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Early Weights and Weighing in Egypt and the Indus Valley

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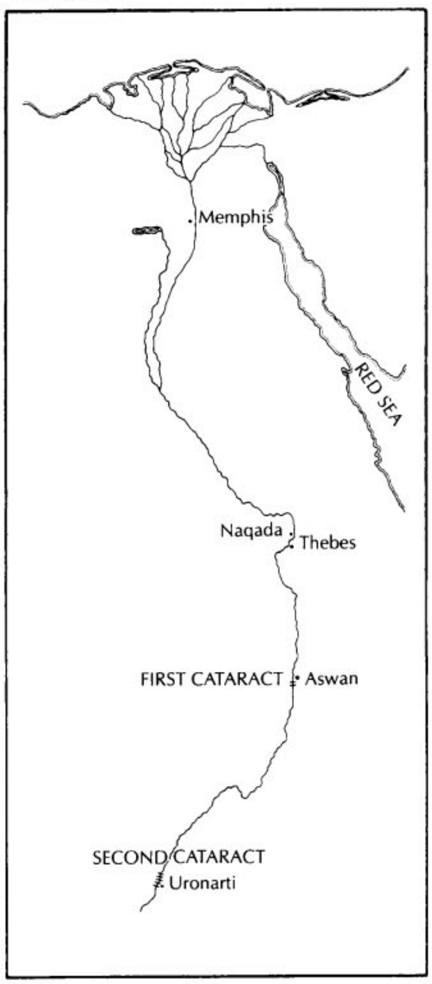
Early antiquarian and archaeological research into the ancient civilizations of the Orient is characterized by a fascination with the stupendous and the monumental. Typically, and quite understandably, the focus of the first researchers was on the largest, most durable, and thus most immediately accessible surviving monuments of the various cultures, notably, temples, royal tombs, civic buildings, and royal art, which either appealed to Western taste or were considered exotic and grotesque. Somewhat after – and largely as a result of – documentation of the magnificent, the focus of archaeological research shifted toward the mundane. Well before the turn of the nineteenth century, intellectual interest in the customs, manners, and artifacts of everyday life in ancient times had begun to manifest itself in European scholarship. Ponderous syntheses like Adolf Erman's *Life in Ancient Egypt* (1886) appeared; such works constituted early attempts to document the life of Everyman in antiquity based upon surviving historical testimonia, literature, and paintings and reliefs depicting scenes from daily life. Archaeological investigation, of course, played a large role in providing the primary data of which these fascinating and useful (if often tedious) tomes were composed. During the same period, the first attempts were made to transform archaeology into a discipline grounded in scientific method. Excavators such as Sir William Flinders Petrie, whose scholarly interests and competence extended to all periods of Egyptian antiquity and to every manner of site, gave legitimacy to the pursuit of data that informed on everyday life. Egypt has been singled out here for purposes of illustration, but a similar trend in interest away from the spectacular and unique toward the commonplace can be seen in current archaeological research in Mesopotamia, Greece, and Italy.

To a certain extent, this trend is reflected in modern depictions of the ancient world by museums. Certainly, exhibitions that emphasize the spectacular (and, by definition, the precious) have always been attractive to the public, and they will continue to be so. In recent years, however, one may note a number of highly successful exhibitions that illustrate life in antiquity by emphasizing the typical; the recent show "Egypt's Golden Age: The Art of Living in the New Kingdom, 1558–1085 B.C.," which premiered at the Museum of Fine Arts (February–May 1982), is a noteworthy example. The enthusiasm with which such exhibitions are received is an index of the viewing public's more refined interest in the world of antiquity.

The Nile Valley



Among the most unassuming objects in the permanent collections of the Museum of Fine Arts are several dozen balance weights from ancient Egypt and the Indus Valley. What these items lack in immediate aesthetic appeal is more than compensated for by the elegant mathematical ideas they express; they give us insight into the minds of their makers and inform us, in a way that few other sources of data can, on how two ancient peoples quantified the world around them.

