EDITORIAL

CREATIONISTS CHALLENGE CREATIONISTS

There have always been disputations within creationism. Recently, however, the disagreements have taken a notable increase in both number and significance. Of more than passing interest is the observation that some of the most "sacred cows" that have characterized creationism are being challenged by other creationists. Significant issues under consideration include: 1) Is the speed of light changing in a way that points to a recent creation? 2) Are the Paluxy River man-tracks valid evidence of the existence of man in the Mesozoic? 3) Is there valid evidence for out-of-order fossils in the paleontological record? 4) Do pleochroic halos demonstrate instantaneous creation? 5) Does variation in the intensity of the geomagnetic field point to a recent creation? 6) Is there valid evidence for the presence of pollen derived from higher plants in the Precambrian?

These disputations are doubtless of concern to many creationists who see some of their most popular arguments weakening under challenge. Further, evolutionists — who have never fully recovered from their Piltdown Hoax — have not exhibited much reticence in announcing these creationistic disagreements to the public press. Although one might be tempted to ignore these problems within creationism, they should be faced candidly and dealt with reasonably by all concerned.

It is not the purpose of this editorial to pass judgment for or against the creationistic arguments, although the readers of ORIGINS will be aware of some of our past concerns. It is our purpose to place these current discussions within creationism in their proper perspective.

In a sense, it is gratifying to note the progress of this self-evaluating process. Creationists have occasionally pointed out the conflicts within evolutionism. The current multiplicity of ideas vying to replace neo-Darwinian evolution is a noted example. Such disputations generally indicate that the data are not overwhelmingly convincing for any particular viewpoint. Likewise, the current disputations within creationism indicate that some arguments used to support creation may not be that convincing, and the sooner we recognize this, the better.

Science, whether performed within an evolutionist or creationistic paradigm, is still a human endeavor. Science has not shown itself to be a steady, unwavering progress towards truth; and we should not expect it to be perfect. If creationists want to incorporate the endorsement of science in their thought system, they should be willing to accept some of its liabilities, which sometimes includes the necessity to revise conclusions. Creationists have been accused of starting with their conclusions. Parenthetically, it has never been completely clear to me that evolutionists did not begin without some conclusions of their own. Nevertheless, the current discussions within creationism regarding the validity of some of the argumentation does seem to challenge the close-mindedness sometimes imputed to creationists.

In a broader context, the current disagreements within creationism should not materially affect the major issues, such as whether or not there is a Creator, or, conversely, the inadequacy of naturalistic evolution to answer such questions as the origin, meaning, purpose, and destiny of man. It should ever be kept in mind that truth is broader than naturalistic science, and that one of the great contributions of creationism is its willingness to recognize this. The basic argumentation in favor of creation remains.

The current creationistic disputations should not materially affect the respect many hold for the Bible, its morality, and the meaning it brings to reality. The concept of the primacy of Scripture accepted by so many creationists has a broad rational basis that lies beyond the discussions within creationism. The degree of agreement between the various writers, along with their integrity, and the historical and archaeological authentication of the Bible all appeal to our reason. The fact that the Bible has been and remains the world's bestseller says something in its favor. The American Bible Society alone has produced over 5 billion copies of the Bible (or parts of it); and there have been translations into 1526 languages. Thus far no substitute for the Bible has come forth. Likewise, the basic questions which evolutionism has failed to answer adequately still remain. These include: 1) How did life originate? 2) How does evolution bridge the gaps between major groups of organisms? 3) How did the complex integrated physiological systems of advanced organisms evolve without intelligent design to foresee the usefulness of incipient organs? 4) How does one adequately answer the problem of conflicting time data for Earth's past history?

Creationists should have been more cautious in advancing some of their evidence. We can learn from the past. It is gratifying to see the painful, but necessary, self-correcting process taking place. Creationists should willingly join the rest of the human race by accepting the fact that not all their interpretations may be correct. Certainly, more caution is warranted than has been exhibited in the past. Under all circumstances, only sound arguments should be entertained. Finally, we should keep in mind that the creation concept, which has been around for millennia, will not stand or fall on the basis of the current discussions within creationism. If creationists are willing to learn, these discussions will be a help to all concerned.

