History of Ancient India

Volume II

PROTOHISTORIC FOUNDATIONS

Editors

Dilip K. Chakrabarti and Makkhan Lal

Vivekananda International Foundation

New Delhi

Aryan Books International

New Delhi

Cataloging in Publication Data—DK
[Courtesy: D.K. Agencies (P) Ltd. <docinfo@dkagencies.com>]

History of ancient India / editors, Dilip K. Chakrabarti and Makkhan Lal.
v. 2 cm.
Contributed articles.
Includes index.
Contents: v. 2. Protohistoric foundations.
ISBN 9788173054815

1. India—History. 2. India—Politics and government. I. Chakrabarti, Dilip K., 1941-
II. Makkhan Lal, 1954- III. Vivekananda International Foundation.

DDC 954 23

ISBN: 978-81-7305-481-5

First Published in **2014** by
Vivekananda International Foundation
3, San Martin Marg, Chanakyapuri, New Delhi - 110 021
Tel.: 24121764, 24106698; Fax: 91-11-43115450
E-mail: info@vifindia.org
www.vifindia.org
in association with
Aryan Books International
Pooja Apartments, 4B, Ansari Road, New Delhi - 110 002
Tel.: 23287589, 23255799; Fax: 91-11-23270385
E-mail: aryanbooks@gmail.com
www.aryanbooks.co.in

Designed and Printed in India at
ABI Prints & Publishing Co., New Delhi.

Contents

II.4.8. Metrology and Linear Measurements

Editorial Note

[The continuity between the Harappan systems of linear and weight measurements and those of the later historical times seems to have entered the realm of certainty now, and from this point of view, the present essay is a clear statement of the situation. The essay also convincingly demonstrates that the Harappan planners of settlements like Dholavira were thinking in terms of definite units and proportions of measurement which survive in texts like the *Arthasastra*.]

Metrology, or the study of units of weights and measures, has a long history in Mesopotamia, ancient Egypt and China, classical Greece and Mesoamerican civilisations, among others. In comparison, studies in Harappan metrology have been few and of limited outcome. The chief reason for this situation (we will see another in the case of linear measures) is the absence of written records: the Harappan script remains undeciphered, and in view of the brevity of the inscriptions found so far, even an accepted decipherment would be unlikely to yield records of transactions involving measured quantities of traded goods. Kinnier Wilson 1984 and Subbarayappa 1997 have independently proposed readings of some signs as numbers accounting for traded commodities such as agricultural produce, but as with any other proposed decipherment, the criteria for verification are problematic. This absence of literary evidence has compelled scholars to work out possible units from archaeological evidence alone. This is in contrast with early India's historical, classical and medieval eras, for which many texts treat units of weight, length, area, volume or time, and the literary evidence far outweighs the archaeological data (for two overviews, see Srinivasan 1979 and Bag 1997).

ASTRONOMY AND TIME

There have been suggestions that the Harappans had some basic astronomical knowledge. For instance, they appear to have used Aldebaran or the star cluster Pleiades to orient Mohenjodaro's streets according to the cardinal directions (Wanzke 1987). It has also been proposed that Mohenjodaro's enigmatic ring stones might have served a calendrical purpose (Maula 1984). More recently, Vahia and Yadav (in press) have suggested that a major structure in Dholavira's Bailey was actually a calendrical and astronomical observatory. If more such lines of research together end up forming a consistent body, they will eventually throw fresh light on Harappan advances in astronomy, which until then must remain conjectural.

Cylindrical objects of shell with deep slits usually at right angles have surfaced at a few sites (Rao 1991: 314; Joshi 2008: 162) and allowed measuring angles of 30°, 45°, 60° and 90°; apart from town planning and construction, they may have been used in astronomy and navigation, although this again remains speculative.

The only artefact clearly relatable to time measurements is a unique terracotta 'hourglass' from Kalibangan, 7cm high and with a maximum diameter of 7cm too. Tests with sand showed that it would have been used to measure a duration of about 10 seconds (Joshi 2008: 166). However, Joshi's suggested relationship with a *muhūrta* appears extremely tenuous; more likely, this might have been a measure of time in some manufacturing process involving a rapid transformation of a specific material (such as metal, powdered minerals, beads, pigments, etc.).

HARAPPAN WEIGHTS

We are on firmer ground with the Harappan system of weights, which was first studied by Hemmy (1931) on the basis of cubical objects of chert or other stone (alabaster, agate, steatite, quartzite etc.) found at Harappa and Mohenjodaro. A few years later, Hemmy (1938) revised his study with the addition of newly discovered specimens and tabulated 331 of them altogether. Although most weights were cubical, a few were truncated spheres, cylinders or cones; those were not made of chert and were generally less accurate than the chert weights (Hemmy 1938: 605). A few scale pans made of bronze, copper or terracotta have survived (e.g., Mackay 1938: 476-77).