Objects of this sort provide the raw data for a rather arcane applied science known as historical metrology, which explores the origins and history of measurement. Exactly when man began to count is an unresolved matter, but one researcher has presented evidence for time-reckoning (in the form of bones and antlers that bear systematically incised markings) as early as the last phase of the Pleistocene period (about 15,000 years ago).[1] The next incontrovertible archaeological evidence we have of man's understanding of number does not appear until the early fourth millennium B.C. A group of six carefully sculpted stone balance weights of various shapes excavated at predynastic Naqada in Upper Egypt betrays an absolute unit value in the vicinity of 13 grams, in denominations of ½, 6, 20, 30, and 40 units.[2] The earliest known balance scale is also Egyptian and of predynastic

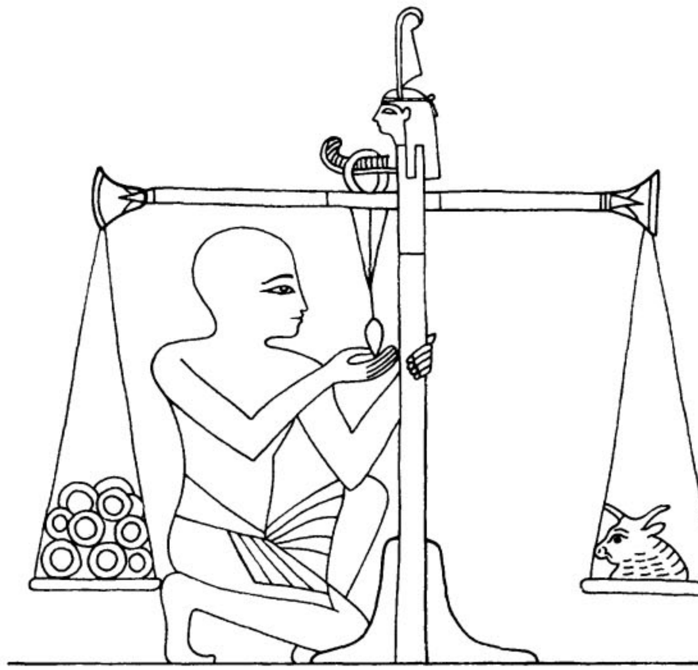
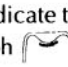


Figure 1 Weighing scene from Tomb 181 at Thebes. (Drawing by Lynn Holden.)

date; it consists of a limestone beam, about 8.5 cm. ($3\frac{5}{16}$ in.) in length, drilled vertically through its center for suspension.[3] Clearly, some economic advance, such as the sanctioning of the evaluation of a precious material or the assaying of a heavy material in terms of a dear one, prompted the manufacture of this apparatus. It is commonly assumed that the earliest commodity to be counterbalanced with the stone weights was gold. More important in terms of technology, however, once the principle of weighing was discovered, scales were pressed into use for other commodities and for purposes other than barter, such as, for example, in determining proportions of the components of a metallic alloy. Weighing technology itself was eventually improved through the introduction of a smaller pivot point, set horizontally rather than vertically through the beam; this too appears to have been an Egyptian invention. A final improvement in precision, attested by the time of the New Kingdom, was the attachment of a plumb bob. A wall painting in Tomb 181 at Thebes shows a weighing scene in which the plumb bob is being used (see fig. 1).[4] The gold rings in the pan at left are counterbalanced with an oxhead balance weight (a common New Kingdom shape, usually made of bronze) in the pan at right. The weigher assures fairness of operation by aligning a plumb line with the beam support.

Egyptian metrology has been well studied, both through examination of the economic texts and through empirical analysis of the balance weights themselves. Many thousands of Egyptian balance weights, ranging in date from predynastic to Roman times, have been excavated and may be seen today in museums and private collections the world over.[5] Indeed, the metrologist who studies Egyptian weighing is faced with an embarrassment of riches. Many surviving weights bear inscriptions indicating their denominations. Typical are the six well-preserved rectangular stone weights shown in figure 2, of which three are in the Egyptian collection of the Museum of Fine Arts and three in Khartoum. They were excavated in a single archaeological deposit, which suggests that they constituted a working set. The site from which they came is Uronarti, an island near the Second Cataract of the Nile in Nubia.[6] Uronarti was one of a network of trading outposts, fortified during the Middle Kingdom (probably in the reign of Sesostris III, ca. 1878–1842 B.C.) to ensure unimpeded transit of gold to Egypt from mines in Nubia. The inscriptions on the six pieces indicate that they were indeed used in the gold trade: each piece bears the hieroglyph  , *nub* (a collar of beads), which was the sign for gold.[7] Beneath

For assistance in the preparation of this article I would like to express my gratitude to the following staff members of the Museum of Fine Arts: Edward Brovarski and Timothy Kendall (Egyptian Department), Vishakha Desai (Asiatic Department), and Pamela England (Research Laboratory).

