drills. Rather, it is proposed that children need training in recognizing the sounds of spoken language and in learning to make those distinctions in spelling that they find difficult. Teachers, too, need to cultivate their phonemic awareness. Armed with a knowledge of the sounds of English and working directly with young writers, they can deduce what words children are attempting and why they spell them as they do. Once this is accomplished, the route to better spelling becomes clear.

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The Origins of Script

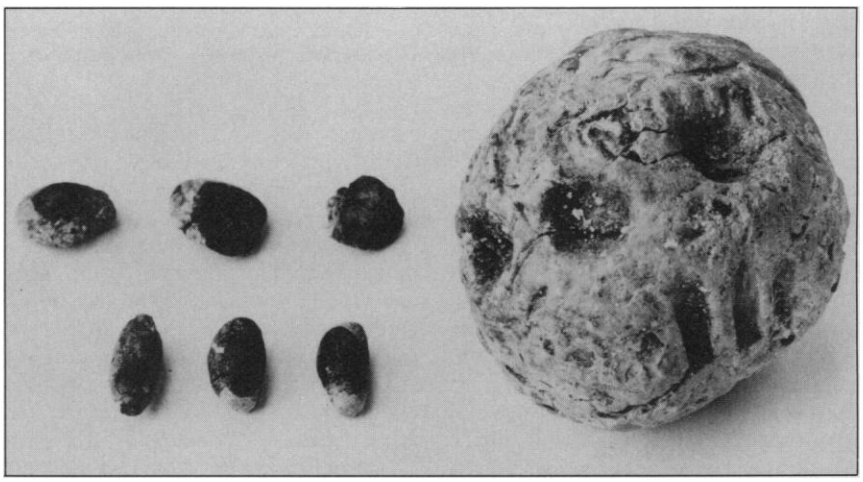
Before Writing. DENISE SCHMANDT-BESSERAT. In two volumes. Vol. 1, From Counting to Cuneiform. xviii, 269 pp., illus. $60. Vol. 2, A Catalog of Near Eastern Tokens. xxxvi, 416 pp., illus. $85. University of Texas Press, Austin, 1992.

From its pictographic beginnings toward the end of the fourth millennium B.C. in the southern Mesopotamian settlement of Warka, the cuneiform script moved through various phases of increasing multivalence—the use of pictographs as syllabic signs—until in the first centuries of the second millennium scribes of the Old Assyrian period in the north of Mesopotamia and of the Old Babylonian of Hammurabi in the south commanded an almost entirely syllabic cuneiform. A further reduction of syllabaries used in the Middle East of the first millennium B.C. to an exceedingly efficient alphabet was a logical consequence in this "democratization" of writing. Such has been the overwhelmingly accepted scheme of script development, in particular since the publication in 1952 of the fundamental *Study of Writing* by I. J. Gelb of the Oriental Institute of the University of Chicago.

Unassuming clay finds from Near Eastern excavations of prehistoric settlements have recently entered the continuing discussion of early writing with all the force of a bilingual inscription. Many of these small, geometrically shaped objects—spheres, disks, cones, and so on, both plain and decorated with various incisions—found seemingly scattered in tells had both figuratively and literally been cast aside by archeologists as objects of dubious importance, interpreted as perhaps gaming pieces or objects used in cultic practices; others found encased within sealed clay balls aroused only moderate interest. Since her first work on such envelopes from the Iranian city of Susa, Denise Schmandt-Besserat has with great effort gathered all available archeological evidence bearing on the possible early use of these objects, which she calls "tokens." She published her first account of the objects in the mid-1970s and has since presented in numerous articles data on the material finds as well as her own interpretation of the objects. In her two-volume *Before Writing* she offers a theory of script development in the Near East that deviates radically from that of Gelb. According to Schmandt-Besserat, cuneiform did not arise suddenly during the late Uruk period as a purely pictographic script, but rather developed in a measured, linear fashion from an already widely conventionalized accounting system employing such tokens.

Much of Schmandt-Besserat's argument is cogent and appealing. These artifacts of an assumed ancient accounting system range from undecorated geometric objects present in stratigraphic levels dating to 8000 B.C. to a mix of plain and decorated ("complex") tokens in the centuries immediately before the appearance around 3200 B.C. of true script in Warka. Many of the complex tokens bear a striking resemblance to signs found on the earliest tablets. The chronological development of these objects suggests that they were indeed the necessary precursors of the fully developed Uruk script. Indeed, these small objects virtually disappeared with the emergence of writing. Moreover, the use of "tokens" as bookkeeping aids in the context of rapid urbanization and social hierarchization mirrors the primary function of early cuneiform tablets: to control the flow of goods and services to and from central authorities. But it is above all the presence of plain and possibly some complex tokens within sealed clay balls, in rare cases with impressions on their surfaces corresponding to the shape and number of the objects inside and found in levels dating to a time immediately before the first tablets, that unmistakably points to a forerunner role of such objects in archaic writing. These tokens formed discrete and meaningful assemblages. In this scheme, the plain tokens represented quantities and were thus precursors of "numerical" signs impressed with the blunt end of a stylus, whereas the complex tokens represented goods and could be considered three-dimensional "ideograms."

