2 d^3] \qquad \text{(X 23cd)},$$

where d and c are, respectively, the diameter and the circumference of a great circle of a sphere. He then refers to Bhāskara II's formula ("Līlāvatī māhiṃ tehano ekavīsamo bhāga joḍavyoṃ cheṃ"):

$$V = \frac{d^3}{2} + \frac{d^3}{2} \cdot \frac{1}{21} \; [\; = \frac{22}{7} \cdot \frac{d^3}{6} \;] \qquad \text{(Līlāvatī 201)}$$

B.

Ex.1. A sphere. d = 3 gajas. V = 14 ¼ cub. gajas.
Ex.2. Grain. c = 18, h = 2 gajas. V = 18 cub. gajas.

When the grain is piled up against a wall, $V' = V - V/2$ = 9 cub. gajas.
Against the inside of a corner, $V' = V - 3V/4 =$ 4 ½ cub. gajas.
Against the outside of a corner, $V' = V - V/4 =$ 13 ½ cub. gajas.
Incidentally, Śambhudāsa refers to the weights of two kinds of grains:
1 cub. gaja of *godhūma* weighs 16 maṇas.
1 cub. gaja of *āricārī* weighs 15 maṇas.

For the same formula as (X 23ab), cf. Tr 56; MS 15.108; SS 13.46. For other formulas for the volume of a sphere, cf. Abh 2.7; Bhāskara I on Abh 2.7; GSS 8.28; L 201; GS 3.65, Uddeśapañcaka 25; GK 4a (khāta).6. For (X 23cd), cf. BSS 12.50; Tr 61-62; GP 30; MS 15.115; SS 13.50; GK Rāśi 10. See also (A 29-31) below.

A 29-31. *Grain heaped up on the ground*

The depth will be one eleventh [of the circumference of the base] if [the grain is] fine, one tenth if coarse, and one ninth if bearded. One sixth of the circumference, squared and multiplied by the depth, will be the quantity [of the grain] in cubic *hastas*. The [partial] circumference at the middle, inside, or outside is multiplied by two, four, or one and a third [severally]. The volume [obtained according to the above rule], divided by its own divisor according to whether [the mound of grain is piled] against the middle of a wall, or the inside or outside of a [rectangular] corner, is the [corrected] volume, which is regarded as being in cubic *karas* (i.e., *hastas*).

$$V = (\frac{c}{6})^2 \cdot h \qquad \text{(cub. hastas)}.$$

The height is calculated from the circumference of its base thus:

$$h = c/a,$$

where a is 11, or 10, or 9, according to whether the grain is fine (*aṇu*), or coarse (*anaṇu*), or bearded (*śūkin*). According to Śambhunātha, fine grains are *cīṇo*, *kāṃga*, *bājaro*, and *nāgalī*; coarse grains are *gahūṃ* (?), *jūāri*, *maga*, and *amaḍa*; and bearded grains are *caṇyā*, *colā*, and *lāṃgi*.

Cf. BSS 12.50; SS 13.51; L 227; GS 3.96-97. See also (X 23) above.

If a mound of grain is piled up against the flat side of a wall, or against the inside or outside of a rectangular corner, then the circumference of the complemented base is calculated by:

$$c = \beta c',$$

where c' is the circumference by actual measurement, and β is 2, or 4, or 4/3, as the case may be. To this value (c) is applied the above rule, and the volume (V) of the complemented cone is obtained. Then, the correct volume is obtained by:

$$V' = V/\beta.$$

Śambhunātha gives no examples.

Cf. BSS 12.51; Tr 64; MS 15.117; SS 13.52; L 229; GS 3.98-100; GK Rāśi 11.

A 32. *Work for sawing a timber with a triangular or trapezoidal section*

Half of the product of the side and the upright is regarded as the area of a triangular field. Half of the sum of the thickness at the foot and top, multiplied by the length, is the area produced on the timber.

This rule gives the areas of triangular and trapezoidal sections of timbers cut by a saw.

$$A = \frac{ab}{2} \qquad \text{for the triangular section (A 32 ab)},$$

where a and b are, respectively, the side (*bāhu*) and the upright (*koṭi*) of a rectangular triangle.

$$A = \frac{a + b}{2} \cdot h$$ for the trapezoidal section (A 32cd),

where a and b are the thicknesses (*piṇḍa*) or the timber measured respectively at its foot (*mūla*) and top (*agra*), and h its length. Here also Śambhunātha refers to the relationship, A sq. aṅgulas $= A/576$ sq. hastas. He gives no examples.

For (A 32cd), cf. Tr 59-60; GP 29; MS 15.112; SS 13.48; L 223; GK Krakaca 8. For the sawing of timbers, see also BSS 12.48-49; GSS 8.63-67; GS 3.87-95.

X 24. *Telling time from a shadow*

The shadow is increased by seven. One should subtract the noon-shadow from it. Half the length of daylight, multiplied by seven and divided by it (i.e.,the result obtained above), is [the time] in *ghaṭikā*, etc.

When d is the length of daylight (*dina*) on a certain day, s_n the length of the noon-shadow (*madhyacchāyā*), and s the length of the shadow at any optional moment of the day, then the time (in *nāḍīs* or *ghaṭikās*), elapsed from sunrise if in the forenoon or remaining until sunset if in the afternoon, is obtained by:

$$t = \frac{7 \cdot (d/2)}{s + 7 - s_n}$$ ghatikās (nāḍīs in B).

60 ghaṭikās = 60 nāḍīs = 1 day. This is a function of three variables (s, s_n, d), and it belongs to one of the two types of approximation formulas used in ancient and medieval India. *Yavanajātaka* 79.32 and *Pañcasiddhāntikā* 4.48, for example, give the formula:

$$t = \frac{12(d/2)}{s - s_n + 12}$$ nādīs.

Cf. GSS 9.15.

These two formulas can be expressed by a single formula.

$$t \frac{g(d/2)}{s - s_n + g},$$

where g is the height of the gnomon, which is usually taken to be 12 *aṅgulas* (fingers) in India. A gnomon of 7 units has not been attested yet in any other Sanskrit works, but a gnomon of "7 feet" is known to have been used in a Syriac work written in A.D. 1279, in which a gnomon of "12 fingers" is also mentioned [Neugebauer 1975, 744].

A formula of the other type has been given by Brahmagupta (BSS 12.52):

$$t = \frac{d/2}{s/g + 1},$$

which is equivalent to the former type when $s_n = 0$.

Cf. Tr 65; GP 30; GSS 9.8; GK Chāyā 12. Cf. also [Davidian 1960], [Pingree 1970, 121-122], and [Stone 1982].

A. Śambhunātha does not refer to the method for obtaining the length of daylight (d); he simply gives the maximum and the minimum values:

max. = 33;34 ghaṭikās,

min. = 27;34 ghaṭikās.

This combination is impossible since the sum of the maximum and the minimum should equal 60 *ghaṭikās*. As for the noon-shadow (s_n), he prescribes a curious method.

The longest noon-shadow = max. daylight − min. daylight
= 33;34 − 27;34 = 6.

The next value = 6 − 6/6 = 5.

The rest is unknown since he stops here.

If, following Śambhunātha, we assume the difference between the max. and the min. to be 6, then we have:

max. = 33 ghaṭikās,

min. = 27 ghaṭikās,

since their sum is 60. This ratio, 33;27, corresponds to the geographical latitude, $\phi \simeq$ 21;28 degrees.

He also gives a versified table of twelve noon-shadows (A 1°), which are gross (*sthūla*) according to him.

B. Śambhudāsa's recension does not indicate explicitly that the result of the computation, $s + 7 - s_n$, is the divisor of the division prescribed. He gives one verse each for the length of daylight (B 25) and the noon-shadow (B 26).

Ex. On the day of the spring equinox. When does the gnomon-shadow reach eleven [units]?

Given: $s = 11$.

Solution: d = 30 ghaṭīs, from (B 25).
s_n = 3, from (B 26).

$$t = \frac{7 \cdot (30/2)}{11 + 7 - 3} = 7 \text{ ghaṭīs.}$$

Therefore, it is 7 ghaṭīs after sunrise, or before sunset.

A 1°. Length of the noon-shadow.

The [length of the] noon-shadow is: two, one, zero, ("a shadow" in ms.), one,[one and a half], two and a half, four less a quarter, five, six, five, five less a quarter, and three and a half.

The ms. being corrupted, this is only a tentative translation based on the text restored with the help of the table in the ms., which is also corrupted:

s_n = 2, 1, 0, 1, 2½, 2½, 3¼, 5, 6, 5, 4¼, 3½.

When compared with Śambhudāsa's a table of noon-shadows (B 26), these values show the following peculiarities, provided that the entry is assumed, as usual, to be the beginning of each zodiacal sign.

1) The integer values, 7 in number, form a linear zig-zag function (dotted lines in Fig.1), but it has been slid to the left by one zodiacal sign for some reason unknown to us.

2) The fractional values, 5 in number, deviate from that linear function. The deviations, as they stand now, are not consistent, but, intentionally or not, every fraction has become closer to Śambhudāsa's corresponding value.

B 25. Length of daylight

The [number of] days [elapsed] from the first point of Capricorn, multiplied by three, increased by zero-three-five-one, and divided by sixty. The quotient is [the length of daylight] in *kalā*. From Cancer [is obtained the length of] the night in the same way.

