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Early Cambrian Marine Fauna

A new hypothesis that can in some measure be tested explains its origin in terms of coastal sites.

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One of the major unsolved problems of geology and evolution is the occurrence of diversified, multicellular marine invertebrates in Lower Cambrian rocks on all the continents and their absence in rocks of greater age (*1, 2*). These Early Cambrian fossils included porifera, coelenterates, brachiopods, mollusca, echinoids, and arthropods (see *3* for details of the groups). In the Arthropoda are included the well-known trilobites, which were complexly organized, with well-differentiated head and tail, numerous thoracic parts, jointed legs, and—like the later crustaceans—a complex respiratory system. From a phylogenetic standpoint the Early Cambrian faunal assemblage is generally interpreted to represent rather simple ancestral types in their respective phyla, which rapidly diversified into numerous types (species, genera, families, orders) during and following the Early Cambrian. Their high degree of organization clearly indicates that a long period of evolution preceded their appearance in the record. However, when we turn to examine the Precambrian rocks for the forerunners of these Early Cambrian fossils, they are nowhere to be found. Many thick (over 5000 feet) sections of sedimentary rock are now known to lie in unbroken succession below strata containing the earliest Cambrian fossils. These sediments apparently were suitable for the preservation of fossils because they often are identical with overlying rocks which are fossiliferous, yet no fossils are found in them. Clearly, a significant but unrecorded chapter in the history of life is missing from the rocks of Precambrian time.

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Explanatory Theories

Numerous theories have been advanced to explain this hiatus in the geologic record of the Precambrian evolution of marine invertebrates. The older ideas have been adequately reviewed by Raymond (*4*) and Seilacher (*2*) and need only be listed here, because none is adequate to explain the record: (i) Any Precambrian fossils which may have been preserved were destroyed by metamorphism. (ii) Precambrian fossils had no skeletons because there was no calcium in the sea. (iii) Precambrian oceans were acid, thus preventing the formation of calcareous skeletons. (iv) Precambrian strata were deposited on land in fresh water of low calcium content. (v) Marine life originated in fresh water and thence migrated down the rivers to reach the oceans by Cambrian time. (vi) Precambrian life lacked hard parts suitable for preservation because life was confined to the surface waters, where skeletons would have been of little use. (vii) Skeletons suddenly appeared due to the adoption of a sessile or sluggish mode of existence on the sea bottom.

More recently expressed views are those of Snyder (*5*), who visualizes the Precambrian existence of a fauna which was as diversified and complicated as that of the Early Cambrian and which, while not otherwise significantly altered, abruptly acquired hard parts owing to environmental (physical and biotic) stress; Schindewolf (*6*), who believes that there were no forerunners of the Cambrian fauna but that it suddenly appeared due to "*Grossmutation*"; and Seilacher (*2*), who agrees with Schindewolf (*6*) about the evolution of the Cambrian fauna and also believes that the soft-bodied benthonic types which formed the trace-fossils (trails, tracks, burrows) of the Precambrian suddenly changed their activities in a similar manner at the beginning of the Cambrian. None of these more recently proposed theories appears acceptable because they do not conform to our present understanding of the evolutionary process (see *7*, chap. 4; *8*, p. 347).

There are, however, two other theories pertaining respectively to the biologic and geologic aspects of the problem which, with suitable modifications, may be integrated to provide a further theory, which appears both consistent with the record and capable of a measure of empirical test.

Cloud (*8*) has suggested that if the Early Cambrian fauna was derived from types that were undergoing eruptive evolution of the type visualized by Simpson (*7, 9*) during the late Precambrian, the problem of their sudden appearance in the record might partly be solved. Judging from the nature of the evidence the suggestion has much merit. However, the question as to why there are no records of these marine invertebrates, which must have had hard parts suitable for preservation prior to the Cambrian, remains unanswered. The immediate forerunners of the Cambrian fauna presumably were rather widespread, to judge from the world-wide distribution of the Early Cambrian fauna, yet we have no records of them. And as mentioned, since the sediments underlying the oldest fossiliferous zone frequently are types which suggest physical environments similar to those of the fossil-bearing strata, there is no apparent reason why the fossils should not have been preserved.

A clue as to why this early phase of evolution is missing occurred to me during a current review of the evolution of land plants. There is much evidence to suggest that the new, major categories (orders and classes) of plants have evolved chiefly in areas of environmental diversity, notably in the uplands, in sites well removed from the lowland basins of deposition where most fossils have been preserved (*10*). A similar environment has been postulated for the evolution of the phyla, classes, and orders of nonmarine vertebrates (*7, 9*). In both cases, fossils representing ancestral types in the eruptive stage of evolution are missing from the record, or at least are very rare. This is chiefly because these types comprised rather small populations living in sites remote from lowland basins of deposition or because, if they did get into the nonmarine record occasionally, those deposits have largely been eroded and the records have been lost (*11*).