Weights have often been unearthed in larger houses, thought to be those of traders, but at Harappa, most were found near the city's gateway, leading Kenoyer (1998: 99) to suggest that they could have been used to tax goods coming into the city rather than for trade. The two purposes, however, are by no means mutually exclusive. Ranging from less than a

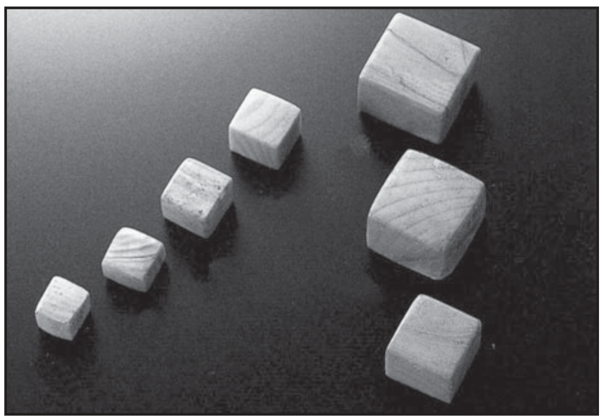

Fig. 1. A set of chert weights from Dholavira (courtesy: ASI).

gram to over 10kg, the weights must have served a multiplicity of purposes. The presence of several Harappan weights in the Persian Gulf (Cleuziou 1992: 93-94; Possehl 2002: 226; Ratnagar 2006: 53) does seem to be a natural corollary of the well-attested Harappan trade with Magan, Dilmun and Mesopotamia.

Studying the distribution of these artefacts' weights, Hemmy noticed that it was not uniform but clustered around a few specific values which were the same at Harappa and at Mohenjodaro; it thus became clear that these artefacts could have been used only as weights. Hemmy's analysis of the standardised values has been confirmed by later finds at many more Mature Harappan sites and have been accepted by archaeologists (e.g., Allchin 1997: 193; Chakrabarti 2006: 186; Kenoyer 1998: 98-99), and more recently confirmed by a statistical study (Vahia and Yadav 2007). The successive weights, in Hemmy's words (1938: 606), "form a series in the following ratios: 1, 2, 8/3, 4, 8, 16, 32, 64, 160, 200, 320, 640, 1600, 3200, 6400, 8000, 12800. The unit weight has the calculated value of 0.857 g, the largest weight, 10970 g. Groups F and G, with weight 13.712 g... and double that amount respectively, are much more common than the others...."

The weights are in the great majority of cases made with considerable accuracy, much more so than in other countries in that period. The unit does not change during the whole occupation of the site [Mohenjodaro].

Disregarding the aberrant weight of 8/3 units (of which Hemmy had only two specimens), we thus find that weights keep doubling in value from 1 unit (of about 0.86 g) to 64 (about 54.85 g). In other words, they initially follow a geometric progression. Why the series does not go on (with 128, 256, etc.) is unclear; this may have to do with Harappan methods of calculation (to get intermediary results from combinations of various weights) or with their numeral notation, both of which we are ignorant of. At any rate, in what is in effect a rudimentary decimal system, values switch to 10, 100 or 1000 times one of the weights in the first series. (The last weight is a curious exception, being 100x128, although there is no weight of 128 units.)

Not all Harappan weights fit perfectly in the above scheme: a few aberrant specimens have come to light from various sites (such as the above 8/3 units), and Kenoyer (2010: 116) reports smaller weights, such as 0.3 g and 0.6 g; they might have been used for special needs not always related to trade (e.g., manufacturing processes). The metrologist V.B. Mainkar (1984: 142) drew attention to a special series of weights from Lothal: rounding off the values to two decimal points, they are 1.22 g, 4.34 g, 8.58 g, 18.16 g and 33.3 g. Rather than go with Mainkar's convoluted attempt to correlate them to Hemmy's series, I would point out that they are respectively very close to 1.5, 5, 10, 20 and 40 times the basic 'unit' of 0.86 g; in other words, they are based on the same unit but follow decimal multiples almost from the start, bypassing the 'standard' geometrical progression. This series seems to be an isolated case, however.

Finally, while it is known that some Harappan weights predate the Mature phase (Kenoyer 2010: 115), a continuity between Harappan and historical weights has also long been noted. Weighing thousands of early historical punch-marked coins of silver, from Taxila in particular, D.D. Kosambi (1941: 53) concluded that there was "every likelihood of the earlier Taxila hoard being weighed on much the same kind of balances and by much the same sort of weights, as at Mohenjodaro some two thousand years earlier". In the same vein, Mainkar (1984: 144-55) compared the Harappan system with the weight systems described in the *Arthaśāstra* and in the *Manusmriti*, and observed that "there is reason to believe that the two systems of weight used later in India had perhaps a common origin which can be traced directly to the Indus Civilisation." Kenoyer (1998: 98) endorsed this continuity: "The Indus weight system is identical to that used by the first kingdoms of the Gangetic Plain around 300 BC, and is still in use today in traditional markets throughout Pakistan and India." (This is not quite true of India any longer, where the metric system has virtually eradicated the traditional one, except in specialised areas such as weighing of gold or precious stones.)

We may also illustrate this continuity through a table prepared by Mitchiner (1978: 75) to compare the traditional system of weights used in India till recent decades and Harappan weights (Table1), with a difference smaller than 1.8 per cent. Such a close match is plainly beyond the realm of coincidence.