1. Alexander Marshack, *The Roots of Civilization* (New York, 1972). On early measurement see also W. Hough, "The Origin and Development of Metrics," *American Anthropologist* 35 (1933), 443–450. On numbers in general, see Karl Menninger, *Number Words and Number Symbols* (Cambridge, Mass., 1969).

2. W. M. F. Petrie, *Ancient Weights and Measures* (London, 1926), p. 18; F. G. Skinner, *Weights and Measures* (London, 1967), p. 3 and pl. I.

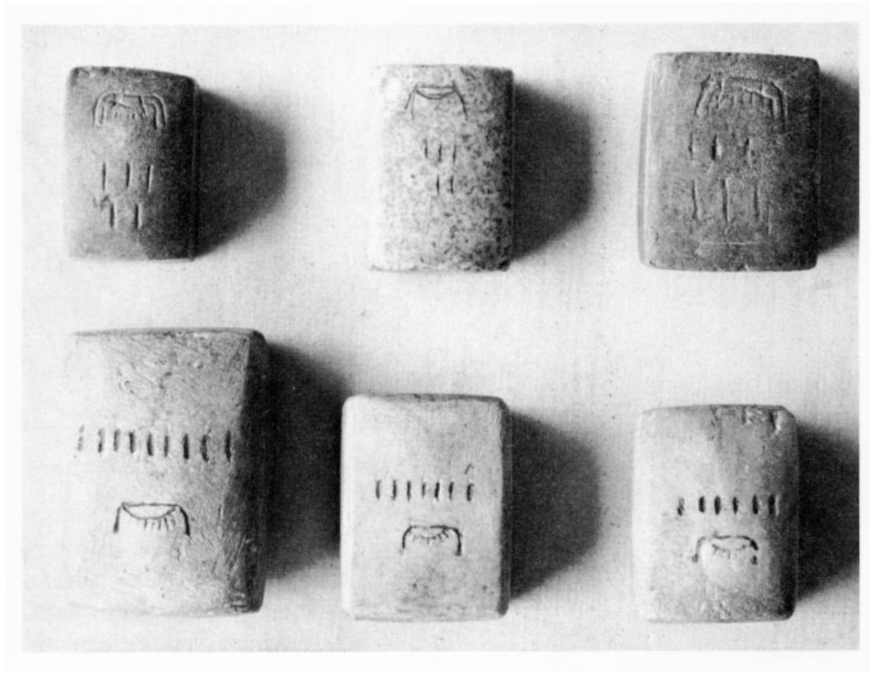
3. W. M. F. Petrie, *Prehistoric Egypt* (London, 1920), p. 29 and pl. XLVI, no. 36; idem, *Ancient Weights and Measures*, p. 42; Skinner, *Weights and Measures*, p. 3 and pl. I.

4. B. M. Cartland, "Egyptian Weights and Balances," *Bulletin of the Metropolitan Museum of Art* 12 (1917), 86. On Egyptian balances, see also F. Chabas, "Sur quelques instruments égyptiens de mesurage," *Zeitschrift für ägyptischen Sprache und Altertumskunde* 7 (1869), 57–63; A. Weigall, "Weights and Balances," in *Catalogue général des antiquités égyptiennes du Musée du Caire* (Cairo, 1908), pp. 3–12; H. Ducros, "Etudes sur les balances égyptiennes," *Annales du Service des Antiquités de l'Egypte* 9 (1908), 32–53; 10 (1910), 240–253; 11 (1911), 251–256; S. Glanville, "Weights and Balances in Ancient Egypt," *Proceedings of the Royal Institute of Great Britain* 29 (1936), 10–40.