There are nonetheless painful cracks in this wall. Though the role of the tokens found within or at least in conjunction with clay balls as forerunners of the highly developed and conventionalized numerical signs of the earliest Near Eastern tablets (the script of which is better called "proto-cuneiform," since its connection to the Sumerian language, presented by the author as fact, remains unproven) is now universally accepted, the many outwardly similar objects from settlements reaching from Palestine up through Anatolia and across Iraq to eastern Iran dating from 8000 to 3000 B.C. can only with great faith be considered members of a systematic and interregionally accepted method of accounting. The author invests much effort in making this system seem to have been in ubiquitous use, to the point of identifying even very dubious small finds as tokens. Thus, pellets found in caves of eighth- and seventh-millennium hunter-gatherers and herders in Persia are for Schmandt-Besserat evidence for prehistoric accounting. Such objects found in rubbish heaps are said to reflect the later practice of discarding accounting tablets in Babylonia upon completion of a transaction; but is an explicit and restricted document comparable to a collection of impersonal calculi? The author believes that small clay objects found in graves of adults underscore the high status of archaic bookkeepers and small stone objects represent quantities of grain offered deceased children. Such assertions cannot be rejected out of hand, since

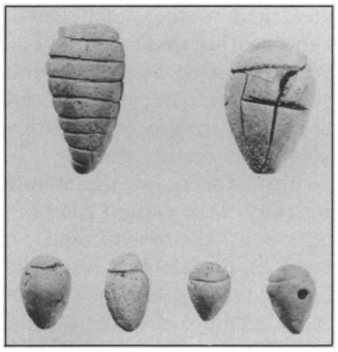


"Envelope bearing impressed markings corresponding to the tokens held inside, Susa (Sb 1940), Iran." The notation seems to represent measures of grain. [From *Before Writing*; courtesy Musée du Louvre, Département des Antiquités Orientales] the all-too-wanting record-keeping of the excavators of these early sites prevents us from learning more about the context of the great mass of early geometrically shaped objects. However, they remain suspiciously ad hoc.

The perhaps more intriguing assertion that decorated tokens appearing from approximately the middle of the fifth millennium B.C. in Warka (but only from about 3500 B.C. in Iran and Syria), often pierced and thus apparently strung, led directly to pictographic script is no less tenuous. Since the argument of graphic similarity is notoriously misleading—it has in the past led Sumerian scribes as far afield as Romania and China—only the tokens found in conjunction with clay balls should be considered relevant to a discussion of Babylonian pictography. These are not many; in fact, only the so-called oil token (presumed to correspond to the proto-cuneiform sign ( ) was clearly enclosed in clay envelopes, and it may be questioned whether this key evidence is not simply a derived numerical sign much like the sexagesimal signs impressed with a single stroke, used, for example, to qualify a particular type of beer in the archaic texts from Warka. Certainly on the basis of this token, found in Uruk and in the Syrian site Habuba Kabira, no judgment is possible about the ultimate role of the myriad of decorated tokens from this period. The fact that only this complex token was found in envelopes leads rather to the question, Why were not other products of the archaic economies—beer, wool, and so forth—so represented?

But perhaps complex tokens are yet to be found in clay balls. The evidence drawn from these most important sources of information could have been much more substantial had the author had access to the contents of at least all such envelopes excavated in the Near East now in Western collections. Fully 80—the majority of all known envelopes—remain intact, and if you take one in your hand and shake it you will hear the calculi rattling inside. Access to this information has been limited by officials responsible for the collections, ostensibly to protect the integrity of the seal impressions on the surfaces. This is a deplorable impediment to research; just as meticulous records of walls, ovens, and so on are kept as stratigraphic levels are removed in the course of destructive excavations, so can seal impressions be recorded before they suffer any damage during the breaking of the envelopes. The prospect of using tomographic analysis in the future is no excuse for this obstruction.