Table 1. Mitchiner's Comparison between Harappan and Traditional Weights.

Harappan weights							
Unit	1	2	4	8	16	32	64
Value in grams	0.8525	1.705	3.41	6.82	13.64	27.28	54.56
Traditional Indian weights							
'*Rattis*'	8	16	32	64	128	256	512
'*Karshas*'			1	2	4	8	16
Value in grams	0.8375	1.675	3.35	6.70	13.40	26.80	53.60

HARAPPAN RATIOS

Before we come to linear measures, we must highlight a neglected area of Harappan metrology: the widespread deliberate use of ratios in Harappan structures. Harappan bricks generally had standardised proportions of 1:2:4 (and often 1:2:3 in the Early phase). The acropolis or upper city at several sites (e.g. Mohenjodaro, Kalibangan, Dholavira) is laid out in a precise 2:1 ratio; their lengths are twice their breadths. The widths of Kalibangan's streets are in ratios of 1:2:3:4, where the unit is 1.8m (Lal 1997: 121). There is evidence that some of these ratios have, in fact, roots going back to Neolithic or Early phases (Lal 1997: 35, 61; Kenoyer 2010: 114). But such observations have not led to a broader understanding of the concepts behind such ratios.

In the case of Dholavira, however, the well-preserved condition of the foundations of the city's fortifications prompted the excavator (Bisht 1997, 1999, 2000) to note a profusion of specific proportions; significantly, the overall city obeyed a ratio of 5:4 (or 1.25) with a nil margin of error, and the same ratio was repeated in the Castle on the acropolis. Supplementing this information (Danino 2005, 2008, 2010a), I added a few more ratios such as 9:4 (or 2.25) between the Castle's and the Middle Town's lengths, and again between the Middle Town's and the city's lengths (Fig. 2). Such repetitive

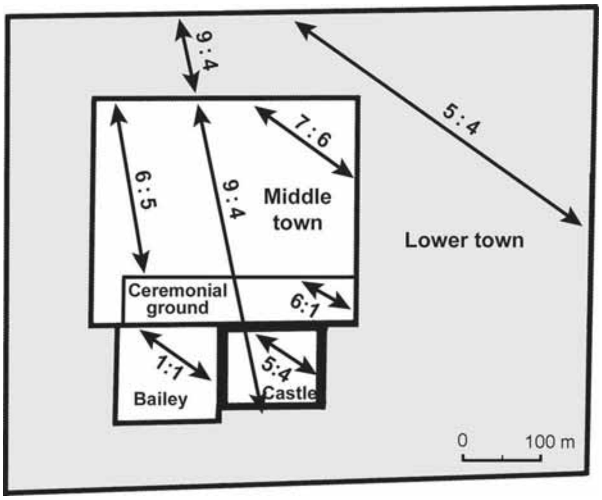

Fig. 2. Main ratios at work at Dholavira (simplified plan).

patterns cannot be accidental, especially in view of the high degree of precision involved despite the terrain's irregularities.

Extending to other sites the thesis that Harappans favoured specific ratios to random proportions wherever possible, a preliminary study (Danino 2010b) showed over thirty structures across seven sites sharing some sixteen ratios (Fig. 3). This included fortifications, large buildings and reservoirs (such as Dholavira's). Clearly, such a distribution cannot be random and reflects a cultural specificity: we would be hard put to locate such a love of proportions in our modern cities.

What, then, could have impelled the Harappan mind to impose such ratios on their landscapes? Probably the same motive that prompted classical Hindu architecture to evolve series of auspicious proportions for temples and other buildings. The *Mānasāra* follows this principle when it states (35.18-20) that "the length of the mansion [to be built] should be ascertained by commencing with its breadth, or increasing it by one-fourth, one-half, three-fourths, or making it twice, or greater than twice by one-fourth, one-half or three-fourths, or making it three times" (Acharya 1934/1994: 374). The outcome is a series of eight ratios regarded as auspicious: 5:4, 3:2, 7:4, 2:1, 9:4, 5:2, 11:4, 3:1. It is significant that all of them are found at Dholavira or other Harappan settlements (Fig. 3). Auspiciousness apart, the *Mānasāra* shows us how such ratios were formed, i.e. through the addition of a simple fraction to unity or multiples of it. It is likely that the Harappan architects followed a similar process: ratios 5:4, 7:4, 9:4 and 11:4, for example, can be simply formed by adding one-fourth to unity (1.25), then adding one-half three times in succession (1.75, 2.25, 2.75).