When n is the number of days elapsed from the beginning of Capricorn (*markarādi*) or from the beginning of Cancer (*karkādi*), then the length of the day or of the night, respectively, on that day is calculated by:

$$d = \frac{3n + 1530}{60} \qquad \text{(kalās)}$$

1 kalā = 1 nāḍī = 1 ghaṭikā. This formula yields 34;30 and 25;30 *ghaṭikās* respectively as the lengths of the longest and the shortest days. This ratio, 34;30:25;30 = 23:17, corresponds to the geographical latitude, ϕ=30;24 degrees. Compare this with the latitude of Ahmedabad, ϕ = 23;03 degrees, where Śambhudāsa wrote this commentary.

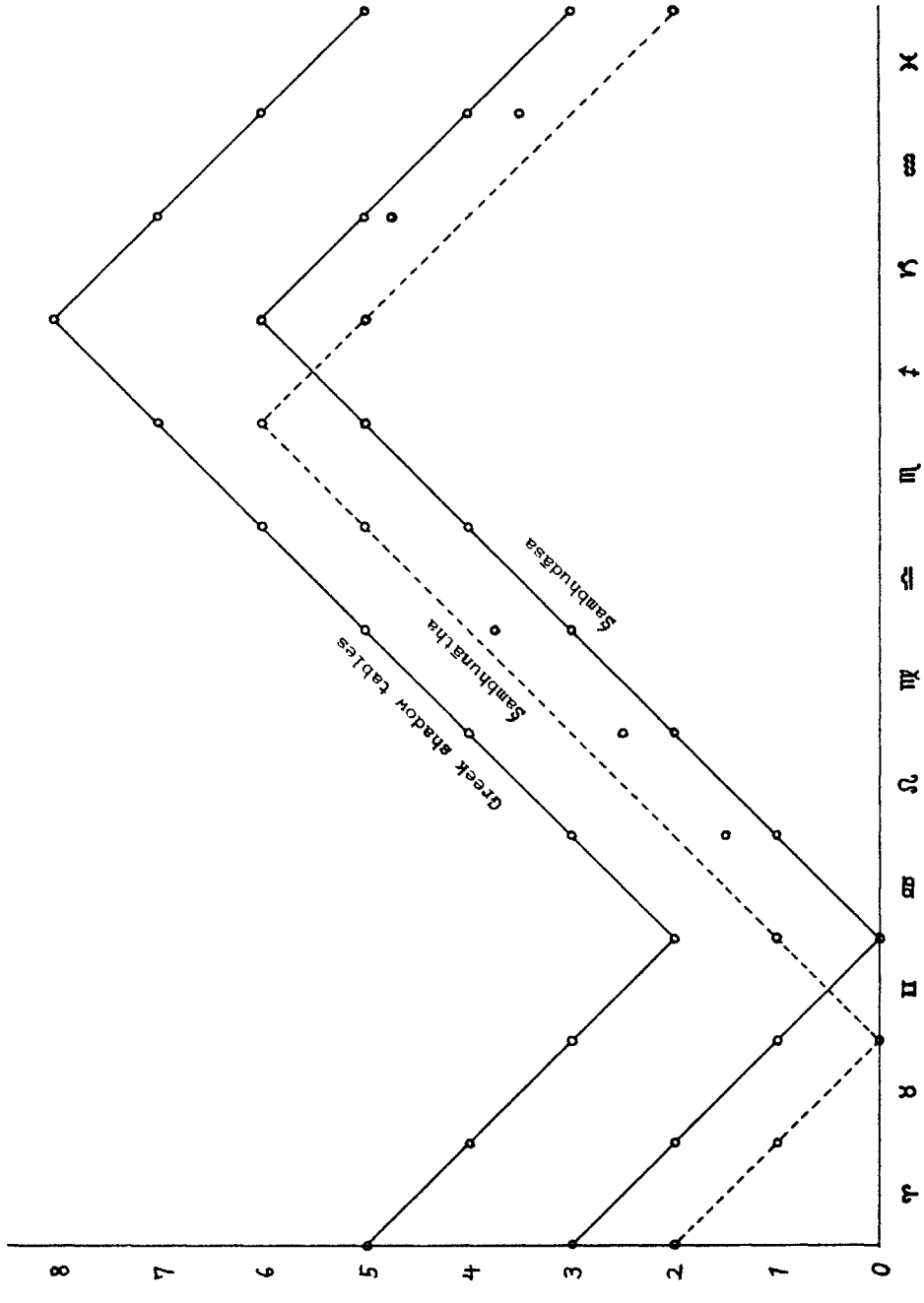


Fig. 1. Noon-shadow

B 26. Length of the noon-shadow

The noon-shadows have been declared in order to be three, two, one, zero, one, two, three, four, five, six, five, and four, from the [time of the sun's] entrance into Aries.

This verse enumerates 12 values of the noon-shadow (s_n) assigned for the day when the sun enters each zodiacal sign beginning with Aries (*meṣa*).

s_n = 3, 2, 1, 0, 1, 2, 3, 4, 5, 6, 5, 4.

These values are used in (X 24). They satisfy a linear zig-zag function of the ordinary type (see Fig. 1). The difference between the maximum and the minimum values, 6, is unusual in India, but it is common in "the Greek shadow tables" of Byzantine codices: in the basic pattern of those tables the max. and the min. lengths of the noon-shadows are 8 and 2 "feet" (or units) respectively [Neugebauer 1975, 738]. Cf. [Yano 1986, 22-26].

[X 25. Colophon of the *Pañcaviṃśatikā* (?)]

Colophon of A (in prose).

Thus is completed the *Gaṇitasāra* composed by Śrī Śambhunātha. [This manuscript was] written on the 13th day of the dark half of the month of Māgha in Saṃ 1786 by Caturavijaya at Śrī Bhujanagara for the sake of its recital. May there be prosperity, good fortune, and welfare. Thus, good fortune will be to both the scribe and the reader.

The date given here corresponds to February 15, Wednesday, (± 1 day), A.D.1730. Bhujanagara is probably modern Bhuje in Kaccha, about 300 km west of Ahmedabad.

B 27. Colophon of B (in verse and prose).

In the year of five-eight-four-one, at the city of Ahammadāvāda, the *Bālabodhāṅkavṛtti* was composed by Śambhudāsa.

(In prose) Thus is completed the *Bālabodhāṅkavṛtti* on the *Pañcaviṃśatikā*, composed by the wise (or the minister) Śambhudāsa.

The year 1485 given here is, as in the colophon of A. no doubt that of the Saṃvat era, and corresponds to A.D. 1428/29 .

APPENDICES

Notation:

A = Śambhunātha's commentary.

B = Śambhudāsa's commentary.

Appendix 1. Multiplication table

	In A 12 & 15	In B 17.
2 × 2 = 4:	dū dū cyāra.	—
3 × 3 = 9:	traṇa trī nava.	—
4 × 2 = 8:	cyāra dū āṭha.	cyāri dū āṭha.
4 × 4 = 16:	cyāra co kūṃ solaṃ.	cyāri cu kū sola.
9 × 3 = 27:	nava trī sattāvīsa.	—
10 × 10 = 100:	dāhe dohe so.	—

Appendix 2. Weights and measures

Weights

A.

tola for gold.
dhara(?) for baladī(?).
māṣa for gold.
sera for ghee.

B.

gadīyāṇa for gold and rūpa (silver?).
caḍatu for "100-caḍatu ṭaṅka" and "60-caḍatu ṭaṅka".
tola for gold.
maṇa for rice, mudga beans, godhūma, āricāri, mañjīṭha, dānta (ivory?), ṣāṇḍa, sūkadi, ācchī, paḍasūtra, seī for seeds.

According to Śambhudāsa (in B)

one cub. gaja of godhūma weighs 16 maṇas,
one cub, gaja of āricāri weighs 15 maṇas.

Money

A.

korī.
dokaḍā.
28 dokaḍās = 1 korī.

This korī is most probably a copper coin minted by Sultan Muzaffar Shah III (1562-72). See [Sircar 1968, 23].

B.

jathala (= jital).
jayasthala (= jital).
ṭaṅka.
dramma.
3 jathalas = 1 dramma(?)
48 jayasthalas = 1 ṭaṅka.

This ṭaṅka is a silver coin issued by Muḥammad bin Tughluq (1325-51), which is equivalent to 48 jitals. See [Sircar 1968, 20].

Length

A.

aṅgula.
hasta.
24 aṅgulas = 1 hasta.

B.

jyeṣṭha aṅgula.
gaja.
visā.
24 jyeṣṭha angulas = 1 gaja.
20 visās = 1 gaja.

Time

A.

ghaṭikā.

B.

kalā.

APPENDIX 3. PRICES

A.

One sera of ghee costs 8 dokaḍās.
A woman 16 years old costs 125 korīs.
One horse costs 235 korīs in one example, and 355 ½ korīs in another.
The investments of three persons are 51, 68, and 85 korīs.

B.

A woman of 16 years old costs 200 ṭaṅkas.
A certain pearl costs 25 drammas of 100-caḍatu ṭaṅka.
One gadīyāṇa of rūpa (silver?) costs 18 drammas.
One tola of gold costs 32 ṭaṅkas.
One maṇa of mañjīṭha costs 35 ṭaṅkas.
One maṇa of dānta (ivory?) costs 36 ṭaṅkas.
One maṇa of ṣāṇḍa costs 81 drammas.
One maṇa of sūkadi costs 64 ṭaṅkas.
One maṇa of ācchī costs 188 drammas.
One maṇa of paḍasūtra costs 308 ṭaṅkas.
The investments of three persons are 100, 500, and 1000 ṭaṅkas.