Coast-line Hypothesis

Owing to analogous circumstances, the problem of the evolution of the late Precambrian marine fauna may thus be resolved in terms (i) of the nature of the areas or sites in which the phyla were evolving and (ii) of the subsequent geologic history of these areas, as a result of which most of the record has not been preserved. Walcott (*12*) considered this problem and coined the term "Lipalian" for "the era of unknown marine sedimentation between the adjustment of pelagic life to littoral conditions and the appearance of the Lower Cambrian fauna." He believed that the pelagic life of the ocean had already become adapted to benthonic, littoral, and near-shore environments by later Precambrian (Algonkian) time but that no record of it was preserved because the continental platforms were above sea level; he felt that any sediments containing remains of this early fauna may be concealed beneath the present oceans. Thus, when the seas encroached on the base-leveled continents at the close of the Precambrian, they brought with them the littoral fauna which had been developing during Lipalian sedimentation. Walcott believed that the sediments which lie in unbroken sequence below the fossiliferous marine Cambrian beds represent continental deposits formed during the later Precambrian, an opinion based chiefly on the absence of marine fossils in them. Most investigators are now agreed that the nonfossiliferous sections which conformably underlie the earliest Cambrian faunas are largely marine, not continental, as Walcott supposed. In other words, the continental platforms were not wholly elevated above sea level but were inundated here and there by broad Precambian seas, much as they were during the Cambrian and later periods.

With respect to the environment of early evolution, the littoral and immediate shore area would almost certainly have been ideal for the Precambrian marine invertebrates. Warm water, ample sunlight, a large supply of mineral nutrients, and dense plankton populations for food would have been in continuous existence. Further, a great diversity of habitats is typical of all shore areas. Local variations in topography, rapid changes in bottom type (rocky, sandy, muddy), or slight differences in temperature or depth or salinity would clearly have resulted in a wide array of ecologic niches (for other factors, see *13*). Fragmentation of populations into discrete interbreeding units would inevitably have developed during Precambrian time. Microgeographic isolation in these areas of abrupt and diverse changes in environment would permit the existence of divergent adaptive types in proximity. The tempo of evolution would quicken, and with strong selection in operation, a host of types would now enter an eruptive phase of evolution. As Walcott has suggested, this early phase may have been proceeding in the immediate coastal strip for a long time prior to the Cambrian. We can agree with Cloud (*8*) that ancestral members of the Cambrian fauna probably were evolving at a high rate, but this alone cannot explain the absence of multicellular, hard-shelled marine invertebrates in the Late Precambrian. Actually, we could scarcely expect much of a record of any fossils that may have been preserved in the near-coastal environment. The hinge line between land and sea is not broad and is eroded as soon as the area is only slightly elevated. Further, if evolution was progressing chiefly in the warmer parts of a broad tropical zone, the area in which fossils might have been preserved through the vicissitudes of more than 550 million years of earth history is further reduced, while the persistence of the record of the environment would appear even less likely.

According to the present hypothesis, therefore, Precambrian faunas were evolving in favorable coastal sites, in areas where any fossiliferous sediments which may have accumulated probably would not have survived the effects of erosion down to the present day. During the eruptive phase of Precambrian evolution the fauna presumably was confined to the near-shore and littoral belts by food requirements, temperature, depth and changes attendant upon it, and a host of other factors which were affecting the physiology of the organisms concerned. In the closing parts of the eruptive phase we may infer that relatively "advanced types" were radiating out into a new environment—the neritic zone—to which they quickly became adapted. These, presumably, are the Early Cambrian descendants of the later Precambrian fauna. They represent types which had evolved sufficiently so that they could invade the relatively deeper parts of the continental shelves and epeiric seas, where they formed the well-known record of the communities of that time. Their earliest appearance in the record probably was due not to a simultaneous migration into deeper waters as the Cambrian began but rather to a gradual deployment into the extralittoral region during an interval of several million years (*14*). This deployment most probably was not only to seaward and into deeper water but also in the relatively cooler, though probably warm, regions at higher latitudes.

This coast-line hypothesis, which has been briefly outlined here, appears to offer certain unifying advantages in that (i) it has the merit of simplicity; (ii) it provides the conditions that are believed requisite for eruptive evolution; (iii) it is consistent with geologic evidence that the site of early evolution probably would not be preserved for long periods of time, and (iv) it can, at least in some measure, be tested.

The Shore as Collecting Area

By conducting careful current-directional studies of Precambrian sediments in selected critical areas it may be possible to find remnants of the old shore line and its fauna; in any event, such studies should bring us closer to the shore as a likely site for collecting. In searching for fossils in these areas we must remember that the more primitive members of phyletic stocks were generally small, as compared with their derivatives. The remarkable living relict *Hutchinsonella,* a cephalocarid-trilobitoid crustacean only 3 millimeters long (*15*), is highly suggestive in this connection. If the primitive Precambrian brachiopods and trilobites and their associates were also quite small, as seems likely, the amount of organic debris that may have been preserved is considerably reduced, the fossils will not be readily visible, and the probability of discovery is lessened. Examination of Precambrian sediments by suitable microscopic, isotopic, and chemical methods may reveal particles of shell fragments and other structures of the ancestral coast-line fauna mixed in with these transported sediments. Organic microstructures of this sort will not be common in Precambrian rocks. Fossils are rare in any event, and with life less abundant in the seas of Precambrian time, the chances of finding these transported materials are correspondingly low (*16, 17*).

