G E N E R A L S C I E N C E N O T E S

ARE MILLIONS OF YEARS REQUIRED TO PRODUCE BIOGENIC SEDIMENTS IN THE DEEP OCEAN?

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WHAT THIS ARTICLE IS ABOUT

How long would it take to produce the thick layers of microscopic shells found on the floor of the ocean? Would this not require millions of years, and would this not invalidate the scriptural account of creation a few thousand years ago?

For several reasons the argument for the necessity of a very long time required to accumulate the microscopic shells on the deep ocean floor is a poor one. At present some data indicate that there is a slow rate of production; on the other hand: 1) the layers of shells are not kilometers thick as has been reported, but probably at best an average of 0.2 km; 2) the biological potential of production is so great that this quantity of shells could probably be produced in much less than 2000 years; 3) a worldwide flood as described in Scripture could provide the nutrients necessary for such production; 4) caution is warranted because of the poor data that are currently available. Because of these factors a firm case against the biblical model of origins cannot be made on the basis of our present knowledge about these sediments.

Recently a number of individuals have raised the question about the conflict between the millions of years required for producing the thick layers of microscopic shells found on the floor of the ocean and the short time suggested in Scripture for life on earth. At first the question appears both reasonable and ominous for anyone believing in the truthfulness of the biblical Genesis account of beginnings a few thousand years ago. The layers on the ocean floor have been reported to be kilometers thick, and the shell remains comprising these layers are usually a small fraction of a millimeter in diameter. It could appear that millions of years are involved in their formation according to present average rates of production. On the other hand, when one considers the recent information regarding the small quantity of these sediments and the reproductive potential of the organisms producing the shells, the challenge appears at best to be equivocal. There are still a number of unresolved questions about this fascinating subject, and the last word is probably well in the future. Some findings and trends are quite significant to the question.

Over one hundred years ago John Murray, a meticulous scientist aboard the oceanographic vessel H.M.S. *Challenger*, pioneered the study of microscopic “shell”-secreting organisms in the open oceans. He also studied the shell-like remains of these organisms on the deep ocean floor. A number of principles which he established have remained valid to this day. These organisms are important in the food chains of our major oceans, and the shells that are left by these organisms on the floor of the ocean can tell us something about the past history of our world. There is considerable interest in these tiny creatures, and the scientific literature discussing them is voluminous.

The oceans cover about 71% of the surface of the world. About 1/5 lie over the shallower continental margins; the rest cover the deeper ocean floor which is usually lined by finer sediment that includes the small shells mentioned above.

Estimates of the thickness of sediments on the ocean floor have varied considerably. Older figures postulate layers as thick as 22 km (Petterson 1954). Such thick layers were proposed in part to accommodate the large quantities of sediment expected from transport by rivers to the ocean over many millions of years. Around the middle of this century estimates were reduced to 2-3 km. More recently the use of seismic methods show that a major portion of the ocean floor has sedimentary layers less than 0.1 km thick, while a smaller fraction, mostly near the continental margins, has a thickness greater than 1 km (Berger 1974). An average depth of about 0.4 km may be generous for the floor of the oceans and is a few percent of what was conceived earlier.

It is usually assumed that the original oceans had no sediments and that directly or indirectly a major portion of the sediments now present were brought in by rivers. Therefore, with an earth over a billion years old, sediments from the rivers would have filled the oceans several times. The paucity of sediments on the floor of the ocean is now explained in part by the plate tectonics model which proposes that marine sediments are subducted deeper into the earth. However, this rate of subduction appears so slow compared to the present input to the ocean by rivers, etc., that the problem of where all the sediments go if one assumes a standard geologic time scale of billions of years is not solved. Estimates of the input of sediments into the ocean by rivers, coastal erosion, wind, etc., vary from 8 to 64 billion tons per year (see Holmes 1965, Holeman 1968, Milliman & Meade 1983), while the rate of removal of sediments by subduction has been estimated by Li (1972) to be at 2.5 billion tons per year. The present estimated volume of sediments on the ocean floor and margins (4×10^{17} tons) could be brought in by rivers, etc., at their present rate of transport in some 10 to 30 million years. One must postulate different conditions in the past to reconcile these figures to either a standard geologic time scale or a short period for earth history as described in Scripture.

Implicit in Scripture and in the folklore of many ethnic groups over the world is the account of a worldwide flood which, of course, represents conditions different from these presently observed which would cause rapid erosion and sedimentation.