5. The most extensive corpus of Egyptian balance weights is to be found in Petrie, *Ancient Weights and Measures*.

6. D. Dunham, *Second Cataract Forts*, vol. 2 (Boston, 1967), pp. 35–37 and pl. XXXV B.

Figure 2 Stone balance weights bearing the hieroglyph for gold, found (1924) by the Harvard University–Museum of Fine Arts Expedition in the ruins of the Egyptian fort at Uronarti, Sudan, Dynasty 12 (1991–1786 B.C.). (Dows Dunham, *Second Cataract Forts*, vol. 2 [Boston: Museum of Fine Arts, 1967], pl. XXXV B.) The presence of such weights on the Nubian frontier emphasizes the fact that by the Middle Kingdom the Egyptians were obtaining most of their gold from Kush, south of the Second Cataract of the Nile.



the sign is a set of single strokes designating what each stone was worth. The following table summarizes the metrological information relevant to our purposes:

Gram Values of Six Inscribed Weights from Uronarti

Object	*Material*	*Inscription*	*Mass (grams)*	*Theoretical derived unit (grams)**
(in Khartoum)	serpentine	"Gold, 5"	61.0	12.20
MFA 24.751	granite	"Gold, 5"	66.3	13.26
MFA 24.750	serpentine	"Gold, 6"	74.5	12.42
(in Khartoum)	alabaster	"Gold, 6"	86.5	14.42
(in Khartoum)	alabaster	"Gold, 7"	92.0	13.14
MFA 24.752	alabaster	"Gold, 9"	116.0	12.89

*Mean theoretical derived unit (grams): 13.06.

Many factors contributed to the degree of precision expected and attained by ancient merchants.[8] The range of the derived units for these pieces (2.22 grams) might strike us today as unacceptable, but according to our understanding of the degree of sophistication of Middle Kingdom weighing technology, such a range would have been tolerated. Each of the six theoretical derived unit values in the table above falls within the range of the *beqa* standard. The *beqa*, which was calculated by Petrie at between 12.18 and 13.61 grams,[9] was a unit whose primary function was the evaluation of gold and gold dust; it is arguably the oldest and longest-lived unit of weight known. It has been proposed that the six uninscribed stone pieces from predynastic Naqada, discussed earlier, conform to the *beqa* standard.[10] Rectangular stone balance weights inscribed *nub* ("gold") were not uncommon in the Old and Middle Kingdoms, and they continued to be important through Dynasty 18 (1558–1085 B.C.).[11] A glance at the register of balance weights attrib-

7. A. Gardiner, *Egyptian Grammar*, 3rd ed. (London, 1957), p. 505. See also H. Brugsch, "Das altägyptische Goldgewicht," *Zeitschrift für ägyptischen Sprache und Altertumskunde* 27 (1889), 85–96.

8. For a discussion of factors related to our determination of ancient precision in weighing, see K. Petruso, "Systems of Weight in the Bronze Age Aegean," Ph.D. dissertation, Indiana University, 1978, chap. 1.

9. Petrie, *Ancient Weights and Measures*, pp. 17–19.

10. Ibid, p. 18; Skinner, *Weights and Measures*, p. 3.

11. Weigall, "Weights and Balances," pp. ii, xiv.

uted to the *beqa* standard by Petrie shows that this unit was multiplied decimally (denominations of 10, 20, 40, 50, 100, and 200 units are common) and divided binarily (1/2, 1/4, 1/8, 1/16 units are typical).[12] This dual approach combines usefulness afforded by tens in tallying large numbers of units with precision afforded by halvings in very small quantities (indeed, halving comes naturally to a person working with a double-pan balance; it is not surprising, then, that such a procedure was applied to a material as dear as gold dust).

The set of balance weights from Uronarti (and the system on which they were based) admittedly had a somewhat rarefied function. Far more common in ancient Egyptian weighing was a system whose standard mass had undergone a fair amount of oscillation before the New Kingdom but was effectively regularized by the time of Dynasty 18. The building block of this system was the *qedet* (variant *kite*), whose mass came to be standardized at between about 9.1 and 9.3 grams.[13] Ten *qedets* made a *deben*, the next denomination up the scale; ten *debens* equaled one *sep*. In this system, as in the *beqa* system, a decimal flavor is clearly visible. The Egyptian numerical notation also followed a decimal system, with different hieroglyphs for the powers of ten up to one million.[14]

It is not possible within the scope of this article to consider fully the topic of ancient Egyptian weighing systems. The corpus of surviving Egyptian weights shows the *beqa* and the *qedet* to have been Egyptian *sui generis*, but several other systems were in use in ancient Egypt as well from the Old Kingdom on. Balance weights inscribed with unit names better known in Syria, Palestine, and Mesopotamia are known from Egyptian archaeological sites, and they testify to a complex system of trade relationships among the states of the ancient East. Since the nineteenth century, historical metrologists have made attempts to prove by mathematical calculation that some national units were standardized to others. In general, though, one ought to regard such attempts with caution, especially for the period preceding the invention of coinage (eighth century B.C.).