Abbreviations

Abh = *Āryabhaṭīya* of Āryabhaṭa I, ed by K. S. Shukla.
AP = *Aparājitapṛcchā* of Bhuvanadeva, ed by P.A. Mankad.
BG = *Bījagaṇita* of Bhāskara, ed by V.G. Āpaṭe.
BGA = *Bijaganitāvataṃsa* of Nārāyaṇa, ed by K.S. Shukla.
BM = *Bakhshālī Manuscript*, ed by T. Hayashi.
BSS = *Brāhmasphuṭasiddhānta* of Brahmagupta, ed by S. Dvivedin.
GK = *Gaṇitakaumudī* of Nārāyaṇa, ed by P. Dvivedin.
GM = *Gaṇitamañjarī* of Gaṇeśa, India Office Library, Eggeling 2881.
GP = *Gaṇitapañcaviṃśī* of Śrīdhara, ed by D. Pingree.
GS = *Gaṇitasāra* of Ṭhakkura Pherū, ed by Agaracanda and B. Nāhaṭā.
GSS = *Gaṇitasārasaṃgraha* of Mahāvīra, ed by M. Raṅgācārya (also ed by L. C. Jain)
GT = *Gaṇitatilaka* of Śrīpati, ed by H.R.Kāpadīa.
L = *Līlāvatī* of Bhāskara II, ed by V. G. Āpaṭe (also ed by K.V. Sarma).
MS = *Mahāsiddhānta* of Āryabhaṭa II, ed by S. Dvivedin.
PG = *Pāṭīgaṇita* of Śrīdhara, ed by K.S.Shukla.
SS = *Siddhāntaśekhara* of Śrīpati, ed by B.Misra.
Tr = *Triśatikā* of Śrīdhara, ed by S.Dvivedin.

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Rasa Ratna Samuccaya, Chapter X, with text, English translation and notes

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रसरत्नसमुच्चयः
अथ दशमोऽध्यायः

मूषा पर्यायाः –

मूषा हि क्रौञ्चिका प्रोक्ता कुमुदी करहाटिका।
पाचनी बन्हिमित्रा च रसवादिभिरीर्यते ॥ 1 ॥

मूषा निरुक्तिः –

मुष्णाति दोषान् मूषेयान् सा मूषेति निगद्यते ॥ 2 ॥

मूषोपादानद्रव्याणि –

उपादानं मवेत्तस्या मृत्तिका लोहमेव च ॥ 3 ॥

मूषा माहात्म्यम् –

मूषामुखविनिष्क्रान्ता वरमेकापि काकिणी।
दुर्जनप्रणिपातेन धिग्लक्षमपि मानिनाम् ॥ 4 ॥

मूषासन्धिलेपनपर्यायाः –

मूषापिधानयोर्मध्ये बन्धनं सन्धिलेपनम्।
अन्ध्रणं रन्ध्रणं चैव संश्लिष्टं सन्धिबन्धनम् ॥ 5 ॥

मूषायोग्या मृत्तिका –

मृत्तिका पाण्डुरस्थूला शर्करा शोणपाण्डुरा।
चिराध्मानसहा साहि मूषार्थमतिशस्यते ॥
तदभावे च वाल्कीमी कौलाली वा समीर्यते ॥ 6 ॥

साधारण मूषामृत्तिका –

या मृत्तिका दग्धतुषैः शणेन शिखित्रकैर्वा हयलद्दिना च।
लोहेन दण्डेन च कुहिता सा साधारणा स्यात्खलु मूषिकार्थे ॥ 7 ॥

मूषामृत्स्नायाः सहयोगिद्रव्याणि –

श्वेताश्मानस्तुषा दग्धाः शिखित्राः शणखर्परे।
लद्दिः किहं कृष्णमृत्स्ना संयोज्या मूषिका मृदि ॥ 8 ॥

वज्रमूषा –

मृदस्त्रिभागाः शणलद्दिभागो भागश्च निर्दग्धतुषोपलादेः ॥
किहार्धभागं परिखण्ड्य वज्रभूषां विदध्यात्खलु सत्वपाते ॥ 9 ॥

योगमूषा –

दग्धाङ्गारतुषोपेता मृत्स्ना वल्मीकमृत्तिका।
तत्तद्विडसमायुक्ता तत्तद्विडविलेपिता ॥ 10 ॥
तया या विहिता मूषा योगमूषेति कथ्यते।
अनया साधितः सूतो जायते गुणवत्तरः ॥ 11 ॥

वज्रद्रावणकोचिता मूषा –

गारभूनागधौताभ्यां शणैर्दग्धतुषैरपि।
समैः समा च मूषामृन्महिषीदुग्धमर्दिता ॥ 12 ॥
क्रौञ्चिका यन्त्रमात्रं हि बहुधा परिकीर्तिता।
तया विरचिता मूषा वज्रद्रावणकोचिता ॥ 13 ॥

गारमूषा –

दग्धषड्गुणगाराढ्या[1] किट्टाङ्गारशणान्विता।
कृष्णमृद्भिः कृता मूषा गारमूषेत्युदाहृता ॥ 14 ॥
यामयुग्ममपिध्माता नाऽसौद्रवति बह्निना ॥

वरमूषा –

वस्त्राङ्गारतुषास्तुल्यास्तच्चतुर्गुणमृत्तिका ॥ 15 ॥
गारश्च मृत्तिकातुल्यः सर्वैरेतैर्विनिर्मिता।
वरमूषेति निर्दिष्टा याममग्निं सहेत सा ॥ 16 ॥

वर्णमूषा –

पाषाणरहिता रक्ता रक्तवर्गाम्बुभाविता ॥
मृत्तया साधिता मूषा क्षितिखेचरलेपिता ॥ 17 ॥
वर्णमूषेति सा प्रोक्ता वर्णोत्कर्षे नियुज्यते।

रुप्यमूषा –

एवं हि श्वेतवर्गेण रुप्यमूषा प्रकीर्त्तिता ॥ 18 ॥

विडमूषा –

तत्तद्विडमृदोद्भूता तत्तद्विडविलेपिता।
देहलोहोपयोगार्थं विडमूषेत्युदाहृता ॥ 19 ॥

वज्रद्रावणमूषा –

गारभूनागधौताभ्यां तुषमृष्टशणेन च।
समैः समा च मूषामृन्महिषीदुग्धमर्दिता ॥ 20 ॥
क्रौञ्चिका यन्त्रमात्रा हि बहुधा परिकीर्त्तिता।
तया विरचिता मूषा लिप्ता मत्कुणशोणितैः ॥ 21 ॥
बालाब्धध्वनिमूलैश्च वज्रद्रावणक्रौञ्चिका।
सहतेऽग्निं चतुर्यामं द्रवेणापूरिता सती ॥ 22 ॥

वृन्ताकमूषा –

वृन्ताकाकारमूषायां नालं द्वादशकाङ्गुलम्।
धत्तूरपुष्पवच्चोर्ध्वं सुदृढं श्लिष्टपुष्पवत् ॥ 23 ॥
अष्टांगुलं च सच्छिद्रं सा स्याद् वृन्ताकमूषिका।
अनया खर्परादीनां मृदूनां सत्वमाहरेत् ॥ 24 ॥

गोस्तनीमूषा –

मूषा या गोस्तनाकारा शिखायुक्तपिधानका।
सत्वानां द्रावणे शुद्धौ मूषा सा गोस्तनी भवेत् ॥ 25 ॥

मल्लमूषा –

निर्दिष्टा मल्लमूषा या मल्लद्वितयसम्पुटात्।
पर्पट्यादि रसादीनां स्वेदनाय प्रकीर्त्तिता ॥ 26 ॥

पक्वमूषा –

कुलालभाण्डरुपा या दृढ़ा च परिपाचिता।
पक्वमूषेति सा प्रोक्ता पोट्टल्यादिविपाचने ॥ 27 ॥

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1. दुग्धे

गोलमूषा –

निर्वक्त्रगोलकाका पुटनद्रव्यगर्भिणी।
गोलमूषेति सा प्रोक्ता सत्वरं द्रवरोधिनी ॥ 28 ॥

महामूषा –

तले या कूर्पराकारा क्रमादुपरि विस्तृता।
स्थूलवृन्ताकवत्स्थूला महामूषेति सा स्मृता ॥ 29 ॥
सा चायोऽभ्रकसत्वादेः पुटाय द्रावणाय च ॥

मण्डूकमूषा –

मण्डूकाकारमूषा या निम्नतायामविस्तरा ॥ 30 ॥
षडंगुलप्रमाणेन मूषा मण्डूकसंज्ञिका ॥
भूमौ निखन्य तां मूषां दद्यात्पुटमथोपरि ॥ 31 ॥

मुसलमूषा –

मूषा या चिपिटा मूले वर्तुलाऽष्टांगुलोच्छ्या।
मूषा सा मुसलाख्या स्याच्चक्र बद्धरसे हिता ॥ 32 ॥