Continuity between the Harappan scheme of ratios and India's classical concepts is further

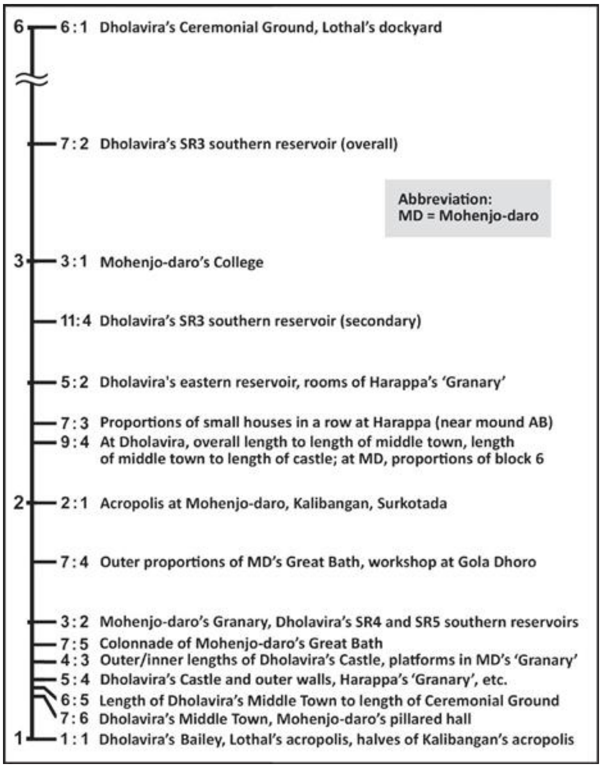

Fig. 3. A sampling of ratios found at a few Harappan sites (on a linear scale), generally with a high degree of precision.

suggested by the famous scholar Varāhamihira, who in the sixth century AD wrote in his *Brihat Samhitā* (53.4-5): "The length of a king's palace is greater than the breadth by a quarter.... The length of the house of a commander-in-chief exceeds the width by a sixth...." (Bhat 1981: 451-52). These two ratios, 1 + 1/4 and 1 + 1/6, are identical to 5:4 and 7:6, two key ratios at Dholavira's ratios (5:4 for the Castle and the overall city; 7:6 for the Middle Town).

In the Indian tradition, adding a fraction reflects the cosmic principle of increase and expansion, and invites prosperity. The main Vedic sacrificial ground, the trapezium-shaped *mahavedi*, measures 24 steps on its eastern side and 30 on its western side (as given in the *Śatapatha Brāhmana* I.1.2.23 (see Sen and Bag 1983: 170), an increase reflecting the gain of the sacrifice. Interestingly, the ratio of increase, 30:24, is the same as Dholavira's 5:4. Much later, Maharaja Jai Singh, the author of the Jantar Mantar observatories, took on the prefix 'Sawai', which means 'one and a quarter' (again 5:4), the rate by which he was said to exceed his predecessor!

The systematic use of specific ratios by Harappans appears to be based on the same concept of sacred proportions; it is an attempt to embody auspiciousness in their urban landscape and can be seen as the origin of such concepts in India's architectural traditions.

HARAPPAN LINEAR MEASURES

The question of Harappan linear measures is much less straightforward than that of weights. To determine the units of length in the absence of literary evidence, a scale is an obvious desideratum. Four artefacts qualifying as candidates have so far been found. (In what follows, I will call them 'scales', although, strictly speaking, there is no proof that any of them was actually intended to be one.)

In 1931, Mackay reported at Mohenjodaro the find of a broken length of shell. It bore nine neatly incised dividing lines creating eight divisions of 0.264" or 6.706 mm each (with a very low mean error of 0.08 mm). A dot and a circle were incised five graduations apart, which suggested to Mackay a decimal system of linear measures. Taking five divisions as a unit, Petrie proposed a "decimal scale of 1.320 [inches]" and related ten such units to a foot in Egyptian, Greek, Roman and medieval British systems (Mackay 1938: 404–05). Since then, the concepts of an "Indus inch" of 1.32" (33.53 mm) and an "Indus foot" of 13.2" (33.53 cm) have found their way into the literature (e.g., Wheeler 1968: 83–84). However, attempts by Mackay to relate such a unit to dimensions in Mohenjodaro were, on his own admission, not very successful, and he suspected the existence "of a second system of measurement" (Mackay 1938: 405).

A few years later, Vats reported from Harappa a fragment of a bronze rod with four divisions of 9.34 mm each. Being 1.39 times larger than the division on the Mohenjodaro scale, it bears no obvious relation to it. Vats attempted a correlation with Egypt's royal cubit and, on that basis, proposed a "Harappan cubit" of 56 times the above division, or 52.3 cm (Vats 1940: 365-66). (A cubit is the distance from the elbow to the tip of the finger.) While trying to apply the above "Harappan foot" (based on Mohenjodaro's scale) and "Harappan cubit" to some 150 structures, Vats used a foot of 33.0 to 33.5 cm and a cubit of 51.6 to 52.8 cm. However, he published only a few examples (such as Mohenjodaro's Great Bath, so-called "Granary", etc.), without margins of error, and used the foot in some cases and the cubit in others, suggesting that it was "very probable that both these systems, one based on the foot and the other on the cubit, were simultaneously in use in the Indus Valley" (Vats 1940: 366). His proposal has been repeated by later scholars (e.g., Wheeler 1968: 84), but never seriously tested. Moreover, it implicitly but questionably assumed an identity between Harappan and Egyptian concepts of measure: although it is indeed very likely that Harappan linear measures were, as elsewhere, rooted in physical concepts of digit, palm, hand span, cubit and height, they need not have been borrowed from contemporary cultures.