Ariel A. Roth

REACTIONS

Readers are invited to submit their reactions to the articles in our journal. Please address contributions to: ORIGINS, Geoscience Research Institute, 11060 Campus St., Loma Linda, California 92350 USA.

Re: Chadwick: Of Dinosaurs and Men (ORIGINS 14:33-40)

As a reader of ORIGINS since its inception, I have long noted its negativistic and defeatist attitude towards Creation studies. The article "Of Dinosaurs and Men" by Arthur Chadwick especially shows this. Regardless of whether or not there are valid human tracks in "pre-human" strata, I feel Chadwick misses the point of these studies.

Chadwick chides Creationists for their alleged lack of objectivity. Does he for a moment suppose that the evolutionists have been willing to seriously consider the Paluxy data? On the contrary, they did everything to discredit these markings at all costs. They were attributed to practically everything: dinosaur toe pads, tail drag marks, etc. etc. before being now ascribed to tridactyl dinosaur footprints. What will be next on the "grocery list" of evolutionistic rationalizations for these markings?

I object to the characterization of the "man tracks" as just active Creationist imagination. The finding of possible human tracks alongside dinosaur tracks in the Soviet Union [*Moscow News Weekly* No. 24 (1983), p 10] proves that one does not have to be a Creationist to (correctly or incorrectly) recognize ancient human tracks in "pre-human" strata. If Creationists have made a mistake, so what? Ichnology is a subjective science, and Creationists should have nothing to be ashamed of. I find it curious that Chadwick accepts the anti-Creationist line that "everything that creationists have proposed will go down after careful scrutiny." I see precisely that happening with evolutionistic theory, and I do not find evolutionists beating their breasts because of it. They simply move on, and invent new theories. So should Creationists.

A controlled experiment should be done. Photos of the possibly human Paluxy tracks should be blindly intermixed with indisputably human footprints from "recent strata". All these should be sent to experts in human footprints in order to ascertain whether or not the Paluxy tracks would then be recognized as human. The factor of preconceived notions would thus be eliminated.

John Woodmorappe

Chadwick replies:

Perhaps Mr. Woodmorappe has missed the point not only of my article, but of numerous other articles in ORIGINS as well. It is important for creationists to be positive, but difficult in the wake of a string of poorly supported contentions which have been passed off as "creation science" These arguments have provided an effective barrier to prevent any interested scientist from being able to seriously consider far more fundamental precepts of creation.

When I began my career as a professional scientist some 18 years ago, I had aspirations of being able to verify scientifically many of the arguments then being used by creationists in support of their beliefs. My colleagues and I wondered why other scientists, creationists or otherwise, had not worked to verify these imposing claims. We soon discovered why. Those creationists who were trained as scientists were not practicing science, but were busily involved in debates and in sharing these "scientific evidences." Evolutionists for their part were too busy arguing among themselves about what evolution really was to take swipes at creationists. I was sorely disappointed to discover, in case after case, that the data being used either did not exist, or were misapplied, or were interpreted in ways that defied common sense. Fortunately, since my belief in creation was not rooted in those interpretations, I was able to recognize that the problem was in the interpreters and not in the theory itself. Most of these ancient "evidences" were promoted by lay people who had little appreciation for the value or methods or power of science.

As a creationist and a scientist, I want to make my theory as attractive as possible to individuals who are looking for internal consistency and elegance in a theory of origins. I have a vested interest in promoting healthy science by creationists. If this occasionally requires excision of a cancerous growth or necrotic tissue, then, painful though it may be, let us operate to promote the health of the patient. Bear in mind that the Paluxy River problem is a problem with the foot, not the head or the heart of the theory!