मूषाप्यायनम् –

द्रव्ये द्रवीभावमुखे मूषाया ध्मानयोगतः।
क्षणमुद्धरणं यत्तन्मूषाप्यायनमुच्यते ॥ 33 ॥

कोष्ठीप्रयोजनम् –

सत्वानां पातनार्थाय पातितानां विशुद्धये।
कोष्ठिका विविधाकारास्तासां लक्षणमुच्यते ॥ 34 ॥

अङ्गारकोष्ठी –

राजहस्तसमुत्सेधा तदर्धायामविस्तरा।
चतुरस्रा च कुड्येन वेष्टिता मृण्मयेन च ॥ 35 ॥
एकभित्तौ चरेद्द्वारं वितस्त्याभोगसम्मितम्[1] ॥
द्वारं चार्धवितस्त्या[2] च सम्मितं सुदृढं शुभम् ॥ 36 ॥
देहल्यधो विधातव्यं धमनाय यथोचितम्।
प्रादेशप्रमिता भित्तिरुत्तरंगस्य चोर्ध्वतः ॥ 37 ॥
द्वारं चोपरि कर्त्तव्यं प्रादेशप्रमितं खलु।
ततश्चेष्टिकया रुद्ध्वा द्वारसन्धिं विलिप्य च ॥ 38 ॥
शिखित्रैस्तां समापूर्य धमेद् भस्त्राद्वयेन च।
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RASA RATNA SAMUCCAYA

TENTH CHAPTER

ENGLISH TRANSLATION

Synonyms of 'Mūṣā' :

Experts of *Rasa-Śāstra* have mentioned the following synonyms of 'mūṣā' (crucible) such as — *Krouñcikā, Kumudī, Karahāṭikā, Pācanī* and *Vahnimitra*. (1).

Root Meaning of the Term 'Mūṣā':

That which removes/destroys all the removable *doṣas* (impurities) is known as *Mūṣā*. (2)

Main Constituents of 'Mūṣā':

Mṛttikā (soil) and *Loha* (iron and its compounds) are the main constituent source materials of *Mūṣā*. (3).

Importance of 'Mūṣā':

The persons of self-respect prefer even *Varāṭikā* (cowrie), a meager amount obtained through the use of the *Mūṣā* treatment rather than the lacs of rupees procured through total submission before the bad persons. (4).

Definition of 'Sandhi Bandhana':

The sealing at the joint of the *Mūṣā* (crucible) and *Pidhāna* (its cover), is known as *Sandhilepanam. Andhraṇa, Randhraṇa, Saṃśliṣṭa* and *Sandhibandhana* are its synonyms. (5).

Mūṣopayogi Mṛttikā:

The yellowish white & heavy soil, the granular & reddish white soil and that which can stand long heating is considered best for preparing *Mūṣā*. In the absence of such soil *Vālmikī* (hillock soil) and *Kaulālī, Mṛttikā* (pot-maker's soil) may also be used. (6).

Associates of 'Mūṣā' Soil:

The burnt husk, the jute pieces, the burnt charcoal and the horse excreta pounded together with the help of iron rod or wooden stick are ordinarily considered the associates of the *Mūṣā* soil. (7).

Other Associates:

White stones, burnt husk, burnt charcoal (oxidised charcoal), jute pieces, earthenware pieces, excreta of various animals, rusted iron and black soil may also be considered as the other associates of the *Mūṣā* soil. (8).

Vajra 'Mūṣā':

Three parts of soil, two parts of jute pieces and the excreta of animals, one part of husk ash and dung cake ash, and half part of rusted iron are to be pounded together and the mixture so prepared is used for making *Vajra Mūṣā*. It is useful for *Satvapātana* purpose. (9)

Yoga 'Mūṣā':

Burnt charcoal, mixed with husk, ordinary soil and hillock soil and associated with respective *Viḍas* is recommended for preparing *Yoga Mūṣā*. This (*Mūṣā*) when plastered with the respective *'Viḍa dravyas'* is called *Yoga Mūṣā*. Mercury treated in this *Mūṣā* becomes highly potentiated. (10-11).

Vajra Drāvaṇī Mūṣā:

Mix *Gāramṛt* (clay obtained either from the river or tank), washings of earthworms, jute pieces, and burnt husk in equal parts and the *Mūṣā* soil equal to all the above ingredients. These when mixed together and pounded with buffalo milk form the constituent material for this *Mūṣā*. It should always be prepared in such a shape and size which may suit the *yantra* in which it is to be used. *Mūṣā* so prepared is called *Vajra Drāvaṇī Mūṣā*. It is suitable for the liquefaction of diamonds. (12, 13).

Gāra Mūṣā:

Six parts of burnt *Gāramṛt* associated with rusted iron, burnt charcoal powder, jute pieces and black soil should be pounded well with milk and then be used to prepare a *Mūṣā*. *Mūṣā* so prepared is known as *Gāramūṣā*. It does not melt even if it is blown in strong heat for 6 hours, i.e. it can stand 6 hours' strong heating. (14).

Vara Mūṣā:

Cloth pieces, burnt charcoal, and burnt husk mixed in equal parts (i.e. one part each) and associated with four parts of ordinary soil and four parts of *Gāra soil* and ground well together are recommended to prepare *Vara Mūṣā*. It can resist 3 hours' heating. (15, 16).

Varṇa Mūṣā:

Red soil made free from stones and triturated with the extractives of *Rakta Varga* drugs is recommended for preparing *'Varṇa Mūṣā'*. *Mūṣā* so prepared and plastered

with alum and ferrous sulphate is known as *Varṇa Mūṣā*. It is used for improving the colour of the materials. (17).

'*Rūpya Mūṣā*':

In the same way when the *Śveta varga* drug's extractives are used with other materials for preparing *Mūṣā*. then that *Mūṣā* is called *Rūpya Mūṣā* (18).

'*Viḍa Mūṣā*':

When the *Mūṣā* is prepared with specific *Viḍas* and *Mṛt* (soil) and plastered with respective *Viḍadravyas* then that is known as *Viḍa Mūṣā*. It is meant for preparing the recipes capable of making the human body very strong like an iron or using the same for both *Deha* and *Loha karma*. (19).

Another 'Vajra Drāvaṇi Mūṣā':

Mix '*Gāramṛt*' (river/tank soil), washings of the earthworm dwellings, husk, and finely pasted jute pieces in equal parts and *Mūṣā* soil equal to all the above ingredients. These should be grounded with buffalo milk and be used to prepare the *Mūṣā* of the specific size to be used in a specific *yantra*. It is said to be of many types. *Mūṣā* so made should be annointed with the blood of bed-bugs and with the extracts of the roots of *Sugandhabālā, Nāgarmustā* and *Ākāśa balli*. It is known as *Vajra Drāvaṇi Mūṣā*. It can resist four *praharas* (12 hours) heating, even if it is filled with liquids. (20-22).

Vṛntāka Mūṣā:

Prepare a brinjal shaped *Mūṣā* with 12 *aṅgula* long tube fixed over it like an inverted *Dhattūra* flower. Make a hole at the height of 8 *aṅgula* in the tube. This is known as *Vṛntākamūṣā*. This is used for the extraction of *satvas* from the soft drugs like *Kharpara*, etc. (23 & 24).

Gostanī Mūṣā:

The shape of the *Gostanī Mūṣā* is like a cow's udder. It is attached with a cover having a long crest. This is meant for the *Śodhana* (purification) and *Drāvaṇa* (melting) of *Satvas* (metallic content of minerals). (25).

Malla-Mūṣā:

A pair of shallow earthenwares (*Śarāvas*) when joined together is known as *Mallamūṣā*. It is used to apply *swedana* (heat) to *parpaṭī*, etc 'Rasa Kalpas'. (26).

Pakva Mūṣā:

The crucible, shaped like a potmaker's pot and fired in a strong heat is called *Pakva Mūṣā*. It is used for applying *Pāka* (heat) to *poṭṭalī*, etc. preparations. (27).

Gola Mūṣā:

The spherical shape crucible having no opening and containing *Puṭana dravya* (material to be heated) is called *Gola Mūṣā*. It can restrain the liquified materials surely and perfectly. (28).

Mahā Mūṣā:

The *Mūṣā* shaped like an elbow at its base and becoming gradually wider and wider towards its upper end resembling a big brinjal in size and shape is called *Mahā Mūṣā*. It is used for doing *Puṭa pāka* (applying heat treatment) and *drāvaṇa* (melting) of *Loha* (metals) and *Abhraka satva*, etc. drugs. (29).

Maṇḍūka Mūṣā:

The crucible shaped like a frog and having the length, depth, and breadth of six *aṅgulas* is known as *Maṇḍūka Mūṣā*. This *Mūṣā* should be kept underground and a prescribed *Puṭa* is applied over it for heating. (30 & 31).

Muśala Mūṣā:

The *Mūṣā* having a flat base, cylindrical shape and eight *aṅgula* height is known as *Muśala Mūṣā*. It is useful for the preparation of *Cakrabaddha rasa*. (32).

Mūṣāpyāyana:

The take-off of the *Mūṣā* from the fire for a moment during blowing while its material is about to melt is known as *Mūṣāpyāyana*. (33).

Koṣṭhī Yaṅtra:

For the extraction of *Satvas* and for their *Śodhana* (purification), various types of *Koṣṭhis* (furnaces) are required and their description is as follows. (34).