In 1950s, excavations at Lothal brought to light a rod of ivory (Fig. 4) marked by 27 graduations that covered 46 mm (Rao 1979: 626). Dividing 46 mm by 26 divisions gives a unit of 1.77 mm (Rao divided by 27 graduations, an error repeated by Mainkar). The sixth and the twenty-first graduations appear longer, perhaps pointing to a decimal intention. Rao's attempts to correlate Lothal dimensions with this unit are too approximate and limited in scope to form a consistent system (Rao 1991: 313-14). Of greater interest is Mainkar's observation that the Lothal unit should be related to India's traditional *angula* (i.e., a digit, originally the width of the middle finger), which, through his careful analysis of metrological traditions across India, he estimated to be 17.78 mm (Mainkar 1984: 147). Ten Lothal units, in other words, were equivalent to the *angula*, a view tentatively accepted by Chattopadhyaya (1986: 231-33).

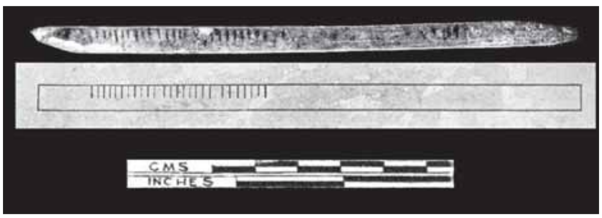

Fig. 4. The Lothal ivory scale (courtesy: ASI).

More recently, Rottländer (1984) investigated Harappan linear units from a different perspective, bypassing the above three would-be scales and taking measurements from house plans carefully drawn by Jansen and his team at Mohenjodaro. His analysis pointed to a foot unit of 34.55 cm and a "double foot" of twice that size, which he related to a unit identified at Nippur in Mesopotamia. Rottländer rejected both the Mohenjodaro and the Harappa scales; the former might have been, he suggested, "part of an ornament or finger-board of a stringed instrument" (Rottländer 1984: 202). Assuming that Rottländer's dimensions were correctly measured on the plans, it remains to be explained why we should expect the lengths of most or all rooms to reflect a whole (or integral) multiple of a basic unit; it is by no means certain that such measurements of actual rooms of houses in our twentieth century would allow us to re-create the unit of a metre. A complex statistical argument is involved, which will require elucidation.

In 2005, I realised that Dholavira's well-defined fortifications, together with their precise proportions, should permit us to work out the linear unit with which the city's walls were measured out. Simple calculations (Danino 2010a) were made with no *a priori* assumption, except that the fortifications' lengths should be integral (that is, non-fractional) expressions of such a unit. Results showed that with a unit of length of 1.901 m, all the principal dimensions of the city (Fig. 5) could be so expressed with a high degree of precision, the average margin of error being a mere 0.6%. Fortifications apart, most dimensions of the city's large reservoirs and of many structures at other Harappan sites could also be expressed as whole multiples of the proposed unit (Danino 2008, 2010b). For instance, the maximum width of the primary

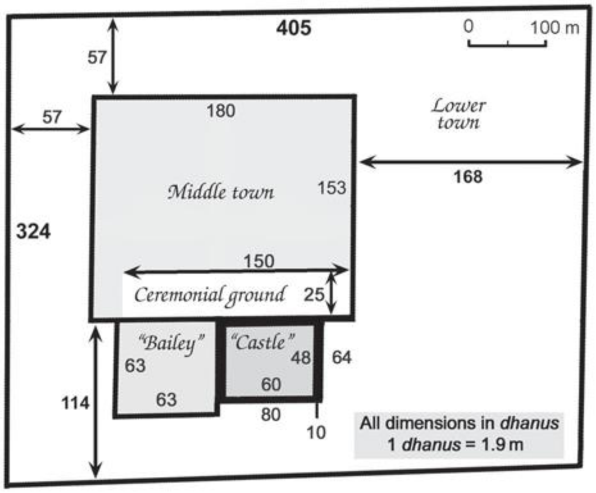

Fig. 5. Dholavira's main dimensions expressed in terms of a unit of 1.9 m.

'SR3' rock-cut reservoir (south of Dholavira's Castle), 9.45 m, is exactly five units (with a margin of error of 0.5%), while the width of the secondary reservoir at the bottom of the same SR3, 5.65 m, is three units (0.9%); two enigmatic stone columns found in the Castle are precisely 3.8m apart, which is two units; etc. Such expressions of short dimensions are, of course, more compelling than those of long ones.