The hard evidence for the graphic continuation of complex tokens in proto-cuneiform could, further, have been emphasized more strongly, at the expense of lists of attested token forms from each excavation, and Schmandt-Besserat could have been more conservative in her identification of complex



"Ovoids, Uruk, Iraq." [From *Before Writing*; courtesy Deutsches Archaeologisches Institut, Abteilung Baghdad]

tokens with proto-cuneiform ideograms, which many nonspecialists will confuse with contextually justified speculations. One of her best arguments for an ideographic connection is almost lost on page 119 of volume 1, in which the Warka find W 20987,27, a set of tokens unearthed together with crushed envelopes, is depicted. Among the plain tokens in that collection are not only the heralded oil token but also three exemplars of what she interprets to be "trussed poultry" (closer to the sign (, "bull") and one of the sort that, when impressed with parallel strokes, has routinely been declared an early representation of the proto-cuneiform sign for silver. Moreover, a possible connection of some of these complex tokens with corresponding signs in the proto-Elamite script, which evolved very shortly after the emergence of proto-cuneiform in Mesopotamia, is left unmentioned, despite the fact that the majority of contextually determined tokens derive from Elamite Susa. I am convinced, for example, that in particular the script designations of small cattle—in both cases so-called abstract signs of the type often mentioned in *Before Writing*—are not only semantically but also graphically related in the two archaic scripts. For example, the proto-Elamite seems clearly related to the proto-cuneiform , meaning collectively "sheep and goats." Even more important may be the few tablets from Susa that seem to represent a link between the envelopes and nonideographic, so-called numerical tablets on the one hand and ideographic accounts on the other. These sealed tablets are impressed with numerical signs and as a rule just one ideogram. One of the ideograms used in Susa, a paraboloid form (numbers 10.4 to 10.10 in the author's list of artifacts), is found on tablets from Warka, which are also sealed and would have been labeled pre-ideographic numerical tablets were it not for the presence of this ideogram.

Schmandt-Besserat presents in the final two chapters of the first volume of her work (volume 2 is devoted entirely to the artifact catalog, listing objects site by site, but unfortunately omitting stratigraphic information) an interpretation of the material finds. Tokens, she argues in chapter 8, "played an important role in the collections of dues and tribute necessary to sustain the first city states"; further, "the presence of complex tokens in distant countries identifies places paying tribute to the southern Mesopotamian temple." I know of no substantial evidence to support this claim. Chapter 9 considers the role of tokens in counting and the emergence of writing. Though it is possible to find fault with the often imprecise terminology employed in this section, historians of science will give more attention to the broad direction the author takes, leading the reader from her understanding of concrete counting with the aid of tokens to the use of abstract numbers in the earliest ideographic texts. To these readers a caveat: Schmandt-Besserat's philological argumentation here suffers from a dependence on her own speculation about widespread early use of tokens, from a lack of attention to the chronology of textual attestations and an unsupported ascription of early numerical systems to Sumerians, and from a postulated abstraction of number in proto-cuneiform that is contradicted by the context-dependent use of numerical signs in the texts themselves. As difficult to understand as proto-cuneiform records may be—proto-Elamite is again left unmentioned—they clearly deserve better coverage than here offered.

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Invertebrates Long Gone

Trilobites. H. B. WHITTINGTON. Boydell, Rochester, NY, 1992. xii, 145 pp., illus., + plates. $79. Fossils Illustrated, vol. 2.

Being probably the most easily recognized and attractive of all invertebrate fossils, trilobites are standard-bearers of invertebrate paleontology, as Stephen Jay Gould notes in the preface to this book. It is no accident that it is a trilobite that is embossed on the front covers of two standard invertebrate paleontology textbooks published 35 years apart (Moore, Lalicker, and Fischer, 1952, and Boardman, Cheetham, and Rowell, 1987). Trilobites dominated Cambrian seas and were still abundant in the Ordovician, were less so in the Silurian and Devonian, and were rare in the Carboniferous and Permian. Whittington's book brings together the considerable amount of information on these organisms that has become available since the publication of the trilobite ing] into an ordinary particle . . . ," I focus on a proposed experiment using a "Stern-Gerlach (SG) apparatus" (*1*).

"[T]he SG experiment epitomizes the quantum mechanical description of microscopic phenomena" (2). The famous SG experiment featured a beam of magnetic atoms (spin 1/2) running through a transverse, inhomogeneous magnetic field, resulting in the splitting of the beam into two components. When the field inhomogeneity is sufficiently strong that the two emerging components do not overlap, one has made a measurement of the transverse component of magnetic moment. With weakening field gradient, from the onset of overlap to undetectable broadening of the beam width, there is no act of measurement.