Aṅgāra Koṣṭhī:

Prepare a quadrangular furnace having 22½" height and the length and breadth half of it. It should be covered with a wall made of soil. Make an opening of 1 *vitasti* (9") in one of the walls. Beneath this, make another opening of half *Vitasti* (4½") size, for blowing the air in the furnace. Cover its upper portion with one *Prādeśa* (4½") diameter wall leaving an opening of one *Prādeśa* (4½") size. Now close both the openings made in the wall of the furnace with bricks and seal their joints after fixing the blowers. Fill the furnace with charcoal and blowing should be done with two blowers. If required throw the charcoal and the substance to be blown through the upper opening. The balls prepared for *satva pātana* should be put in five numbers at a time. This is known as

aṅgāra koṣṭhī. It is used for extracting *satvas* from the *khara dravyas* (hard substances[1,2,3]. (35-40).

Patāla Koṣṭhī:

Verses 41-44 deal with *Patāla Koṣṭhī*.

Gāra Koṣṭhī:

Prepare a furnace of 12 *aṅgula* depth in one *prādeśa* (4½") diameter. Make a ring-like structure at the height of 4 *aṅgula* in the furnace. Place a circular earthen plate having many holes over the ring-like structure. Fill charcoal in it and blow it with *vaṅka nāla* (bent tube). This is described as *Gāra Koṣṭhī*. It is meant for separation/destroying of the associated metallic impurities from the *satvas*. (45-47).

Vaṅka Nāla:

Prepare a strong tube of an *Aratni* (about 16 *aṅgula*) size by the same soil as was used for preparing *mūṣā*. Attach another tube of five *aṅgula* size, transversely to the lower end of this tube facing downward. This is known as *vaṅka nāla*. It is described to be used for strong blowing. (48).

Siddharasa Koṣṭhī:

Furnace for preparing *siddha rasa* may be prepared as follows. It should have the height of 12 *aṅgulas* and the base of 4 *aṅgulas*. It should have an opening of 4 *aṅgulas* breadth at its base for transverse blowing. It is used for purifying *mṛdu dravyas*. (49 & 50).

Description of "Puṭas"

Definition:

That which indicates the quantum of heat required by the *Rasa* (mercury) and other drugs of mineral origin for their proper *pāka* (calcination/incineration) is known as *puṭa*, as neither more nor less heating is desirable. Further the medicines prepared by

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[1]In the original text, the size of the lower opening has been mentioned as of 1½ '*vitasti*', which seems to be incorrect, and the original text requires correction, i.e. in place of *Sārdha Vitasti* which seems to be incorrect, and the original text requires correction, i.e. in place of *Sārdha Vitasti* it should be *Caraha Vitastya*.

[2]The upper opening which is mentioned to be of one *vitasti* size has practically no purpose. Further it is advised to be closed with bricks and the joint should be sealed; hence it may be taken as an emergency exit.

[3]The covering wall, which is advised to be made on its upper portion should be one *prādeśa* (4½") size. Author also advises to make an opening of the same size on this portion. This is also not very clear. Hence, covering wall of the upper portion should be as thick as *Prādeśa Pramāna* and an opening of one *prādeśa* size may be made on its upper portion.

applying desired heating are only considered best, i.e. pharmaceutically suitable for use. (51).

Aims and Objectives of Puṭas:

By applying *Puṭas* (different heating schedules), *lohādi* drugs (metals) are made *Apunarbhava* (irreversible to their original metal form), to possess better properties than original, non-sinkable (floatable) in water and enterable into the furrows of the finger tips. Further the *puṭa* application also helps to make the heavier materials lighter, quickly absorbable into the system and stimulants to digestion and other body functions. The metals subjected to *puṭas* (various heating schedules) become more potentiated than *jārita* (specially treated) mercury. (52, 53).

Mode of Action of 'Puṭas':

As the external fire applied through the *puṭas* enters/penetrates deeper and deeper into the metals and minerals these are rendered into very fine particles/compounds and made associated with better and better qualities/properties proportionately. (54).

Mahapuṭa:

Prepare or dig a quadrangular pit of 36″ width and depth. Fill one thousand *upalas* (dung cakes) in it and place the *mūṣā/śarāva* on it containing material to be subjected to *puṭapāka*. Cover the same with remaining five hundred *upalas* (dung cakes). Ignite the fire in the *upalas* to apply heat. This is known as *Mahāpuṭa*. (55, 56).

Gajapuṭa:

Prepare or dig a quadrangular pit of 22½″ width and depth. Fill it with dung cakes up to the neck. Place the *mūṣā* (crucible) or *śarāva* filled with *puṭana* material over it and cover the same with remaining half quantity of *upalas*. Ignite it with fire. It is said as *Gajapuṭa*. It induces best qualities in the products. (57-59).

Varāha Puṭa:

When *puṭa* is applied in a quadrangular pit of an *Aratni* (about 16″) size pit then that is known as *Varāhapuṭa*. (60).

Kukkuṭa Puṭa:

When *puṭa* is applied over the earth in the dimension of 1 *vitasti*[1] (about 9″ in width and height) then the same is known as *kukkuṭa puṭa*. (61).

[1]According to the printed text the second part of the verse reads '*VITASTI DVITAYOCCHRAYAM*! This seems to be incorrect, as if we accept this then its size becomes bigger than that of '*Varāhaputa*', while in real sense it should be similar to *Kukkuṭa* (cock) which is always smaller than *Varāha* (pig). Therefore, it is suggested that the original text '*VITASTI DVITAYOCCHRAYAM*' should be corrected as in size, i.e. it should be one *Vitasti* (9 ″) in size, i.e. in length, breadth and depth. The description of '*Kukkuṭa puṭa*' in the contemporary texts also supports this view.

Kapota Puṭa:

The *puṭa* which is given over the earth with eight *vanyopalas* (forest dung cakes) is called *Kapota puṭa*. It is used for converting solidified or fixed mercury into ashes. (62).

Gorvaraputam:

Dried and powdered cow-dung by the repeated stampings of cows in cattleshed is known as *govara*. It is considered the best for *Rasasādhana* (mercurial processing). When *puṭa* is applied by using *govara* or 'tuṣa' then that is known as '*govara puṭa*'. It is useful for preparing *Rasabhasma*. (63, 64).

Bhāṇḍapuṭa:

When the heat is applied to the *mūṣā* through *tuṣāgni* in a strong and big earthen pot then that is known as *Bhāṇḍa puṭa*. (65).

Bālukā Puṭa:

In *Bāluka puṭa* heat is applied to the *mūṣā* through the hot sand covering the *mūṣā* from all sides. (66).

Bhūdhara Puṭa:

Fix the *mūṣā* (crucible) at the depth of 2 '*aṅgula*' under the earth and apply *puṭa* over it through cow-dung cakes. It is known as *Bhūdhara puṭa*. (67).

Lāvaka Puṭa:

When the *puṭa* is given over the earth using about one *Ṣoḍaśikā* (pala), i.e. about 50 g. *tuṣa* (husk) or *govara* (dung powder), then that is known as *Lāvaka puṭa*. It is meant for heating *mṛdu dravyas*. (68).

General Instructions:

Where the *puṭa māna* (quantum of heat) is not specified, one should decide the type of *puṭa* on basis of the nature and the tolerance power of the drug. It has been mentioned by experienced experts. (69, 70).

Synonyms of Upala:

Piṣṭaka, Chagaṇa, Chāṇa, Upala, Utpala, Giriṇḍa, Upala Sāṭhī and *Varāṭī* are the synonyms of *Chagaṇa*. (71).

Lohas (Metals):

Gold, Silver, Copper, Tin, Lead, and Iron are the six metals. Bell metal and Brass are the *Kṛtrima lohas* (alloy metals). (72).

Lavaṇas (Salts):

Salts are six, such as *Sāmudra, Saindhava, Biḍa, Sowvarcala, Romaka* and *Culikā Lavaṇa*. (73).

Three Kṣārās (Three Alkali materials):

Yava kṣārā, Sarjikā kṣāra and *Taṅkaṇa kṣāra* are known as three *kṣārās* (alkaline substances). (74).

Five Kṣārās (Five alkali-containing drugs):

Palāśa Kṣāra, Muṣkaka kṣāra, Yava kṣāra, Suvarcikā kṣāra and *Tila nālodbhava kṣāra* all together are known as *kṣārapañcaka*. (75).

Madhura Traya (Three sweet materials):

Ghṛta, Guḍa and *Mākṣika* are known as *Madhura Traya* (three sweet substances). (76).

Taila Varga (Group of oily drugs):

Kaṅguṇī, Tumbinī. Ghoṣā, Karīva, Srīphala (bilva), *Kaṭu Vṛntāka, Siddhārtha, Somarājikā, Vibhītaja, Atasīja, Mahākālī, Nimbaja, Tilaja, Apāmārga, Devadālī, Dantī, Tumburu, Aṅkola, Unmatta, Bhallāta* and *Palāśaja* from *Taila Varga*. The oil collected from these plants materials is used in *Rasa Karmas* (mercurial operations). (77-79).

Vasā Varga (Group of fatty animals):

The *Vasās* (fats) obtained from *Jambūka* (fox), *Maṇḍūka* (frog), *Kacchapa* (tortoise), *Karkaṭī* (crab), *Śiśumārī 'Go'* (cow), *Śūkara* (pig), *Nara* (human), *Ajā* (goat). *Uṣṭra* (camel), *Khara* (ass) and *Māhiṣa* (buffalo) are included in *Vasā Varga*. (80).