The many different kinds of sediments on the floor of the deep ocean have varied sources. A little less than half of the ocean floor is covered by fine clay. Though sometimes called "red clay" because of its color, it is often not red. This clay usually originates from the continents or from submarine vulcanism. When more than 30% of the sediments consist of the shells of organisms, they are called oozes. About half of the deep ocean is covered by light-colored carbonate oozes, consisting mainly of calcium carbonate and containing an abundance of microscopic shells that are of special concern in this note. These shell-rich deposits produced by microscopic plants and animals living nearer the surface of the ocean cover about ¼ of our planet. When the organisms die, the shells sink to the ocean floor. A large 150 mm (0.15 mm) foraminiferal shell may take 10 days to sink to the bottom of the ocean; smaller ones take much longer. A significant number dissolve before they ever reach the ocean floor.

If all the water were removed from the ocean, one would be surprised to find the tops and flanks of the submarine mountains covered with whitish carbonate deposits including many microscopic shells, while the deepest parts of the ocean, usually 4500-5000 m below the present sea level, would be covered with darker clay sediments. This would give somewhat the same appearance as mountains on the continents covered with snow down to a given level sometimes called the snow line. In fact, the level in the ocean below which carbonate deposits are generally absent has sometimes been labeled the "snow line." More properly called the calcite compensation depth (CCD), it is that depth at which the rate of dissolution of calcium carbonate shells, etc., exceeds the rate of input from above.

A smaller portion of the ocean floor (about $^1/_7$) is covered by silicious oozes which are found mainly at high latitudes. These oozes are provided with an abundance of shells secreted by rapidly reproducing microscopic plants called diatoms and microscopic animals called radiolarians. Their shells which are composed mainly of silica (SiO_2) are in sharp chemical contrast to the more abundant carbonate (mainly $CaCO_3$) shells mentioned earlier.

The skeletal remains of many different kinds of organisms are found in the abundant carbonate deposits of the ocean floor. These are often called foraminiferal oozes because of the high proportion of foraminiferal tests (shells) (Figure 1a) present; however, these shells do not necessarily

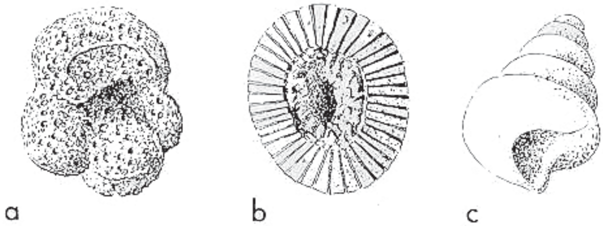

FIGURE 1. Examples of shells from organisms producing biogenic carbonates on the deep ocean floor. a) foraminiferal test (×120), b) coccolith (×400), c) pteropod shell (×30).

dominate the deposits. Three of the main types of organisms producing carbonate shells will be considered.

The foraminifera that produce these shells are called planktonic foraminifera because they live in the open seas. They produce a shell usually a fraction of a millimeter in diameter that often consists of several lobes or chambers (Figure 1a). A second group of major importance are plants called coccolithophores. These brown algae produce microscopic platelets often shaped like a small washer about $^1/_{100}$ mm in diameter called a coccolith (Figure 1b). One coccolithophore may secrete 12 to 100 coccoliths which form a sheath around the outside of the organism. A third group of lesser importance are the pteropods which are much larger (1-2 mm) snail-like mollusks (Figure 1c). While very interesting, pteropod oozes are estimated to cover less than 1% of the ocean floor and will not be considered here in detail.

Basic to the question of how long it would take to produce all these carbonate sediments are estimates of the quantities present. Major portions of the ocean-floor sediments have less than 1-2% carbonate (Kennett 1982, p 461). No exact figures can be given, but reasonable estimates can be suggested. Since shallow and deep ocean currents can transport these fossil shells for considerable distances and cause local accumulations of greater depth, average figures will have to be used. At present foraminiferal oozes dominate the ocean floor; however, this was apparently not the case in the past. Bramlette (1958) has shown that at least in the Pacific Ocean coccolith production was greater than that of foraminifera during the early- and mid-Tertiary. Another irregularity is that in the smaller Atlantic Ocean, sediments are usually thicker than those in the Pacific Ocean and have fewer "red clay" areas. One can estimate that for an average 0.4 km thickness of sediment in the deep ocean, about half (0.2 km) would be "red clay" and half (0.2 km) carbonate oozes. Of these about half (0.1 km) would be coccoliths and half (0.1 km) foraminiferal skeletons. We are not dealing on an average with kilometers of foraminiferal sediments as has been conceived; nevertheless, considering how small these skeletal remains are, an average of 100 m of foraminiferal shells and 100 m of coccoliths can appear as a challenge to any model of rapid sedimentation.