Ironically, the system of weighing used in the prehistoric Indus Valley, even though it is supported by no historical or economic testimonia, is even less ambiguous as regards the absolute value of its standard. As in the case of Egypt, a large enough sample of Indus Valley balance weights survives to permit statistical analysis with a view to determining both the absolute values of the denominations in use and the structure of the system.

The museum possesses a splendid collection of fifty-eight stone balance weights excavated in the 1930s at Chanhu-daro, now in Pakistan, by an expedition of the Museum of Fine Arts and the American School of Indic and Iranian Studies.[15] The civilization of the Indus Valley, designated as Harappan (ca. 2400–1700 B.C.), unknown to archaeology until the discovery of Mohenjo-daro in 1921, was one of the great early urban cultures of the Near East. The Harappan culture is technically prehistoric. In the absence of contemporary documentation on the mathematical basis of the economy, the historical metrologist is faced with the task of searching for a quantum or quanta upon which the system of weight might have been based. The possibility that each city had its own standard cannot be overlooked; to complicate matters, it is not unlikely that more than one system might have been used at any single site. Fortunately, metrological analysis of the available data has demonstrated that the Indus sites possessed a unique and elegant system of weight mensuration, which, by all indications, was regulated with great precision over an immense geographical area.

A. S. Hemmy, in a preliminary analysis of the weights from Mohenjo-daro, was able to demonstrate a clear series of binary relationships (i.e., in which adjacent

12. Petrie, *Ancient Weights and Measures*, tables XL–XLI.

13. The history of the quest for the absolute value of the *qedet* is a fascinating one and in many ways stands as a metaphor for the history of metrological studies in general. The reader is referred to F. Chabas, "Note sur un poids égyptien de la collection de M. Harris, d'Alexandrie," *Revue archéologique* 3, 2nd ser. (1861), 12–17; H. Lepsius, "Die Metalle in den ägyptischen Inschriften," *Abhandlungen der Berliner Akademie*, 1871, p. 41; E. von Bergmann, "Die Anfänge des Geldes in Aegypten," *Numismatische Zeitschrift* 4 (1872), 161–180 (esp. pp. 165–169); and O. Viedebantt, *Antike Gewichtsnormen und Münzfusse* (Berlin, 1923). Not until Petrie's *Ancient Weights and Measures* appeared in 1926 did the emphasis in isolating the absolute value of the *qedet* shift from textual sources to the balance weights themselves.

14. Gardiner, *Egyptian Grammar*, p. 191. On Egyptian numbers and mathematics, see O. Neugebauer, *The Exact Sciences in Antiquity* (Oxford, 1951), chap. 4.