Mūtra Varga (Urine group):

The urines obtained from *Hasti* (elephant), *Karanbha* (camel), *Mahiṣī* (buffalo), *Khara* (donkey), *Vājī* (horse). *Go* (cow), *Aja* (goat) and *Strī* (women) are included in *Mūtra* varga and the 'menstrual secretion' of women and the 'Semen' of man are also recommended to be used in *Rasa Karmas*. (81).

Māhiṣa-pañcaka (Five materials of buffalo):

Buffalo's urine, curd, milk, ghee, and the dung juice are the five substances known as *Māhiṣa pañcaka*. In the same way all the above-mentioned five substances if obtained from the goat are known as *Cāgala pañcaka*. (82).

Amla Varga (Group of sour drugs):

Amlavetasa, Jambīra, Nimbū, Bījapūraka, Cāṅgerī, Caṇakāmla, Amlīka, Kola, Dāḍima, Aṁbaṣṭhā, Tintiḍīka, Nāraṅga, Rasa Patrikā, Karavenda, and also other substances are included in *Amla varga*. Only *Caṇakāmla* is considered best amongst all. Only *Amlavetasa* is further considered the best. These are good for the *Śodhana, Jāraṇa* and *Drāvaṇa* of *Rasa*, etc. mineral drugs. (83-86).

Amla Pañcaka (Group of five sour drugs):

Kola, Dāḍima, Vṛkṣāmla, Cullikā and *Cukrikā* are the five drugs of *Amla pañcaka* group. It is also known as *Pañcāmlaka*. (87).

Pañca Mṛttikā (Group of five soils):

Iṣṭikā (brick), *Gairika* (red-ochre), *Lavaṇa* (salt), *Bhasma* (ash), and *Valmīka Mṛttikā* (hillock soil) are known as *Pañca Mṛttikās* by the experts of *Rasa-Śāstra*. (88).

Viṣa Varga (Group of poisonous drugs):

Śṛṅgīka, Kālakūṭa, Vatsanābha, Kṛtrima and *pīta* are the five drugs of *Viṣa Varga*. This group is considered best for *Rasa Karma*. (89).

These are good for mercury processings and also for its solidification. If used without proper care these may kill the persons surely. (90).

Upa-Viṣa Varga (Group of subpoisonous drugs):

Lāṅgalī, Viṣa muṣṭi, Karavīra, Jayā, Nīlaka, Kanaka and *Arka* all together form *Upaviṣa Varga*. (91).

Dugdha Varga (Milk or latex group):

Hasti (elephant), *Aśva* (horse), *Vanitā* (woman), *Dhanu* (cow), *Gardbhī* (she ass), *Chāgikā* (goat), *Āvikā* (sheep), *Uṣṭrikā* (she camel), are the *Jaṅgama* sources of milk. *Uduṁbara, Aśvatha, Arka, Nyagrodha, Tilvaka, Dugdhikā, Snuhi-gaṇa, Uttama-Kanyakā* are the plant drugs from which latex can be obtained and used in *rasakarmas/rasa* preparations. (92 & 93).

Viḍ-Varga (Excreta group):

The fecal matter of *Pārāvata* (dove), *Cāṣa (Nīlakaṇṭha)*, *Kapota*, *Kalāpin* (peacock), *Gṛdhra* (eagle) and *Kukkuṭa* (cock) is included in *Viḍgaṇa*.

This is used to purify all the metals by *lepana* (pasting) and *Puṭana* (heating by *puṭa* system). (94).

Rakta Varga (Group of red drugs):

Kusumbha, *Khadira*, *Lākṣā*, *Mañjiṣṭhā*, *Rakta-candana*, *Akṣīva*, *Bandhu jiva*, *Karpūra-gandhinī* and *Mākṣika* all together form *Raktavarga*. It is considered as a powerful dyer. (95 & 96).

Pīta varga (Group of yellow coloured drugs):

Kimśuka, *Karṇikāra*, *Haridrā dvaya* (*Haridrā* and *Dāru haridrā*) all together form *Pītavarga* which is used in mercurial operations. (97).

Kṛṣṇa Varga (Group of black colouring drugs):

Kadalī, *Kāravallī*, *Triphalā*, *Nīlikā*, *Nala*, *Paṅka*, *Kāsīsa* and *Bālāmra* all together form *Kṛṣṇa varga*. (98).

Uses of 'Rakta', etc. groups:

Materials to be subjected for *Jāraṇa* to be macerated/ triturated with the juices of the above-mentioned groups of drugs for obtaining respective colours. (99).

Śodhanīya gaṇa (Group of purifiers):

Kāca, *Ṭaṅkaṇa* and *Śodhanīya* group. It is used for destroying impurities of *satvas*, solidified mercury and metals. Experts of *Rasa Śāstra* claim that these substances destroy impurities obtained by *Kāpālika* practices. (100).

Mṛdukara Varga (Softening drugs):

Kalinga, *Dhavabīja* are bones of rabbit together form *Lohākaṭhinya nāśaka gaṇa* (metal hardness destroying group), i.e. these can remove the hardness of the metals. (101).

Drāvaṇa Varga (Liquifying drugs):

Guḍa, *Guggulu*, *Guñjā*, *Ājya*, *Sāragha* (honey) and *Taṅkaṇa* form *Drāvaṇa varga* (liquifying group). It is meant to help in early melting of the metals which otherwise melt with difficulty. (102).

All the *Kṣāras* (alkalies) are used to destroy *malas* (impurities). *Amlas* (sour drugs) are used to do *Śodhaṇa* (purification) and *Jāraṇa* (calcination). *Viṣas*' (poisons) are used to destroy *mandatā* (sluggishness), while *Sneha dravyas* (fatty substances) are used to produce *Snigdhatā* (smoothness and softness). (103).

Māna Nirdeśa (Terms indicating weights): (104-107).

6	*'Truṭi'*	=	*1*	*'Likṣā'*
6	*'Likṣā'*	=	*1*	*'Yūkā'*
6	*'Yūkā'*	=	*1*	*'Rajas'*
6	*'Rajas'*	=	*1*	*'Sarṣapa', Siddhārtha'*
6	*'Siddhārtha'*	=	*1*	*'Yava'*
6	*'Yava'*	=	*1*	*'Guñjā'*
3	*'Guñjā'*	=	*1*	*'Valla'*
6	*'Guñjā*	=	*1*	*'Māṣa'*
12	*'Māṣa'*	=	*1*	*'Tolā'*
4	*'Tolā,*	=	*1*	*'Pala'*

Tenth Chapter on *Koṣṭhikas* ends.

NOTES ON THE TENTH CHAPTER

In 10th chapter of *Rasa Ratna Samuccaya Mūṣas, Puṭas, Koṣṭhies* and a few groups of mineral, herbal and animal origin drugs essentially required for mercury and other processes are described.

Though *Mūṣās* are also a type of apparatus required for different kinds of heating schedules, these are described separately, probably due to their very high importance in processing the mercury and other meneral/metallic drugs with heat treatment.

As the term *Mūṣā* indicates, these can destroy or remove various *doṣas* (impurities/unwanted materials) from various kinds of drugs through various types of heat treatments. As these have to remain in contact with heat (strong to mild) for quite a long time, these should be made with such materials/ingredients which can stand strong heating even for longer duration. In modern science, these are known as 'crucibles' and are described to be of many kinds.

In *Rasa Śāstra* processes, *Mūṣās* are highly essential for *Satvapātana* process, as for this process sometimes very high temperature is required and if suitable container or apparatus is not used then the chances of losing whole material are there. And probably this fact might have been realised by the ancient scholars and encouraged them to evolve many kinds of *Mūṣās*, their construction and constituent materials and also their lining or coating materials. In *Rasa Ratna Samuccaya* nearly half of the 10th chapter is devoted to describe *Mūṣās*. In all 17 types of *Mūṣās* are found described in this text along with its synonyms, definition based on root meaning, main constituent materials, suitable soils, associated materials and their importance.

Its synonyms are *Krouñcika, Kumudī, Karahātikā, Pācinī*, and *Bahnimitrā*. Of these some terms throw light on its shape and purposes and others on its specific property, i.e. it is friendly to fire. For construction/preparation of '*Mūṣā*' different kinds of soils, *Loha* (iron) and its *Kiṭṭa — Maṇḍūra* and a few other drugs are essential requirements.

Constituent materials of Mūṣā:

In soils, yellowish white and heavy soil and the granular reddish white soil is preferred and in absence of that hillock soil or pot-maker's soil (greyish sticky soil) may also be used. It should be associated with burnt husk, burnt charcoal, jute pieces, earthenware pieces, white stones, horse, and other animals excreta, rusted iron and black soil, pounded well and mixed together. These should be mixed in prescribed proportions and be used for preparing *Mūṣās*.

The *Mūṣās* are also found described in other *rasa* texts, but in all these texts only six more *Mūṣās* are found mentioned than '*Rasa Ratna Samuccaya*', viz., *Mañjūṣa mūṣā, Garbha mūṣā, Prakāśa mūṣā, Andha mūṣā, Dīrgha mūṣā* and *Bhasma mūṣā*. All the twenty three (23) *mūṣās* are found described in different *rasa* texts.