I am pleased that we agree that creationists have been mistaken on the tracks and that we should go on from here. But let's not continue to make mistakes because we were not careful. There is no virtue in being wrong.

Re: Roth: Science, A Good Place to Begin ... (ORIGINS 14:5-6).

I recently subscribed to receive "Origins" and I usually subscribe to the articles and always to the creationist position.

I must share my reaction to the last statement in the editorial in Vol. 14, No. 1, 1987.

The editorial stated: "Truth must look beyond science for many explanations. That is where God comes in."

My immediate reaction was: "Oh? I thought God came in from the start! The things we can explain demand a creator-God as much as or more than the things we can't yet explain!"

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ARTICLES

FORAMINIFERS IN THE FOSSIL RECORD: IMPLICATIONS FOR AN ECOLOGICAL ZONATION MODEL

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WHAT THIS ARTICLE IS ABOUT

Foraminifers — shelled protozoans — are found fossilized in marine sedimentary rocks through most of the geologic column. They exemplify many of the problems of fitting the fossil record into a short chronology. These problems include the existence of large numbers of specimens and thousands of named species, and apparent evolutionary sequences of simple to more complex forms. Any short-time creationist model must be able to explain these features.

Foraminifers are able to reproduce rapidly and are quite variable morphologically, depending on environmental conditions. These factors make it seem plausible that the numbers of species and individuals in the geologic column could have lived in the time since creation week. In addition, the general distribution of foraminifers in the fossil record resembles their depth profile in the ocean today, with benthic forms distributed through a greater variety of environments than planktonic species. Although not a comprehensive study, the results suggest that the distribution of foraminifers in the geologic column may be consistent with an explanation based on burial by a worldwide flood.

The fossils in the geologic column have been thought to be a record, although certainly not a complete record, of the development of life on Earth. Because the prevailing paradigm assumes that the current processes operated at current rates in the past, the fossil record is assumed to have been formed slowly as evolving plants and animals lived, died and were buried, as we observe today.

Scientists working under that paradigm look for different kinds of information than do those who assume that the fossil record is the result of a major catastrophe. Because they think that fossils buried low in the geologic column must be much older than and ancestral to those buried in the upper parts of the column, they look for similarities and differences indicating evolutionary relationships.

Many scientists also assume that the fossils lived in the area where they were buried and fossilized, only being transported before burial in ways similar to those observed today. Fossils would thus give information about the environment of the area where they lived and died.

If a major catastrophe such as the Noachian flood was involved, the fossil distribution would be the result of factors other than just time and evolutionary change. A scientist looking at the fossil record under a flood paradigm would assume that most of the fossilized plants and animals had been living contemporaneously, and this scientist would look for characteristics of the fossils that would explain their order of burial during a major catastrophe. Some of the information needed for such an interpretation is often included in the reports generally published, but much is not.

Species descriptions give information about the shape and structure of the fossil, but may not give differences in size, thickness and weight that would be significant in studies of their buoyancy and other transport characteristics. Differences in preservation, which could be indicative of extensive transportation, are generally only mentioned as problems for their identification. Stratigraphic occurrences (the vertical range of the fossil in the geologic column) and geographic occurrences (the locations where the species has been found) are generally given when known. However, only a small fraction of the sedimentary rock in the crust of the earth has been examined for fossils, so their true distribution and abundance can only be estimated.

Another problem with using published descriptions and stratigraphic data is that fossils are often placed in different taxa, even in different superfamilies, if they are found at different levels, even though they might be placed in the same genus or species if found together. It is therefore difficult to recognize potentially equivalent species in the geologic column.

Several questions must, however, be asked of the fossil record to determine if its formation could have taken place within a short period of time. To show the plausibility of a model in which a significant part of the geologic column was deposited during a one-year, worldwide flood and its aftermath, one must show that all the fossils in flood deposits could have been deposited or reworked during the flood events into the observed biostratigraphy, and that similar organisms living after the flood would have a biogeographic distribution and genetic variability consistent with the loss of most of their population during the flood events.