References and Notes

1. We are concerned here only with the remains of multicellular, hard-shelled organisms which make up the bulk of the record and not with "trace-fossils" such as trails, burrows, tracks, and other signs of the activities of soft-bodied bottom dwellers whose systematic relations are unknown and which occur in Precambrian rocks. For a discussion of organisms of the latter type, see A. Seilacher (*2*).
2. A. Seilacher, *Neues Jahrb. Geol. u. Paläontol.* 103, 155 (1956).
3. R. R. Schrock and W. H. Twenhofel, *Principles of Invertebrate Paleontology* (McGraw-Hill, New York, ed. 2, 1953).
4. P. E. Raymond, *Bull. Geol. Soc. Am.* 46, 375 (1935).
5. F. G. Snyder, *J. Geol.* 55, 146 (1947).
6. O. H. Schindewolf, *Der Zeitfaktor in Geologie und Paläontologie* (Schweizerbart'sche, Stuttgart, Germany, 1950).
7. G. G. Simpson, *The Major Features of Evolution* (Columbia Univ. Press, New York, 1953).
8. P. E. Cloud, Jr., *Evolution* 2, 322 (1948).
9. G. G. Simpson, *Tempo and Mode in Evolution* (Columbia Univ. Press, New York, 1944).
10. D. I. Axelrod, *Evolution* 6, 29 (1952).
11. For a more complete discussion and documentation of this argument, see *7, 9,* and *10*.
12. C. D. Walcott, *Smithsonian Inst. Publs. Misc. Collections* 57, 1 (1910).
13. R. H. Fleming, *Geol. Soc. Am. Mem. No. 67* (1957), vol. 1, p. 87.
14. The problem of their exact time of appearance in the record rests in part on determining the synchroneity of the base of the Cambrian across the world. Since the earliest faunas are meager in number and distinctive type and, also, display important regional differences, precise correlation of widely separated areas is not readily possible. There is a strong probability that the basal Cambrian fossiliferous rocks are not of exactly the same age everywhere in the world; some appear to be older than those of the type section in Wales.
15. H. L. Saunders, *Systematic Zool.* 6, 112 (1957).

16. For critical comments and suggestions I am indebted to C. A. Nelson, Alexander Stoyanow, and E. L. Winterer of the Department of Geology, University of California, Los Angeles; to Robert E. Smith, Department of Physiology, University of California Medical School, Los Angeles; to Joel W. Hedgpeth, director, Pacific Marine Station; to James Gilluly and Preston E. Cloud, Jr., U.S. Geological Survey; to Ralph W. Chaney and J. Wyatt Durham, Department of Paleontology, University of California, Berkeley; and to Eliot Blackwelder, Hubert G. Schenck, and A. Myra Keen, School of Mineral Sciences, Stanford University.
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American Use of Soviet Medical Research

A study of 500 medical scientists shows that they make comparatively little use of Soviet work.

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During the past several years there has been a growing interest in the United States in Soviet scientific research. This interest has arisen in part from the political concern of the United States in the over-all activities of the Soviet Union and in part from a growing awareness of an acceleration of activity in science and technology in the Soviet Union since World War II.

One outgrowth of the increased interest in Soviet science has been a program organized by the National Institutes of Health to make Soviet medical research information more readily available to American medical scientists. This program was instituted at the request of the Committee on Appropriations of the United States Senate. It grew out of testimony at the 1956 appropriations hearings of the Department of Health, Education, and Welfare, during which it was observed that Soviet medical scientists are keenly aware of American developments in medicine but that American medical scientists know very little about Soviet medical research activity. The presumed advantage that Soviet medical scientists have over the American scientists is twofold. First, the Soviet scientists benefit from a broad and intensive foreign-information-gathering and translation program in the Soviet Union which covers practically every area of science and practically every nation's literature; second, where American medical research information is concerned, the average Soviet scientist has the advantage of having a fair working knowledge of the English language.

This article (*1*) is an account of the findings of an interview study which was performed at the request of the National Institutes of Health to define the extent and character of the need for Soviet medical research information among American medical scientists and to evolve the best means of meeting this need. The study was also designed to analyze the present mechanisms of use of Soviet medical research information among American medical scientists. In cases where Soviet research information was not being used, it was also the purpose of the study to ascertain and evaluate the reasons for the lack of use. Among the questions considered in ascertaining the reasons for any established lack of use of Soviet information were those of the respondents' familiarity with Soviet work in their fields of science and their general attitudes toward the Soviet Union and Soviet science.

Derivation and Character of the Sample

The sample for the study consisted of 500 American medical scientists. These scientists were drawn from 59 medical research organizations in six American cities. The organizations represented hospitals, medical schools, government agencies, pharmaceutical firms, and independ-

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