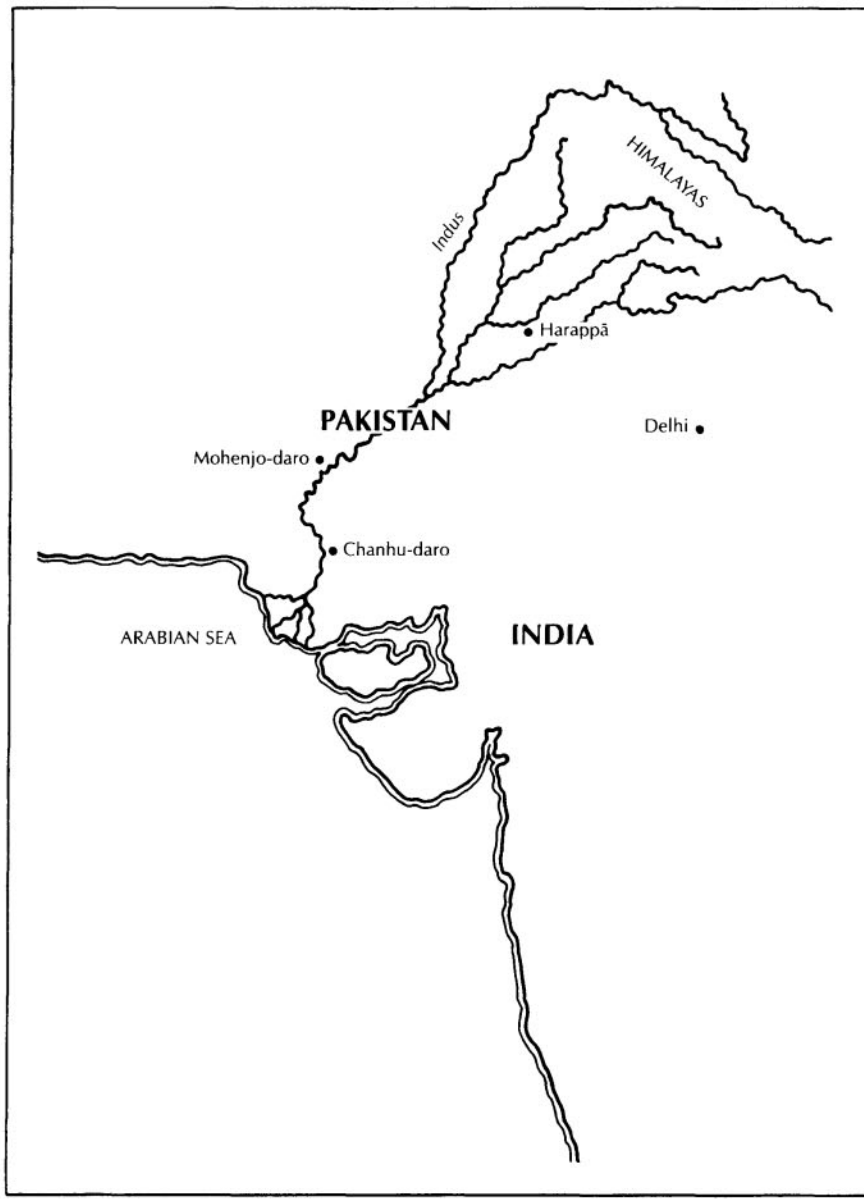
15. E. J. H. Mackay, *Chanhu-daro Excavations, 1935–36* (New Haven, 1943).

denominations were generated by doubling or halving).[16] A series in the following denominations was apparent to him in the early stages of his research: 1, 2, 4, 8, 16, 32, 64.

That the people of the Indus knew and made use of a decimal base as well is evident from many excavated weights of larger multiples. Weights of the following denominations were in evidence at Mohenjo-daro:

Basic denominations:	1	2	4	8	16	32	64	
Factors of 10:					160	320	640	
Factors of 100:		200			1,600	3,200	6,400	12,800
Factor of 1,000:				8,000				

The Indus Valley



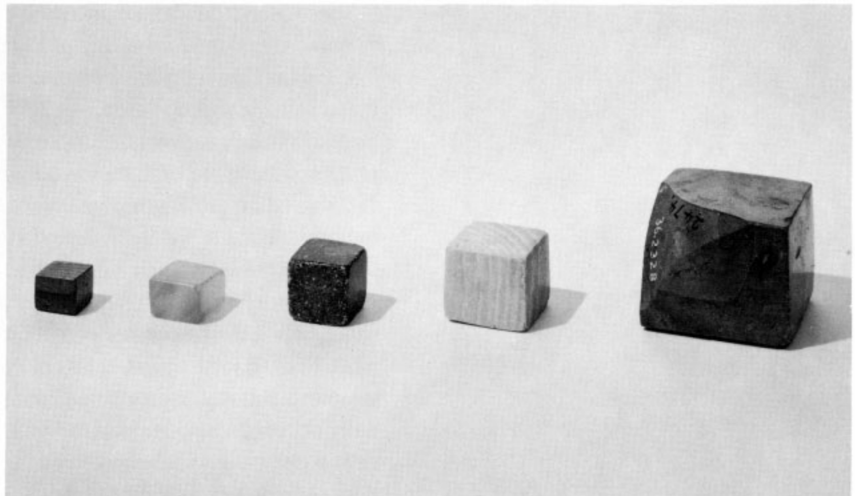


Figure 3 Stone balance weights excavated at Chanhu-daro, Pakistan, late 3rd–early 2nd millennium B.C. Joint expedition of the American School of Indic and Iranian Studies and the Museum of Fine Arts, Boston (1935–1936). From left to right: *36.2305, 36.2307, 36.2281, 36.2321, 36.2328.*

These provide the pattern for the basic system of factors. In addition, intermediate factors at other convenient denominations (e.g., 2/3, 24, and 48) may be seen in the inventory of the approximately 2,000 specimens known.

