Tokens of Plenty

How an ancient counting system evolved into writing and the concept of abstract numbers

By IVARS PETERSON

"It must have required many ages to discover that a brace of pheasants and a couple of days were both instances of the number 2." — Bertrand Russell

One, two, three, four. . . . We learn to count at such an early age that we tend to take the notion of abstract numbers for granted. We know the word "two" and the symbol "2" express a quantity that can be attached to apples, oranges or any other object. We readily forget the mental leap required to go from counting specific things such as apples to the abstract concept of number as an expression of quantity.

Just such a leap may have occurred roughly 5,000 years ago among people living in ancient Mesopotamia, a fertile region watered by the Tigris and Euphrates rivers in the Middle East. Ten thousand years ago, counting was a concrete affair. Residents of small agricultural settlements kept track of their goods by maintaining stores of baked clay tokens — one token for each item, different shapes for different types of items. A marble-sized clay sphere would stand for a bushel of grain, a cylinder for an animal, an egg-shaped token for a jar of oil.

Thousands of years later, the growth of villages into cities and the increasing complexity of human activities forced a shift to more efficient means of data storage. The token system evolved into a kind of shorthand in which signs indicating standard measures of grain, impressed on a clay tablet, came to represent not grain or any other specific commodity but the concept of pure quantity. The coupling of signs for numbers with pictorial symbols for specific goods — the beginning of writing — provided ancient accountants with the tool they needed to record the multitudinous and varied activities of a city's citizens.

It was a revolution in both accounting and human communication, says archaeologist Denise Schmandt-Besserat of the University of Texas at Austin. For the first time, it provided a reckoning system applicable to any and every item under the sun. It put an end to a cumbersome scheme in which particular tokens were used for counting different goods. It also made taxation on a broad scale feasible.

For Schmandt-Besserat, this new picture of the origin of abstract numbers and the beginning of writing is the culmination of nearly two decades of study that began with a search for the earliest examples of the human use of clay. "I wanted to find out how clay was discovered, for what and when, so I went from museum to museum to review clay collections from the times between 10,000 and 6,000 B.C.," says Schmandt-Besserat. "I was looking for things like bricks and pots. Instead, I was surprised to find all these little clay objects. Nobody really knew what they were."

The objects, recovered from archaeological sites ranging from Turkey and Palestine to Syria and Iran, came in a variety of geometric shapes, including cones, spheres, disks, cylinders and pyramid-like tetrahedrons. Some appeared to be miniature models, an inch or less in size, of animals, tools and other natural or human-made items. Others bore markings such as incised lines. Sometimes excavators found only a few specimens; occasionally they encountered large collections of these mysterious objects.

Traditionally, archaeologists separated these objects into different categories according to shape and tried to guess the use of each particular class of objects. For instance, the disks, they thought, may have been lids for small jars and the spheres could have been marbles.

In contrast, Schmandt-Besserat tackled the problem from the point of view of what these objects had in com-

Archaeologist Denise Schmandt-Besserat with a collection of ancient clay tokens from the Middle East.

Beverly Spicer

Courtesy Schmandt-Besserat

Plain clay tokens in the shape of cones, spheres, disks and tetrahedrons were used in ancient Mesopotamia to represent quantities of various agricultural products.

mon: They were all made of clay. They were similar in size and manufactured in roughly the same way.

"It was obvious to me they belonged together," Schmandt-Besserat says. Once these objects, or tokens, came to be considered as a group, their role in counting and record keeping gradually became more clear.

"Within a year, I realized that I was dealing with the precursors of writing," Schmandt-Besserat says. "But it took me a long time to see their connection with counting and numbers."

It was like working on a puzzle, she says. It meant tracking the development of writing on clay tablets backward in time, from what are known as cuneiform symbols back to pictographs and then to token shapes.

"Unfortunately, very few pictographic signs can be traced back and identified with tokens," Schmandt-Besserat. "There are many tokens for which there is no known translation."

The first appearance of clay tokens in the archaeological record coincides with the development of agriculture, especially grain cultivation, in the period from 8,000 to 7,500 B.C. People in Mesopotamia, once mainly hunters and gatherers, began settling in villages and relying on a farm economy based on grain consumption.