The unit of 1.901 m turned out to be nearly 108 times larger than the Lothal digit, which prompted me to propose a Dholavira digit of 1.76 cm. The factor 108 is prescribed in the *Arthaśāstra* (2.20.19) as the ratio between an *angula* ('finger') and a *dhanus* (bow) or *danda* ('stick') for the specific purpose of measuring city walls and streets (Kangle 1986: 139) (the ordinary *dhanus* is only 96 *angulas*). Varāhamihira also stated in his *Brihat Samhitā* (68.105) that the height of a tall man is 108 *angula*s (which tallies with 1.9 m), that of a medium man 96 *angula*s (1.69 m with the Dholavira *angula*, again a good match), and that of a short man 84 *angula*s (Bhat 1981: 642). I therefore suggested that the most common Mature Harappan brick size, which is 7x14x28 cm (Jansen quoted by Rottländer 1983: 202; Kenoyer 1998: 57), could be expressed as 4x8x16 *angulas*. (Kalibangan's terracotta hourglass mentioned above also measures 7 cm of 4 *angulas* in both height and diameter.) A system of the multiples of *angulas* including the palm (4 *angulas*) and the *hasta* or cubit (in this case 27 *angulas*) was also proposed, but its wider applicability remains to be demonstrated.

Independently, Pant and Funo (2005) studied block and plot divisions at several ancient sites. At Thimi in Nepal, a 1,500-year-old town, blocks of habitations were divided by regularly spaced east–west streets with an average width of 38.42m. Besides, a pattern of divisions on a long nearby strip of fields yielded an average of 38.48 m. Pant and Funo turned to the highly regular street pattern at Sirkap, one of Taxila's three mounds, and found that the average distance between parallel streets was, again, 38.4m, even though a millennium separates the two sites. Moreover, on the nearby Bhir mound, they found "a number of blocks [of houses] in contiguity with a width of 19.2 m" (Pant and Funo 2005: 57), that is, half of 38.4 m. Finally, studying Mohenjodaro's plan, they noticed in major cluster blocks at three different parts of the city a frequently occurring dimension of 19.20 m. They were led to correlate these figures with the *Arthaśāstra* system of linear measures and reached the same conclusion that Dholavira's fortifications had led me to: they adopted a *danda* (an equivalent of the *dhanus*) of 108 *angula*s, and, as prescribed by the text, a *rajju* (or 'rope') of ten *danda*s. Their *danda* had a value of 1.92 m, so that Mohenjodaro's block dimensions of 19.2 m were equivalent to 1 *rajju*, and those of 38.4 m twice as much (a unit called *paridesha*). At the other end of the scale, their value of the *angula* was 1.78 cm

(1.92 m divided by 108). Their *danda* and *angula* were thus almost identical in value to the units I had independently proposed (and since some of Dholavira's dimensions are expressed as 10, 60, 80, 150 or 180 *dhanus,* there is a good case for the use of a *rajju* of 10 *dhanus* there too). Pant and Funo's observation on the continuity between Harappan and historical linear measures also paralleled my own: "There is continuity in the survey and planning tradition from Mohenjodaro to Sirkap and Thimi.... The planning modules employed in the Indus city of Mohenjodaro, Sirkap of Gandhara, and Thimi of Kathmandu Valley are the same" (Pant and Funo 2005: 57).

Finally, Kalibangan's excavation brought to light a crude 9 cm-long rod of terracotta with a few markings. It was scrutinised only recently (Balasubramaniam 2008a, Balasubramaniam and Joshi 2008) and yielded a unit of 1.75 cm, which Balasubramaniam related to the proposed Dholavira *angula* of 1.76 cm and to 10 Lothal units (1.77 cm), thereby lending some weight to my and Mainkar's theses. Additionally, Balasubramaniam showed that most divisions on Kalibangan's terracotta scale were one-eighth of 1.75 cm, which is in accord with the *Arthaśāstra*'s definition (2.20.6) of an *angula* as the combined widths of eight grains of barley (Kangle 1986: 138).

Balasubramaniam went on to apply the linear units worked out at Dholavira to historical structures: the dimensions of the Delhi Iron Pillar (Balasubramaniam 2008b), the Mauryan rock-

Fig. 6. The Kalibangan terracotta scale (courtesy: ASI).

cut caves at Barabar and Nagarjuni hills (Balasubramaniam 2009b) and the Taj Mahal's modular planning (Balasubramaniam 2009a) took felicitous expressions when formulated in terms of the proposed units, suggesting the survival of the Harappan system, or of a system akin to it.

Table 2 summarises the above discussion and the proposed Harappan linear units. It remains, of course, wholly possible that different unit systems were used for different purposes. If other ancient cultures are any guide, we should not expect a single Harappan system to cover beads, seals, bricks, buildings, reservoirs and long fortification walls. It may also be that one system was related to another in ways not yet understood; for instance, Mainkar (1984: 146) noticed that 10 units on Mohenjodaro's scale added to 15 units on Lothal's equals 10 units on Harappa's scale, which is correct to within 0.1% (Danino 2008: 74). Whether this relationship is accidental or the result of some design remains to be worked out. Finally, even smaller linear units than those shown in Table 2 might have been in use, as the sophisticated techniques of bead making point to (Kenoyer 2010: 111-12).