It is evident that besides *Rasa Ratna Samuccaya* almost similar number of *mūṣās* are found described in *Rasa Prakāśa Sudhākara* and *Rasendra Cūḍāmaṇi*. In other texts like *Rasārṇava, Rasa Ratnākara, Rasa Kāma Dhenu* and *Rasa Taranginī* only a few *mūṣās* are found described.

Parts of Mūṣās:

Mūṣās have mainly two parts, viz.

1. Body or basal part and

2. Cover/*Pidhānaka or* upper part.

In basal part drugs are kept while upper part is used to cover it from upside. It is called *Pidhānaka* also. In some cases *Mūṣā* and *Pidhānaka* are to be sealed at the joint to make these air-tight. This sealing of joint is known as *Sandhilepana* or *Randhraṇa*.

General uses of Mūṣā:

The *mūṣās* may be used for the following purposes.

Rasa Mūrcchana, Rasa Śodhana, Rasa Māraṇa, Rasa Bandhana, Rasa Jāraṇa, Rasa Sāraṇa, Rasa Rañjana, Drāvaṇa, Dvanda Melapana, Satvapātana, Vajra drāvaṇa, Bīja nirvāpaṇa, Varṇot Karṣakaraṇa, Pācana and *Poṭṭalī*, etc. *Kalpa Pācana*.

Various aspects of Mūṣā description:

On the basis of critical analysis of *mūṣā* description it may be said that the *mūṣā* description should cover the following aspects:

1. Constituent materials.
2. Shape and size.
3. Method of preparation
4. Purpose or uses and
5. Heat resistant capacity.

If we go through the description of *Mūṣās* we hardly find the description of all these aspects. If the descriptions of all the different texts are collected at one place even then all the aspects mentioned above could not be covered with regard to all the *Mūṣās*.

The ordinary *Mūṣā* now available in the market is generally made of graphite. Its shape is almost like a glass which is narrow at the end and broader towards upper end. But other forms indicating shape are also found described in the textual description, such as *Gostanākāra* (like an udder of cow) which is very narrow at the base and very wide at the upper end. The other form mentioned is like a *Bṛntāka* (brinjal — long or

round); in this case *mūṣā* must have a *Pidhānaka* (cover) also with a crust on its back. Another form is like a *Bhāṇḍa* which is wide at the base and narrow at the mouth. Still another form is like a 'round ball'. It may be either round or oval like an egg. The other terms indicating forms are *Kūrparākāra* like an 'elbo-joint', *Musalā-Kāra* like a cylinder and *Maṇḍūkākāra* like a 'frog' or box. Thus, seven terms indicating shape or form are found mentioned in the texts for *Mūṣās*.

As regards heat resistant capacity, it is found to vary from 1 *yāma* (3 hours) to 4 *yāma* (12 hours). *Vajra mūṣā* and *Vajradrāvanī mūṣā* have high heat resistant capacity, i.e. four *yāmas*. *Yoga mūṣā* stands second, i.e. two *yamas* and other *mūṣās* stand next in the series, i.e. one *yāma* only.

As regards the constituent materials, the high heat resistant *mūṣās* must contain *loha* or *loha kiṭṭa* (rusted iron) along with soil, jute, horse excreta, burnt husk, stones etc., as constituents. Further, the grinding of constituent materials with *Mahiṣīdugdha* (buffalo milk) is also recommended to help to make these more heat resistant. The *mūṣā* materials without having *Kiṭṭa* (iron rust) as their constituent are generally less heat resistant.

The lining, painting or coating materials:

In the case of some *mūṣās*, the painting, lining or coating of the *mūṣās* with some liquids is also recommended. The materials are *Kṣiti* (alum) liquid, *Khecara* (ferrous sulphate) liquid, *Viḍa* liquid, *Matkuṇa Śoṇita* (bed bugs blood) and *Balābdadhwani mūla rasa*.

Puṭas (heating schedules):

Besides *Mūṣās* different kinds of *Puṭas* (heating schedules) are also mentioned in this chapter which are necessary for applying different graded heatings to various drugs (mineral or metallic nature) required for their conversion into *bhasma* form.

In general sense, the term *Puṭa* means a mode or system of applying heat and also the quantum of heat necessary for the conversion of mineral or metal into *bhasma* (ashes) form. *Bhasma* form means a suitable dosage form or the form absorbable into the system. Thus, heating by '*Puṭa-system*' applying specific heat is known as *Puṭapāka* and this *(Puṭapāka)* forms a part of *Māraṇa process*. This further helps in the disintegration of the particles to a fine state of subdivision and to change the drug into some compound form as a result of the chemical reaction taking place during *Puṭapāka*.

From the point of view of source of heat, *Puṭa* may be of two types, viz. (1) *Agniputa*, and (2) *Śūryaputa*. A third type *Candraputa* is also mentioned by late Shri Jādavaji Ācārya, though it is not found mentioned in other texts, as in this type the *pāka* through heat does not take place. Of these, the *Puṭapāka* through *Agni* (fire) is more common and may be divided into following types, viz. *Mahāputa, Gajaputa,*

Varāhapuṭa, Kukkuṭa puṭa, Ardhagaja puṭa, Laghu puṭa, Kapota puṭa, and *Lāvaka puṭa*. Further, the *puṭas* may also be divided on the basis of the type of fuel and the apparatus used for '*Gorvara puṭa, Bhāṇḍa puṭa, Bhūdhara puṭa, Bālukāpuṭa*', etc.

Method of Puṭapāka:

For doing *Puṭapāka*, the drugs made into pellets must be closed in *Śparāva Saṁpuṭa* (between two shallow earthen lids) and sealed properly at the joint and dried. It is then placed in the middle of the furnace inside the fuel used for the purpose in such a way that the drug subjected to *Puṭapāka* may remain in contact with heat for a maximum period and utilise its heat fully to be converted into the desired compound.

Mode of action of Puṭāgni:

The *puṭāgni* applied externally enters into the drug slowly and steadily and as and when it enters it helps to convert the drugs into fine form and inducts the drug with the desired properties in proportion to the heat penetrated into the drug.

Aims and objectives of Puṭa application:

Puṭas are applied to change the shape, size, characteristics and forms of the drugs subjected for. Not only this, the products prepared by *Puṭapāka* are reduced to such a fine state of subdivision that these when put on water float on its surface, enter into the fine furrows of the fingers, acquire better therapeutic properties, become *niruttha* (non-convertible into original metal form) and *laghu* (light to digest). It is said further that these acquire the power to spread quickly after absorption, stimulate normal metabolic functions of the body tissues and remove/reduce or change their toxic properties and effects and thus make the products non-toxic/least toxic or harmless to the vital organs of the body.

Description of Puṭas:

Mahā puṭa: It is the biggest *puṭa* from the point of view of size, shape, fuel consumption and heat application through it. It is 2 *hasta* (about 36″) in depth and breadth. It needs 1500 '*Vanyopalas*' (forest cow dung cakes) as fuel. Of these, 1000 *upalas* are kept below the *Mūṣā* or *Saṁpuṭa* and fired.

Heating time and temp.: In this puṭa intense/strong heat (about 900-1000°C) is maintained for longer duration (1 hour-1½ hour) depending upon the quality of fuel, place and season.

Gaja puṭa: This is the second larger puṭa. It is '*Rājahasta*' (about 22½″) in depth and breadth. The quantity of fuel needed is 1000 '*Vanyopalas*' to be kept up and down of ***Mūṣā/Saṁpuṭa*** (two-third down and one-third up).

Heating time and temp.: In this *puṭa* also intense/strong heat (850°C-950°C) is maintained for long time (45 to 60 minutes approximately). Wherever strong heat for longer duration is required these *puṭas* may be applied.

Varāha puṭa: This is medium type *puṭa*. It is one *Aratni* (about 8") in depth and breadth. The quantity of fuel *(Vanyopalas)* is not specified here but may be used in the quantity sufficient for filling up the pit.

Heating time and temp.: In this *puṭa* strong heat is maintained for much less time, i.e.(800°C -850°C) for 20-30 minutes.

Ardha Gaja puṭa: Though it is not described in any texts, it is found indicated in many places. Its size should be cut to half of the *Gaja puṭa* size. Hence, its size is smaller to *Varāha puṭa* (i.e. its depth is 11¼" and breadth 22½").

Heating time and temp. : There may not be much differences in highest temp, but its maintenance and cooling time may be less.

Kukkuṭa puṭa: It may be included in the group of smaller *puṭas*, as its size is one *'vitāsti'* — 12 *'angulas'* (about 9"). In the original text of *Rasa Ratna Samuccaya*, its size is mentioned as two (2) *'Vitāsti'* (24 *angulas*/18"), but in other texts its size is mentioned as 16 *'angulas'* and 6 *'angulas'*. Hence, there are many opinions about the size of *'Kukkuṭa puṭa'* but one *'Vitāsti'* size and 10 *'Vanyopalas'* as fuel quantity may be considered as the most appropriate and correct. And if it is accepted, then only it may be claimed smaller to *'Varāha puṭa'* and bigger to *'Kapota puṭa'*.

Heating temp. and time — In this *puṭa* the maximum temp. may rise to 600°C-650°C and may be maintained for 10-15 minutes only and then slowly allowed to decline.

On the basis of the textual indications and the size and the fuel quantity, it may be used to apply heat to *Mṛdu dravyas* like Gold, Silver, etc.