Hemmy, in his thoughtful early attempts to "decode" the Harappan system, argued that the mass of the fundamental unit on which the entire system was constructed was in the vicinity of 0.86–0.87 grams.[17] In the absence of any clues (inscribed pieces, historical or economic texts, etc.) that might have pointed toward the mass of primary importance, he chose the smallest factor, having assumed implicitly that the system was generated by multiplications of it (rather than by multiplications and divisions of a larger unit). In the final publication of the Chanhu-daro excavations, Ardelia R. Hall, formerly of the museum's Department of Asiatic Arts, chose instead as the primary unit a mass in the vicinity of 13.63 grams (i.e., a 16-factor of Hemmy's proposed unit).[18] A mass of this order would bring the unit into the range of the other standards in the ancient world (about 5–15 grams) for which contemporary inscriptional evidence exists.[19] In the final analysis, however, whatever the absolute value of the standard Indus unit may have been, the mechanics of the system are clear, and they inform us on the mathematical proclivities—both binary and decimal in mode—of the merchants who used these stones.

Five of the fifty-eight balance weights excavated from Mound II at Chanhu-daro are at present on display in the museum's gallery of ancient Near Eastern art (fig. 3). In shape and material they are typical of the Harappā culture: cubes or rectangular solids fashioned from dickite, chert, chalcedony, and diorite. The weights are pleasantly varied in color and grain pattern and have smoothly polished surfaces. (The photograph cannot do justice to the colors, of purplish brown, brownish grey, banded ivory, yellow, and black.) The method of manufacture was simple enough: the pieces would be chiseled into roughly cubical shape and then rubbed on a hard, grainy, but flat surface, being weighed frequently, until they were brought down to the desired mass.

16. A. S. Hemmy, "Systems of Weights at Mohenjo-Daro," in J. Marshall, ed., *Mohenjo-Daro and the Indus Civilisation*, vol. 2 (London, 1931); idem, "System of Weights," in E. J. H. Mackay, ed., *Further Excavations at Mohenjo-Daro*, vol. 1 (Delhi, 1938).

17. Marshall, *Mohenjo-Daro*, p. 591.

18. A. R. Hall, "The Cube Weights in Boston," in Mackay, *Chanhu-daro Excavations*, pp. 239–246.
The reader should not conclude that there is any historical significance in the fact that the units calculated for Egypt and the Indus Valley are so close in mass. It may not be assumed, as has been done commonly by many historical metrologists (e.g., Petrie, *Ancient Weights and Measures*, and, most prominently, A. E. Berriman, *Historical Metrology* [1953]), that similarities in absolute unit values demonstrate contact between cultures. This *caveat* takes on special significance in analyses of metrical data of prehistoric cultures. One must avoid the temptation to make sweeping cultural generalizations on the basis of mathematical calculations of derived metrical units. All indications are that the Indus Valley system of weight mensuration was South Asian *sui generis* and developed quite independently from that of Egypt.

19. See Petrie, *Ancient Weights and Measures*, passim.

These particular pieces are quite well preserved. The largest (36.2328) appears to have been damaged at one of its corners, but close examination reveals that the fracture (accidental?) has been intentionally and carefully rubbed smooth. Their masses, in ascending value, are 3.97, 6.84, 13.41, 28.87, and 131.47 grams. These absolute values express the approximate ratio 1:2:4:8:40. In terms of Hemmy's proposed standard unit, they would represent denominations of 4, 8, 16, 32, and 160; based on the alternative unit of about 13.63 grams, they would represent denominations of 1/4, 1/2, 1, 2, and 10 units.

Each of these balance weights had a different stratigraphic context (i.e., they were not found as a set). The first four (from the left) represent a practical binary series, while the heaviest piece, if provisionally assigned a value of ten units, would more likely have begun a series of the second order (10, 20, 40, 80, 160, etc.). It is tempting, though unproductive, to speculate whether the largest piece had originally occupied a position in the first order (say, 16 units) and, as a result of accidental chipping, was salvaged by being abraded down to occupy the 10-unit denomination in a different set.

