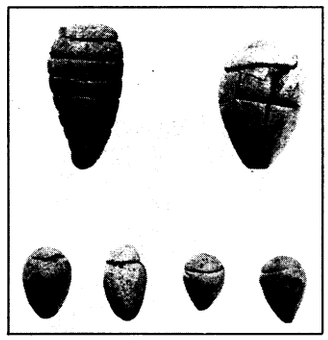
the all-too-wanting record-keeping of the excavators of these early sites prevents us from learning more about the context of the great mass of early geometrically shaped objects. However, they remain suspiciously ad hoc.

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

volume of the *Treatise on Invertebrate Paleontology* in 1959. The treatment assumes a working knowledge of paleontology in general and trilobites in particular.

The abundance of trilobites, particularly in Cambrian faunas, is exaggerated by the fact that they moulted periodically, with the result that many if not most of the remains found are those of moults rather than of living animals. Whittington notes that the existence of moults permitted workers such as Barrande, a French civil engineer exiled to Prague, to describe growth series for trilobites as early as 1852. Growth stages of several species are illustrated in this book, which has 120 excellent plates accompanied by detailed explanations that are a very useful feature of the book.

Questions often asked by students and non-paleontologists are How did trilobites live and What did they eat? Whittington notes that the early larval stages were probably soft-bodied and presumably planktonic, as with many modern marine invertebrates, but that in later life most trilobites probably lived on the sea floor as predators of smaller animals, scavengers, and sediment feeders. Others may have burrowed in the mud. Whittington suggests that some may have been swimmers, perhaps by sudden enrollment that produced quick, spasmodic movements. Other groups, particularly those that are small and have thin shells, may have been planktonic. Even though trilobites have the earliest known visual organs, some groups were blind and may have been adapted to deeper, darker waters.

Drawing in part on specimens found in the famous Middle Cambrian Burgess Shale of British Columbia, Whittington discusses the anatomy and functional morphology of trilobites in some detail. In this as in other parts of the book the subject matter is put into historical context. For example, Whittington describes the techniques used by early workers in dealing with features such as trilobite limbs. The amount of painstaking work undertaken by workers such as Størmer, who serial-sectioned enrolled specimens in order to look at the appendages inside, must have been enormous. More or less as a postscript to the section on anatomy and trilobite activity Whittington discusses traces supposedly left by trilobites. He suggests that of *Rusophycus* and *Cruziana*, two trace fossils generally accepted as having been formed by trilobite activity, only *Rusophycus* is likely to be due to trilobites. However, he does not offer an explanation for the formation of *Cruziana*.

Discussing the relationships between depositional environment, depth of water, substrate, and types of trilobites, Whittington points out the use of Lower Paleozoic trilobite faunal provinces in providing both positive and negative evidence regarding plate tectonics and continental drift, concepts that many Northern Hemisphere geologists accepted long after their southern colleagues. It is curious that in this section of the book the only diagram showing depth relationships of different trilobite groups, and the only one showing former continental distributions, shows post-Cambrian situations.

As Whittington notes, the morphological complexity of the earliest trilobites from near (but not at) the base of the Cambrian suggests a long Precambrian history of soft-bodied trilobites. He also points out that only one new family of trilobites, the Phillipsidae, originated after the early Ordovician. Whittington notes that despite many years of endeavor, there is no single widely accepted classification of trilobites; he stresses the need for more detailed knowledge of trilobite morphology and development. One topic not covered in any detail is the use of trilobites in biostratigraphy, which is the most practical application of paleontology. In these days of increasing difficulty in getting financial support for paleontological research, it would seem necessary to stress the more utilitarian aspects of the subject.

In summary, this is an excellent, readable book packed with detailed information on how trilobites lived, functioned, evolved, and eventually became extinct.

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Dolphin Echolocation

The Sonar of Dolphins. WHITLOW W. L. AU. Springer-Verlag, New York, 1993. xii, 277 pp., illus. $79.

I attended an animal sonar conference in 1979 and remember feeling a little smug about what I perceived to be a superior understanding of echolocation on the part of the bat researchers over those working with dolphins. Dolphin studies seemed mired in the difficulties of working with mammals whose popularity with the public prevented the neurophysiological experiments that, at least to me, seemed essential. Au's new book demonstrates that these restrictions may have been blessings in disguise. The noninvasive methods (for example, x-ray cinematography, signal detection theory) that have been used to probe the mechanisms of sonar production and processing in dolphins have provided an understanding of these animals' perceptive abilities that may have outstripped what we know of bats.

Au's book is not for the timid. It assumes a thorough understanding of acoustics and no small measure of mathematical facility. Filled with informative illustrations, it provides an exhaustive chronology of the studies of dolphin auditory and vocal mechanisms and target detection and discrimination and ends with a comparison of dolphins and bats and some suggestions for future work. In addition to describing the many experiments that have been performed on dolphins, Au analyzes their strengths and weaknesses, with a view to establishing the extent and limits of our knowledge of dolphin sonar.

The answers to many of the basic questions are still elusive. How do dolphins hear? Apparently not through their ear canals, but how exactly constitutes a fascinating detective story that gradually unfolds. It seems that a route through the fatty tissues of the lower jaw is most plausible. Where do dolphins produce their sounds? This is another persistent puzzle, with researchers now favoring the nose over the larynx. Although Au summarizes the information currently available, he never totally dismisses any of the theories and thus preserves the excitement that these questions evoke. In fact, to the book's credit, I was left with more questions than answers about dolphin sonar. Why don't the peak frequencies of dolphin echolocation clicks match the frequencies of their maximum auditory sensitivity? What is the trade-off between echolocation and social vocalizations in the design of their ears? As we ponder explanations offered by laboratory studies, Au reminds us that dolphins live in a real world and face problems (such as the remarkable din created by snapping shrimp in the bays of Hawaii) not encountered in soundproof chambers.

Cetacean sonar presents a wonderful opportunity for comparative studies, and the book could have benefited from a more evolutionary perspective. For example, Au reviews the work done to test whether dolphins manipulate the pitch of their clicks, as do insectivorous bats. An evolutionary approach would suggest that since most echolocating animals (for example, swiftlets, oilbirds, fruit bats) do not frequency-manipulate, there is little reason to expect this ability in dolphins. An understanding of the phylogenetic occurrence of echolocation may help steer the future course of dolphin research.

Au's book is an excellent synthesis of the mountain of work on dolphin sonar and serves as a reminder of the experiments yet to be performed on the other echolocators. It should be required reading for young (and occasionally smug) scientists about to start off in this line of research.

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