Archaeological studies of the period show evidence of grain cultivation in fields surrounding villages, the construction of communal silos for storing grain and a rapid increase in population. In such a setting, individual farmers needed a reliable way to keep track of their goods —especially the amount of grain stored in shared facilities. The answer they found was to fashion clay tokens, or counters, in the form of simple geometric shapes with plain, unmarked surfaces.

The Sumerians, as the people living in this region were called, used different token shapes for different types of goods. Cones and spheres referred to the two most common Sumerian measures of grain: a small unit roughly equivalent to a liter and a larger one approximately equal to a bushel. Larger cones and spheres and flat disks probably signified even larger measures of capacity. Cylinders and lens-shaped tokens represented animals.

In such a system, two clay spheres represented two bushels of grain and two egg-shaped tokens represented two jars of sesame oil. There were as many tokens of a certain shape as there were of that item in the farmer's store. The concept of "two," or any other number, as a quantity didn't exist.

"Representing units of real goods in a one-to-one correspondence, these counters were doubtless lined up in front of accountants who organized them according to types of goods, producers or recipients, entries or expenditures," Schmandt-Besserat says. They could even be arranged in visual patterns to facilitate estimation and counting of items at a glance.

This token system persisted practically unchanged for almost 4,000 years, spreading over a large geographic area. The next major change was the appearance of more elaborate tokens, especially in early cities in southern Mesopotamia, alongside the well-established system of simple counters. Though similar in size, material and color and fabricated in much the same way as their plainer cousins, the new tokens bore various kinds of surface markings and showed a greater variety of shapes, including twin cones, bent coils and miniature models of tools, utensils, containers and various animals.

These elaborate tokens, one of the first signs of increasing urbanization and the growing complexity of Sumerian society, were probably used for items such as manufactured products — the output of Sumerian workshops. For instance, incised cones, egg shapes and diamond-like rhomboids represented quantities of processed foods such as loaves of bread, jars of refined oil and vessels of beer. In the textile industry, disks and parabolic tokens with linear markings signified different types of fibers, cloths and finished garments, whereas incised cylinders and rectangles stood for strings and mats. Other tokens represented luxury goods such as perfumes and various kinds of metalwork.

The advent of complex tokens coincided with the rise of powerful central governments and the construction of monuments and great temples, beginning around 3,350 B.C. Art from that period shows the pooling of community resources and the management and redistribution of goods to support an elite and for celebrating large community festivals that required considerable planning and the bringing together of vast quantities of goods.

Tokens were used to manage these massive tasks. "They provided, for the first time, a precise system for keeping records and thus were a means of control and power in the hands of the leadership," Schmandt-Besserat says. "Indeed, complex tokens clearly seem to be associated with the world's first system of coercive taxation and redistribution of goods." Scenes from Sumerian art show punishments such as beatings, hinting that even then citizens did not always pay their taxes willingly.

Courtesy Schmandt-Besserat

Musée du Louvre, Paris

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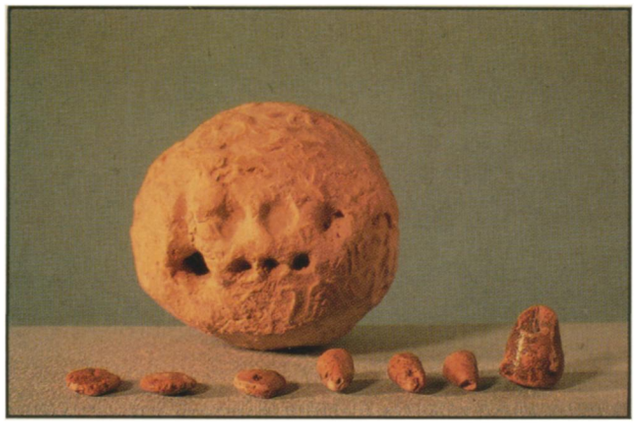
Complex tokens, excavated from a city in southern Mesopotamia, come in a variety of shapes and often bear markings or perforations (top). Each shape represents a particular item, such as a trussed duck (middle), a jar of oil, a sheep, a garment, or units of land, string or metal (bottom).

Sumerian clerks stored plain tokens in clay globes, or envelopes. To indicate what each envelope contained, they pressed the token into the soft clay surface before sealing and baking the envelope, leaving a distinctive set of imprints.