Table 2. Summary of the Various Proposed Systems of Linear Units (A Few of Them not Discussed in the Text). All Dimensions Are in CM and Rounded Off to Two Decimal Points (Three for the First Column).

	basic unit	digit/ inch/ *angula*	palm (4 digits)	foot	cubit/ double foot	*dhanus*/ *danda*
Mohenjodaro scale (Mackay and Petrie)	0.671	3.35	—	33.53	—	—
Harappa scale (Vats)	0.934	1.87	7.49	—	52.3	—
Lothal scale (Rao and Mainkar)	0.177	1.78	—	—	—	—
Rottländer	—	0.69	6.91	34.55	69.1	—
Kalibangan scale (Balasubramaniam)	—	1.75	—	—	—	—
Dholavira units (Danino)	—	1.76	7.04	—	47.52	190.1
Mohenjodaro (Pant and Funo)	—	1.78	—	—	—	192

Only a systematic study of all the precisely measured Harappan structures analysed with modern statistical methods will provide a final answer to the question of the Harappan systems of linear measures.

CONCLUSION

As one more example of a promising line of research, a brief mention may be made of Harappan volumetric units, which had until recently defied analysis. Like Kinnier Wilson (1984) and Subbarayappa (1997), Wells (2009) interpreted a few Harappan signs as numbers, but went on to correlate them with markings on pots, some of them vertical strokes. He found that the larger the pot, the more vertical strokes, which seemed to point to some relationship with the pot's volume. Measuring three pots precisely, he found that their volumes were consistent with a unit of 9.24 litres per vertical stroke. Of course, such investigations should be pursued with many more specimens before they may be regarded as conclusive.

In the meantime, Harappan metrology, despite our incomplete knowledge of it, appears to be as sophisticated as Harappan crafts and technologies. Indeed, this was to be expected.

REFERENCES

Acharya, Prasanna Kumar. 1934/1994. *Architecture of Mānasāra*. Vol. 4. *Mānasāra Series*. Republished. New Delhi: Munshiram Manoharlal.

Bag, A.K. 1997. Concepts and Measures of Length, Weight and Time. In A.K. Bag (ed.), *History of Technology in India*. Vol. 1. New Delhi: Indian National Science Academy, pp. 663-76.

Balasubramaniam, R. 2008a. On the Continuity of Engineering Tradition from the Harappan to Ganga Civilisation. *Man and Environment* 33(1): 101-05.

——. 2008b. On the Mathematical Significance of the Dimensions of the Delhi Iron Pillar. *Current Science* 95(6): 766-70.

——. 2009a. New Insights on the Modular Planning of the Taj Mahal. *Current Science* 97(1): 42-49.

——. 2009b. New Insights on Metrology during the Mauryan Period. *Current Science* 97(5): 680-82.

Balasubramaniam, R. and Jagat Pati Joshi. 2008. Analysis of Terracotta Scale of Harappan Civilisation from Kalibangan. *Current Science* 95(5): 588-89.

Bhat, M. Ramakrishna. 1981. *Varāhamihira's Bṛhat Saṃhitā*. New Delhi: Motilal Banarsidass, Vol. 1.

Bisht, R.S. 1997. Dholavira Excavations: 1990–94. In J.P. Joshi (ed.), *Facets of Indian Civilisation: Essays in Honour of Prof. B.B.Lal*. New Delhi: Aryan Books International, vol. 1, pp. 107-20.

——. 1999. Dholavira and Banawali: Two Different Paradigms of the Harappan Urbis Forma. *Puratattva* 29: 14-37.

——. 2000. Urban Planning at Dholavira: A Harappan City. In J. McKim Malville and Lalit M. Gujral (eds.), *Ancient Cities, Sacred Skies: Cosmic Geometries and City Planning in Ancient India*. New Delhi: Indira Gandhi National Centre for the Arts and Aryan Books International, pp. 11-23.

Chakrabarti, Dilip K. 2006. *The Oxford Companion to Indian Archaeology: The Archaeological Foundations of Ancient India*. New Delhi: Oxford University Press.

Chattopadhyaya, Debiprasad. 1986. *History of Science and Technology in Ancient India*. Calcutta: Firma KLM, Vol. 1.

Cleuziou, Serge. 1992. The Oman Peninsula and the Indus Civilisation: A Reassessment. *Man and Environment* 17(2): 93-103.

Danino, Michel. 2005. Dholavira's Geometry: A Preliminary Study. *Puratattva* 35: 76-84.

——. 2008. New Insights into Harappan Town planning, Proportions and Units, with Special Reference to Dholavira. *Man and Environment* 33(1): 66-79.

——. 2010a. Unravelling Dholavira's Geometry. In P. Chenna Reddy (ed.), *Rama Vijayam: Recent Researches in Archaeology, History and Culture (Festschrift to Prof. K.V. Raman)*. Delhi: Agam Kala Prakashan, pp. 179-93.

——. 2010b. Further Research into Harappan Metrology at Dholavira. *Man and Environment* 35(2): 35-44.

Hemmy, A.S. 1931. System of Weights at Mohenjo-Daro. In John Marshall, *Mohenjo-Daro and the Indus Civilisation*. London: Arthur Probsthain, pp. 589-98.