Most of the cubical balance weights found at Chanhu-daro were excavated in Harappā II levels from Mound II. Twenty-two weights were found in and about one particularly well appointed house, which, to judge by the finds within, was a beadmaker's workshop. In addition to the weights and fragments of copper scale pans, dozens of complete and unfinished beads of bronze, carnelian, lapis lazuli, and other semiprecious stones were found in context with stone-polishing equipment and lapidary tools. Hemmy concluded, quite logically, that the smallest weights (of just over half a gram each) would have been used to evaluate beads made from the dearest stones. It is significant that one room in this atelier contained two complete sets of weights in denominations from 2/3 to 64 units.[20]

One other factor that is worthy of note in discussing the Indus system is the remarkable consistency of absolute mass demonstrated in specimens widely separated in time and place. Comparison of the calculated unit values from the main excavated sites (Mohenjo-daro, Harappā, and Chanhu-daro) reveals an astonishing degree of precision in their manufacture. Deviations from Hall's calculated theoretical mass of 13.63 grams are unexpectedly low: within ± 2% of that figure over some seven centuries (compared with, for example, the estimated deviation for ancient Egypt of (± 5%).[21] That such precision was so demonstrably within the capability of the Harappan weighing apparatus (again, the simple double-pan balance) leads one to wonder at the political and economic circumstances that produced this unprecedented degree of accuracy. Consistency of standards is often taken as an indication of strong central market authority or, alternatively, in the opinion of Sir Mortimer Wheeler, a high level of "civic discipline."[22] Far more commonly attested in ancient systems of measurement (capacity and length, in addition to weight), especially in those cultures for which the historical metrologist is blessed with a great amount of data, is the fluctuation, often extreme, of absolute standards.

For the historical period there exists occasional evidence of an intentional devaluation or other adjustment of a unit by royal decree (such as Solon's reform of weights and measures in Athens in the sixth century B.C.). Even in the case of nonliterate peoples, one must allow for occurrences of various market activities, both on the social level (for example, inflation) and on the individual level (for example, shortweighting). Metrological analysis of such information provides tantalizing glimpses into the workings of antique economic systems. Unfortunately, however, the metrologist is very seldom able to offer satisfying and irrefutable reconstructions of those economic systems. This discipline is still in the stage of documentation and

20. Mackay, *Chanhu-Daro Excavations*, pp. 41–58, 243.

21. Skinner, *Weights and Measures*, p. 10.

22. M. Wheeler, *The Indus Civilization*, 3rd ed. (Cambridge, 1968), p. 83.

23. For an example of the kinds of more abstract questions about economic systems that might be raised by metrological data, see K. Petruso, "Reflections on Minoan and Cycladic Metrology and Trade," in J. L. Davis and J. F. Cherry, eds., *Papers in Cycladic Prehistory* (Los Angeles, 1979), pp. 135–141.

the testing of preliminary hypotheses that might account for demonstrable metrical changes through time. It is to be hoped that, with the increase of scholarly attention to metrical artifacts, the study will move beyond the question-formulating stage.[23]

Even more fascinating than the economic issues that can be raised in metrology are the issues related to the history of mathematics. Metrical artifacts such as balance weights, graduated vessels for the measurement of dry and liquid capacity, and linear rules are concrete expressions of those abstract concepts we call numbers. As such they are subject to empirical analysis. The balance weights from Harappan sites suggest that, like the Egyptians, the ancient people of the Indus Valley used a counting system based upon the number ten, doubling and halving certain quantities with facility (to be sure, doubling and halving are the simplest functions to perform on the single-beam balance). The number ten is the basis of the decimal system, whose main advantage is the ease of tallying it affords, and whose inspiration is commonly believed to have been the number of fingers with which we are equipped. But there lurks in the Indus system of weight measurement something more subtle, namely, an understanding of the *powers* of ten, at least to the fourth exponent (ten thousands). Balance weights of this order of magnitude (which were doubtless used for the parceling out of grain and other foodstuffs) indicate that the Harappans had a familiarity with large numbers, a familiarity that would not have made itself known to us through any line of research other than historical metrology. It is hoped that this essay has suggested, through these examples, some of the fascinating routes of inquiry – historical, economic, political, and intellectual – that can be pursued by examining objects as humble as stone balance weights: they teach us something about the conceptual development of ancient man.