Consider feeding a single beam from one SG apparatus into a second one that has the direction of the inhomogeneity rotated by the angle θ relative to the first one. Geometrical intuition correctly suggests that the average spin emerging from the second apparatus is provided by projection of the initial output, as expressed by the factor cosθ. Then the fractions that emerge in the two beams are

$$\frac{1}{2}(1+\cos\theta) = \left(\cos\theta\,\frac{1}{2}\,\theta\right)^2$$

and

$$\frac{1}{2}(1-\cos\theta) = \left(\sin\frac{1}{2}\,\theta\right)^2$$

These fractions are consistently interchanged when the directions of the beams are interchanged through the substitution $\theta \longleftrightarrow \pi - \theta$.

One sees the emergence of fractions—probabilities—as squares of more fundamental quantities: probability amplitudes. I use this designation, rather than "wave" or wave function, because the latter invite misleading analogies with classical waves and classical determinism. In contrast, probability amplitude makes no reference to individual acts, which are generally unpredictable, but recognizes that microscopic phenomena are statistically predictable.

According to Freedman's account, in the proposed SG experiment, the inhomogeneity of the transverse "magnetic field is kept weak." I interpret this to mean that no SG measurement is performed, but a detectable broadening of the beam can occur. Then comes the new ingredient: a strong homogeneous field along a different direction. That certainly acts to suppress the effect of the inhomogeneous field, conceivably to the point that no beam broadening remains. Yet the claim is made that a slight deflection of the whole beam should be observable. I prefer to leave that as a moot point, because it is irrelevant.

Omitted from this description is a much more important phenomenon: the longitudinal SG effect (2). When a magnetic atom enters a region of homogeneous magnetic field, thereby acquiring an additional positive, or negative, potential energy, its kinetic energy correspondingly decreases, or increases, to maintain the total energy.

This slowing down, or speeding up, of individual atoms produces a splitting of the beam in time, rather than space. A magnetic moment measurement is realized when the ratio of magnetic energy to kinetic energy is sufficiently large that no overlap of the outgoing beams occurs. The extreme example appears when one type of atom is brought to rest and sent into retreat, while the second type emerges from the other side. Here, indeed, is the ultimate clash between the two concepts. Tenets anyone?

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1. Y. Aharonov, J. Anandan, L. Vaidman, *Phys. Rev. A.* 47, 4616 (1993).
2. J. Schwinger *et al.*, *Z. Phys.* D10, 135 (1988).

Response: Schwinger's disagreement with Freedman's article in the preceding letter is irrelevant to the proposed "protective" Stern-Gerlach (SG) experiment (*1*). The inhomogeneous magnetic field here is the Stern-Gerlach field with the usual strength, and not a weak field such that "no SG measurement is performed," as stated by Schwinger. This ordinarily splits the wave function of a neutral spin-1/2 atom into two wave functions with opposite spins. But if the spin state is "protected" by a homogeneous magnetic field (which is large *compared* with the inhomogeneous magnetic field) in the unknown direction of the spin, then the wave function would not split. Even though the inhomogeneous field is small compared with the homogeneous field, it is large enough to cause a shift in the position of the center of mass of the particle, which is larger than its quantum spread. By observing this shift for three such experiments, one can determine the spin state for a single particle, instead of having to use an ensemble.

We also studied (*1*) the longitudinal SG experiment that Schwinger mentions. Here also when the spin state is protected the wave function does not split, as ordinarily happens. By observing the displacements of the wave packet for three such experiments, one can reconstruct the spin state. In both experiments the spin state would be determined in a nonstatistical way for a single particle.

These proposed experiments are special cases of a general scheme to measure the wave function of a *single* particle "protectively," as shown (*1*). And this *is* allowed by the laws of quantum theory. But it provides a new meaning to the wave function that seems to go beyond the usual meaning of the "probability amplitude" used by Schwinger.

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Security of E-Mail

Users of e-mail as well as publishers of articles or data in bulletin boards should be aware that the information they are transmitting is not secure. This can affect, indeed destroy for most of the countries of the world, the rights of the transmitter (and of the transmitter's employer) to obtain patent protection. Indeed, the transmitter, if transmitting without the knowing consent of the employer to the specific information being transmitted (as for any publication), may be breaching provisions that appear in a great number of employment contracts. This is true of university employment contracts to a somewhat lesser extent than industry employment contracts. The e-mail user may not be risking as much as the bulletin board user because an e-mail message, while it is no doubt stored at least temporarily at each station from which it is forwarded, may not be accessible to the public. However, there have been no decisions of which I am aware in any country on this point.

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Corrections and Clarifications

In Robert K. Englund's review of *Before Writing* by Denise Schmandt-Besserat (University of Texas Press, Austin, 1992) in the 11 June issue (p. 1670), two cuneiform characters in columns 1 and 2 on page 1671 were misrepresented. The correct characters are as follows.