Musée du Louvre, Paris

Throughout this later period, both simple and complex tokens coexisted, one associated with products of the granary and farm, the other with products of the urban workshop. In fact, temple excavations reveal the Sumerians handled the two kinds of tokens separately and stored them differently.

Sets of simple tokens were stored in clay globes, or "envelopes," that often bore markings indicating what was enclosed and seals that may have recorded transactions (perhaps contracts, receipts or even IOUs). The envelope markings were important because the enclosed tokens, once sealed in their clay cocoon, were hidden from view. Initially, temple clerks probably marked the envelopes simply by pressing tokens into the soft clay surface before sealing and baking it – making visible the number and shape of tokens enclosed. Excavated specimens show circular markings of various diameters and depths and wedges of different lengths and widths.

Complex tokens couldn't be stored in clay envelopes because they left indecipherable impressions. Instead, they were often perforated and could be strung together and attached to a clay tag, which apparently identified the account.

In Schmandt-Besserat's view, these two categories of tokens and their different means of storage evolved into Sumerian script. The plain tokens gave rise to numerals while the complex tokens, with their patterns of inscribed lines, gave rise to writing.

One key step was realizing that once the envelopes were marked, it was no longer necessary to keep the tokens themselves. It would do just as well to mark the appropriate shapes on a clay tablet and to forget about the rest.

At the same time, the markings on complex tokens also could be inscribed, using a stylus, directly onto a clay tablet instead of on the token itself. For example, an incised ovoid token would be replaced by a neatly drawn oval with a slash across it. Such pictographic signs would indicate the nature of the items being recorded.

The result was a new, more practical, less cumbersome data storage system. It was easier to handle a few clay tablets with neatly aligned signs than a large collection of loose tokens. It also became clear that using a stylus was quicker than making an impression of every token.

Then came the great leap, perhaps the deed of an accountant who arguably could be given the title *Homo mathematicus*. Around 3,100 B.C., someone had the bright idea that, instead of representing, say, 33 jars of oil by the symbol for a jar of oil repeated 33 times, it would be simpler to precede the symbol for a jar of oil by numerals – special signs expressing numbers. Moreover, the same signs could be used to represent the same quantity of any item.

The new signs were symbols for the two basic measures of grain – used in a novel fashion. The wedge (impressed cone) came to stand for 1 and the circle (sphere) for 10. There were no special symbols for other numbers.

This economical notation spread rapidly. It was no longer necessary to have differently shaped counters for different items. Anything of importance could be expressed compactly and flexibly on clay tablets. This accounting system fulfilled the needs of an emerging state bureaucracy, increasing the amount of information recorded and making possible a comprehensive system of taxation.

Clay tokens themselves became obsolete by 3,000 B.C., replaced by pictographic tablets that could express not only "how many" but also "where, when and how." With the introduction of a new type of stylus, pictographic writing developed into cuneiform notation. The resulting record-keeping system was so efficient and convenient that it was used in the Middle East for the next 3,000 years. Eventually, it was displaced by Aramaic script written with a flowing hand on papyrus, which proved to be even more efficient.

Meanwhile, the ancient Babylonians adopted and modified the Sumerian system for dealing with abstract numbers. From there, the system traveled to Greece, at length becoming part of the great flowering of mathematics in the ideas of Pythagoras, Euclid and Archimedes.

Royal Ontario Museum, Toronto

This pictographic clay tablet from a site in present-day Iran carries the symbols for the numeral 33 (three wedges and three circles) and the sign for a jar of oil. The inscription can be read as "33 jars of oil."

"This story is, in essence, a study in the stages whereby human culture slowly, and then ever more quickly, mastered the art of abstraction," Schmandt-Besserat says. Whether a similar process leading to the concept of abstract numbers occurred in other civilizations, such as the Chinese or Maya, isn't known. "Nobody has looked into the development of counting there," she says. "Everybody always assumes abstract counting is a given."

The invention of abstract numbers must be accorded a prominent place among the greatest of human contrivances, Schmandt-Besserat says. Too frequently, in studies of the development of mathematics, the invention of zero and the advent of place notation are heralded as major accomplishments of the civilized world, while abstract numbers are mistakenly regarded as intuitive.

"This is simply not the case," she says. The token system is just one piece of evidence proving that counting was not spontaneous but rather the product of a long, slow cultural evolution. □