Strange as it may seem, biological productivity does not appear to be a limiting factor. We are dealing with some of the fastest reproducing organisms known. In the surface layers of the ocean these carbonate-secreting organisms at optimum production rates could produce all the carbonate on the floor of the ocean in probably less than one or two thousand years. For instance, if one assumes a high concentration of foraminifera of 100 l^{-1} as has been reported (see Berger 1969), a doubling time of 3.65 days (Berger 1976, p 273, 299) and an average of 10,000 forams g^{-1} of carbonate (Berger 1976, p 298), the top 200 m of the ocean would produce 20 g carbonate $cm^{-2}y^{-1}$or (at an average sediment density of 2 g/cm^3) 100 m in 1000 years. Under present conditions all would not be preserved. As mentioned above, in the deepest parts of the ocean which are below the CCD there is dissolution of much of the carbonate. One might want to increase the time allowed, even by a factor of 2 to compensate for this, if one assumes that the CCD was at the same level in the past as now. On the other hand, increased carbonate input (as will be discussed later) would tend to lower the CCD (Berger 1976, p 308) and favor a greater proportion of preservation. Also, reproduction below the top 200 m would likewise tend to shorten the time required.

Although planktonic foraminifera have been the subject of extensive study, their natural life cycles are still poorly understood. Some factors suggest short life spans of a few days and great reproductive potential which favor rapid shell production. Bé et al. (1977) noted that one mother cell of *Globigerinoides sacculifer* collected near Bermuda released 280,000 gametes during gametogenesis which took about 13 hours. Spindler et al. (1978) reported comparable figures for *Hastigerina pelagica* and Bé et al. (1977) noted that in the laboratory shell chamber formation took place in a few hours.

Coccolithophores may reproduce faster than foraminifera and are “among the fastest growing plankton algae” (Paasche 1968), sometimes multiplying at the rate of 2.25 divisions per day. If one assumes that an average coccolith has a volume of 22×10^{-12} cm^3 (Honjo 1976), an average weight of 60×10^{-12} g per coccolith [Honjo’s 1976 figure of 8×10^{-12} g is in error; he believes it is more like 80×10^{-12} g (personal communication)], 20 coccoliths per coccolithophore, 13×10^6 coccolithophores per liter as reported for Oslo Fjord (Black & Bukry 1979), a dividing rate of 2×/day and a density of 2 g per cm^3 for the sediments produced, one gets a potential production rate of 54 cm of $CaCO_3$ per year from the top 100 m of the ocean. In other words it is possible to produce the average 100 m thickness of coccoliths proposed for the sea floor in less than 200 years. If one assumes that the CCD is at the same level now as in the past, the time should be doubled to allow for dissolution as mentioned for foraminiferal shells. One might also need to increase the time by some unknown factor to allow for light reduction due to the heavy concentration of these organisms that require light for coccolith production. Conversely one might need to reduce the time by some unknown factor to allow for those organisms producing coccoliths below the top 100 m of the ocean. Regardless, the biological potential for production is so great that it does not seem to challenge a model of a few thousand years for earth history.

It must be emphasized that the high rates given above are optimum and do not appear at all to represent average present-day rates. The figures given represent the biological potential of these organisms. There is a great deal of variation in the number of organisms present at different localities, and various methods of analyses yield highly differing results. Some recent studies using sediment traps (Honjo et al. 1982; oral reports, GSA annual meeting 1984) suggest that at present in a number of localities the carbonate flux to the floor of the ocean is in the order of 25 to 250 mg m^{-2} day^{-1} which is several thousand times slower than the potential figures given above. Such figures would appear to challenge Scripture; however, lack of precise information regarding the quantity of shells, much higher potential production rates and the nutritional enhancement of catastrophes must be given due consideration.

There is some agreement that the carbonate production rate by these organisms based on comparing the thicknesses of sediments in protected areas with the standard geologic time scale of millions of years is 5 to 10× greater than what appears to be the final average accumulation rates on the floor of the ocean (Berger 1970, Kennett 1982, p 459). This final accumulation rate is based on the amount of calcium carbonate and/or calcium ion supplied by the rivers to the ocean system. Rivers are the ultimate source of minerals for the oceans. It has been noted that rivers carry only about 10-20% of the carbonate that the organisms are estimated to produce now. The discrepancy between production by organisms and river input is explained by assuming that the major portion of the carbonate deposited on the floor of the ocean is dissolved and recycled into the system to form new shells. The discrepancy can likewise suggest non-equilibrium conditions, e.g., the rivers are carrying less calcium to the ocean now than in the past and equilibrium has not yet been reached. If one assumes a balanced steady-state model, it does appear that at present the slow input of calcium carbonate into the oceans from rivers, etc., may be a major limiting factor in carbonate skeletal production and preservation in the ocean.