——. 1938. System of Weights at Mohenjo-Daro. In E.J.H. Mackay, *Further Excavations at Mohenjo-Daro*. Delhi: Government of India. Vol. 1, pp. 601-12. [I have modernised Hemmy's abbreviation 'gms' for a gram into 'g'.]

Joshi, Jagat Pati. 2008. *Harappan Architecture and Civil Engineering*. New Delhi: Rupa and Infinity Foundation.

Kangle, R.P. 1986. *The Kautilya Arthaśāstra*. New Delhi: Motilal Banarsidass, Part II.

Kenoyer, Jonathan Mark. 1998. *Ancient Cities of the Indus Valley Civilisation*. Karachi and Islamabad: Oxford University Press and American Institute of Pakistan Studies.

——. 2010. Measuring the Harappan World: Insights into the Indus Order and Cosmology. in Iain Morley and Colin Renfrew (eds), *The Archaeology of Measurement: Comprehending Heaven, Earth and Time in Ancient Societies*. Cambridge: Cambridge University Press.

Kosambi, D.D. 1941. On the Study and Metrology of Silver Punch-marked Coins. *New Indian Antiquary* 4(2): 1-35 and 49-76.

Lal, B.B. 1997. *The Earliest Civilisation of South Asia*. New Delhi: Aryan Books International.

Mackay, E.J.H. 1938. *Further Excavations at Mohenjo-Daro*. Delhi: Government of India. Vol. 1.

Mainkar, V.B. 1984. Metrology in the Indus Civilisation. In B.B. Lal and S.P. Gupta (eds.), *Frontiers of the Indus Civilisation.* New Delhi: Books and Books, pp. 141-51.

Maula, Erkka. 1984. The Calendar Stones from Mohenjo-Daro. In M. Jansen and G. Urban (eds), *Interim Reports on Fieldwork carried out at Mohenjo-Daro, Pakistan 1982–83.* Aachen and Rome: German Research Project Mohenjo-Daro and Istituto Italiano Per Il Medio Ed Estremo Oriente, Vol. 1, pp. 159-70.

Mitchiner, John E. 1978. *Studies in the Indus Valley Inscriptions*, Delhi: Oxford and IBH, 1978.

Pant, Mohan and Shuji Funo. 2005. The Grid and Modular Measures in the Town Planning of Mohenjo-Daro and Kathmandu Valley: A Study on Modular Measures in Block and Plot Divisions in the Planning of Mohenjo-Daro and Sirkap (Pakistan), and Thimi (Kathmandu Valley). *Journal of Asian Architecture and Building Engineering.* 4(1): 51-59.

Possehl, Gregory L. 2002. *The Indus Civilisation: A Contemporary Perspective.* Oxford: Altamira Press, (Indian edn, Vistaar, New Delhi, 2003).

Rao, S.R. 1979. *Lothal, a Harappan Port Town (1955-62).* New Delhi: Archaeological Survey of India, Vol. 2.

——. 1991. *Dawn and Devolution of the Indus Civilisation.* New Delhi: Aditya Prakashan.

Ratnagar, Shereen. 2006. *Understanding Harappa: Civilisation in the Greater Indus Valley.* 2nd edn., New Delhi: Tulika.

Rottländer, R.C.A. 1984. The Harappan Linear Measurement Unit. In M. Jansen and G. Urban (eds.), *Interim Reports on fieldwork carried out at Mohenjo-Daro, Pakistan 1982–83.* Aachen and Rome: German Research Project Mohenjo-Daro, and Istituto Italiano Per Il Medio Ed Estremo Oriente, Vol. 1, pp. 201-05.

Sen, S.N. and A.K. Bag. 1983. *The Sulbasastras.* New Delhi: Indian National Science Academy.

Srinivasan, Sarada. 1979. *Mensuration in Ancient India.* Delhi: Ajanta Publications.

Subbarayappa, B.V. 1997. *Indus Script: Its Nature and Structure.* Madras: New Era Publications.

Vahia, M.N. and Nisha Yadav. 2007. Harappan Weights. *Puratattva* 37: 213-17.

——. In press. A Possible Astronomical Observatory at Dholavira.

Vats, Madho Sarup. 1940. *Excavations at Harappā.* Delhi Manager of Publications, Vol. I.

Wanzke, Holger 1987. Axis Systems and Orientation at Mohenjo-Daro. In M. Jansen and G. Urban (eds.), *Interim Reports on Fieldwork Carried out at Mohenjo-Daro, Pakistan 1982–83.* Aachen and Rome: German Research Project Mohenjo-Daro and Istituto Italiano Per Il Medio Ed Estremo Oriente, Vol. 2, pp. 33-44.

Wells, Bryant. 2009. As reported by T.S. Subramanian, Indus Civilisation Reveals its Volumetric System. *The Hindu.* 15 November 2009.

Wheeler, Mortimer. 1968. *The Indus Civilisation.* 3rd ed. Cambridge: Cambridge University Press.

Wilson, Kinnier J.V. 1984. The Case for Accountancy. In B.B. Lal and S.P. Gupta, (eds.), *Frontiers of the Indus Civilisation.* New Delhi: Books and Books, pp. 173-78.

[MD]