Kapota puṭa : No specific size has been mentioned for this *puṭa*. It is given on the ground/earth using 8 *Vanyopalas* as fuel. It is the smallest *puṭa* where *Vanyopalas* are used as fuel. It is recommended for preparing *Rasa bhasma* or *Rasa bandha.*

Heating temp. and time — In this *puṭa* the temp. may not go above 400°C-500°C and that too for a very short period. As it is given in an open atmosphere, the above-mentioned temp. may not last more than 5-10 minutes and may start falling due to the effect of open atmosphere and may cool down completely within 2-3 hours.

Lāvaka puṭa: In this *puṭa Vanyopalas* are not used as fuel and instead of that *Tuṣa* (husk) or *Govara* powder is advised as fuel, which may not give higher temp., i.e. more than 200°C; it may range between 100°C and 200°C for 20 to 30 minutes. The quantity of husk is also mentioned as one *pala,* which may not last more than 15-20 minutes.

Govara puṭa is also similar to *Lāvaka puṭa* and may give very little heat for very less period. Both may be used for preparing *Rasa bhasma*.

Bhāṇḍa pūṭa: Here also, *Tuṣa* is advised to be used as fuel, but the quantity of *Tuṣa* is more here, i.e.sufficient to fill a big size *bhāṇḍa* (pot). In this *puṭa*, *Putāna dravya* is placed inside the husk filled in the *bhāṇḍa* and then *Tuṣa* is fired. Hence, slow heat is given for longer period.

Bālukā puṭa: For this, *bhāṇḍa* is filled with *bālukā* (sand). *Putāna dravyas* is put inside *bālukā* and heat is applied to *bhāṇḍa* from outside. Hence, the idea of giving uniform heat for a specified period is there.

When no puṭa is mentioned:

In such cases, the types of *puṭa* may be decided on the basis of the nature and the heat tolerance capacity of the drug to be subjected. *Mṛdu dravyas* may be given smaller *puṭas* and *Kaṭhina-dravyas* bigger *puṭas* or medium *puṭas*. It is left on the description of the *Rasa Vaidya*.

Koṣṭhies (Furnaces):

Three or four *Koṣṭhies* (furnaces) have been mentioned in *Rasa Ratna Samuccaya*. These are described for *Satvapātana* purposes (metal extraction from the minerals).

Satvapātana is the most important process of *Rasa Śāstra* which is now-a-days almost out of practice partly due to its tediousness and partly to non-usefulness, as *Satvas* (extracted metals) are mostly used in mercury *samskaras* (special process) prescribed for potentiating mercury from *Loha Vedha* point of view. And *Loha vedha* (alchemy) is also now out of practice, as in this the chances of success are very less or quite rare and labour much more.

Further, the therapeutic usefulness of *satvas* claimed in the texts is also not so far proved scientifically, as in the name of *satvas* we get some or other metals only, which are now-a-days abundantly available in the market. And if so, then why should one go for such a difficult and time-consuming process. Moreover, with these *Koṣṭhies* we may not always get success in getting *satvas* in sufficient quantities, as through these required degree of temp. could not be achieved or maintained. Hence, for drugs which require high temp. for reduction and smelting, these (*Koṣṭhies*) may not prove useful even if blowers are used. These could only be used successfully in case of drugs which may need low degree of temp. for smelting and extraction of *satvas*. Thus, ancient '*Koṣṭhies*' may now have little importance.

After describing *Mūṣās, Koṣṭhies* and *Puṭas*, a few groups of vegetable, mineral or animal drugs required for mercurial operations and other pharmaceutical treatments are described in this chapter, viz. Metals (six pure metals and two alloy metals), six *lavanas* (salts), three and five *Kṣāras* (alkalies), three sweet drugs, twenty one oily drugs, twelve

animal fats, eight animal urines, including that of women alongwith menstrual discharge of lady and semen of man, five products of buffalo, fourteen drugs of sour group, and a group of five bitter sour drugs, group of five earths/soils, five drugs of poison group, seven drugs of subpoison group, a group of milk of eight animals and the latex of eight vegetable drugs, excreta of six animals, a group of nine red coloured drugs, a group of six white coloured drugs, a group of eight black colouring drugs, a group of three purifying drugs, a group of three softening drugs, a group of six liquifying drugs are mentioned in this chapter; these are claimed useful either in mercury processes or in other pharmaceutical operations in some way or other.

In the end, common effects of *Kṣāras* (alkali group of drugs), *Amlas* (acidic group of drugs), *Viṣas* (poisonous group of drugs) and *Snehas* (oily group of drugs) are described. Then the chapter ends with a mention of a few terms indicating weights.

NEWS

I. Conferences

The XIX International Congress of History of Science is scheduled to be held at the Science Faculty, Zaragoza on 22-29 August 1993. Official languages of the Congress will be English, French and Spanish. The *First Circular* will be distributed by the National Committees of the IUHPS/DHS or may be requested from Prof. Mariano Hormigon, President, Organizing Committee, Faculty of Sciences (Mathematics), Ciudad Universitaria, E-50009 Zaragoza, Spain.

The III Latin American Congress of History of Science and Technology (under ICSU, UNESCO) will be held at Mexico City on 12-16 January 1992. The general theme of the Congress will be *America in the formation of a New World: 500 years of Scientific exchanges. For further information contact: Prof. Dr. Juan Jose Saldana, President, Apartado Postal 21-873, 04000 Mexico, D.F. MEXICO*, Fax: (525) 534 4651

II Projects renewed/approved for the year 1991-92

A. Ancient Period

1. "Study of Scientific Concepts in Brahmanical, Buddhist and Jaina Literature in Ancient India" by Prof. S.N. Sen, Calcutta.
2. "A Critical Study of *Kāśyapa Saṃhitā* (Vṛddha Jīvaka Tantra)" by Prof. (Km) P.V. Tewari, Varanasi.
3. "English Translation of the Cakradatta" by Prof. P.V.Sharma, Varanasi.
4. "Vṛkṣāyurveda of Parāśara with English translation and notes" by Shri N.N. Sircar, Calcutta.
5. "Preparation of Historical Atlas of India — Śaka Kushāna Age" by Prof. B.N. Mukherjee, Calcutta.
6. "Restoration of *Amṛta Aṣṭaṅga Hṛdaya Gūhyopadeśa Tantra* — A lost Āyurvedic Text in Sanskrit" by Vaidya Bhagwan Dash, Delhi.
7. "Astronomical Parameters" by Dr. George Abraham, Madras.
8. "Mathematical Models in Bijaganita of Bhāskaracārya" by Prof. Mahadev Dutta, Calcutta.

B. Medieval Period

9. "A Critical Study of *Yogaratnākara*" by Dr. Nirmal Saxena, Izzatnagar, Bareilly.
10. "A Critical Study of Sanskrit Alchemical Text — *Rasopaniṣad*" by Dr. (Mrs.) V.J. Deshpande, Pune.
11. "Evolution of Kashmir Shawl Craft and Design — Based on Persian sources" by Dr. K.N. Pandita, Jammu.
12. "The Temple of Orissa — A Historical Documentation of its Structural Engineering Aspects" by Dr. S.K. Misra, Bhubaneswar.

13. "Minerals and Metals in Pre-modern India (1200-1900 A.D.)" by Prof. A.K. Biswas, Kanpur.
14. "Shipping and Ship-building in India — Medieval Period" by Shri Baldeo Sahai, New Delhi.
15. "The Process of Modernization of Indian Science (17th and 18th Centuries)" by Prof. M.A. Alvi, Aligarh.
16. "Physical Sciences in Medieval India" by Mr. S. Jafar Mahmud, Delhi.
17. "Eclipses and Occultation in Indian Astronomy" by Prof. K.S. Shukla, Lucknow.

C. Modern Period

18. "History of Botany in India in Modern Times" by Prof. B.M. Johri, F.N.A., Delhi.
19. "A Bibliography of Scientists in India — Part I" by Dr. (Mrs.) A. Vasantha, New Delhi.
20. "History of Magnetic Studies in India (1850-1989) by Prof. S.N. Sen, Calcutta.
21. "A History of Past Major Cyclones in India" by Shri A.K. Sensarma, Madras.
22. "Food Technology Development in India (1800-1947)" by Dr. K.T. Achaya, Bangalore.
23. "Origin and Development of Nuclear Physics in India" by Dr. B.B. Baliga, Calcutta.
24. "History of the Cultivation of Sandal Wood Tree and Its Prospects for Promotion" by Prof. S.P. Raychaudhuri, FNA, New Delhi.

III. PROJECTS COMPLETED DURING THE YEAR 1990-91

1. "Alibin Rabban at Tabari — 9th Century Arab Physician on Ayurveda," by Professor M.S. Khan, Calcutta.
2. "Calendar Reforms in India in Modern Times" by Commdr. S.K. Chatterjee, New Delhi.
3. "Minerals and Metals in Ancient India upto 1200 A.D." by Prof. A.K. Biswas, Kanpur.
4. The Prastāra Ratnāvali of Muni Ratnachandra (An English translation with notes)" by Prof. L.C. Jain, Jabalpur.
5. "On the Development of Physics, Astrophysics, Astronomy and Geophysics during the Period (1800-1950)" by Prof. S.N. Sen and Prof. Santimoy Chatterjee, Calcutta.

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