While evaluating whether the quantity of carbonate shells on the floor of the ocean challenge the validity of Scripture, one must take into account that any model must be tested using its complete conceptual framework and that implicit in the scriptural model is a worldwide flood which would produce dramatic changes in the sedimentary cycles of the earth. Of special significance would be a major input of calcium ion to the hydrosphere due to erosion of continental and marine environments. According to most models of the Genesis flood, the carbonate available would be essentially free of ^{14}C, thus giving old dates for the marine sediments produced soon after this catastrophe. The disequilibrium produced by such a catastrophe would be reflected in rapid continental erosion rates for many subsequent centuries as readjustments took place; also, carbonates that would have settled to the ocean floor could be dissolved and recycled through shell-secreting organisms, as is assumed to occur now to account for the greater production rate compared to river input mentioned above.

One would expect greater rates of production by foraminifera and coccolithophores after such a catastrophe due to the influx of nutrients from the destruction of the biota and the solution of minerals. At present, as expected, production is greater in regions of high nutritional concentrations (Berger 1969, Kennett 1982, p 462).

Under the right conditions significant increases in the concentration of marine microorganisms can occur as in plankton "blooms" and red tides. For instance, a microscopic bioluminescent protozoa in Oyster Bay, Jamaica is known to increase from 100,000 l^{-1} to 10,000,000 l^{-1} during bloom periods (Seliger et al. 1970). The reasons for these blooms are poorly understood but suggestions include turbulence of the sea, wind (Pingree et al. 1977), decaying fish (Wilson & Collier 1955), nutrients from fresh water inflows and upwelling, and temperature (Ballantine & Abbott 1957). Some of these conditions would be generated during a catastrophe such as a worldwide flood and could favor rapid production of carbonate skeletons by foraminifera and coccolithophores. The pollution from large duck ranches on the borders of Moriches Bay, New York is thought to contribute to a peak concentration of phytoplankton of more than 10 billion organisms per liter. On the other hand, if the Ca ion input was limited, the expected increase in CO_2 in the water resulting from decaying organic matter would favor the dissolution of carbonate shells reducing the rate of accumulation. The total picture appears much more complicated than the few comments this note will allow.

A few words of caution regarding our present state of knowledge are pertinent to this discussion. We have yet much to learn about the nature and origin of sediments on the floor of the ocean. The estimate given above of an average of 100 m of foraminiferal shells may be generous. Ph. H. Kuenen (1950, p 351) warns:

> *According to Arn. Heim, there is a general tendency to overestimate the percentage of tests [shells]. He contends that more than 90% of recent and fossil calcareous sediments consist of a fine calcium carbonate silt which has been formed by chemical precipitation. Although this estimate is probably much exaggerated there certainly is frequently a large measure of uncertainty as to the amount of lime represented by tests still recognizable and by lime in submicroscopic particles.*

Rates of production may be underestimated. With reference to pteropod shells in the north Pacific, Whitfield (1984) states that “the flux of calcium carbonate shells from the surface layers into the deep oceans has been grossly underestimated.” Also because of poor sampling techniques, we do not appear even to have good figures on the abundance of these organisms. The usual procedure of collecting by using fine nets does not seem very adequate. Kennett (1982, p 543) feels that results obtained for foraminifera may be “much too low because many specimens are lost through coarse mesh sizes.” Berger (1976, p 294) suggests that the large spread (10^8) of foraminiferal concentration reported in the literature may be largely due to different sampling techniques. He states “incredibly, concentrations are sometimes reported, and often quoted without specifying the mesh size used to filter the water; such numbers are essentially useless.” He also refers to research results which warn that values for phytoplankton are “considerably higher” using a membrane filter instead of the usual net, yet membrane filters yield results that are “much smaller” than those obtained by settling techniques.

In conclusion, the thickness of the layers of microscopic shells found on the floor of the ocean is much less than proposed earlier. Present rates of production appear relatively slow, while the biological potential for the rapid production of these shells is tremendous. Limiting factors for rapid production such as paucity of carbonate sources and nutrients could be obviated by a worldwide catastrophe such as the flood described in Scripture. Information is meager and some of it of poor quality. Because of these factors the biblical model of origins does not seem to be invalidated on the basis of our present knowledge about the microscopic shells found on the floor of the ocean.

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