To fully answer all these questions for all the fossil groups would require many lifetimes of research. This paper will explore only the group with which I am most familiar — the microfossils called foraminifers.

Significance of Foraminifers

Protozoans of the Order Foraminiferida have been used extensively for relative dating of marine sedimentary rocks. They are small, generally less than a millimeter in length, and often found in such abundance that hundreds of specimens can be recovered from a mudstone sample with only a few hours of work. Because they are easily recovered from drilling chips, they are used to correlate strata in oil wells. An extensive literature of taxonomy and stratigraphic occurrences has therefore been developed for economic as well as academic reasons.

Foraminifers have more architectural diversity than any other fossil group. Many forms are long-ranging, being found through major segments of the fossil record. Other more specialized forms have very restricted ranges, and so are useful as index fossils. Foraminifers can therefore be used to correlate most marine sedimentary deposits.

Foraminiferal Architecture and Mineralogy

Foraminifer shells, called tests, have many designs including simple tubes, straight series of chambers, coils of chambers and even complex labyrinths. Their walls can be formed of foreign particles agglutinated in organic or calcareous cement, or totally of calcareous material secreted by the foraminifer. They interact with their environment through pores in the test wall and apertures of varying shapes and sizes, including some produced on long delicate necks. Foraminiferal taxonomy is based first on the wall mineralogy and microstructure, then on chamber arrangement, apertural shape and position, and ornamentation (Loeblich & Tappan 1964).

Foraminiferal Biology and Ecology

Foraminifers are abundant today and live in environments ranging from deep sea trenches to estuaries and even freshwater lakes. Planktonic and pelagic species live in the water masses at various depths, while benthic species live near, on or in the sediment on the sea floor. Some are permanently attached to the substrate or to the shell of another animal, but most are free living.

Pseudopodia, hair-like extensions of the foraminifer cell protoplasm, are used for locomotion, for gathering food and building materials, and, with the aid of adhesive material secreted by the foraminifer, for attaching to the substrate. In planktonic species the pseudopodia are symmetrically distributed around the test, which is also surrounded by frothy ectoplasm to aid in flotation. Because they have little control of their movement, planktonic species are passive feeders, randomly attaching to organic particles, algae, bacteria, or copepods which come into range of their pseudopodia (Loeblich & Tappan 1964).

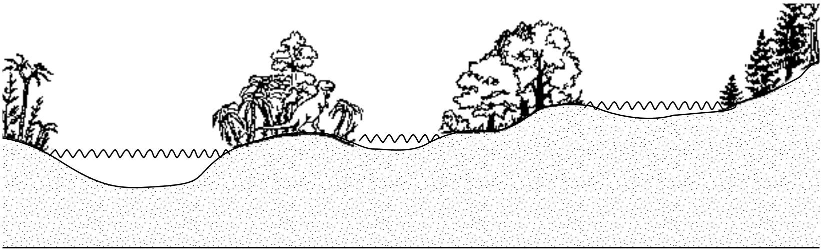
Some foraminifers attach to the sea floor and agglutinate sponge spicules or other material into a tall branching structure to form a base for their network of pseudopodia (Haynes 1981). They are also passive feeders. Free-living species of both infaunal habit (living within the sediment) and epifaunal habit (living on the sediment surface) are generally active feeders, searching for food particles and prey. In burrowing species, the pseudopodia may form a bundle at the aperture to move aside sediment grains. Foraminifers have been clocked at velocities of several millimeters per hour while moving through coarse sand (Haynes 1981).

Foraminifers are tolerant of extreme conditions, with forms living in areas of low oxygen levels, hyper- and hypo-salinity, and extremes of pH and temperature. In deep ocean environments where calcareous material is dissolved, foraminifers with agglutinated tests predominate (Haynes 1981). In nearly anoxic environments (<0.1 ml O_2/l water), foraminifers may be flattened to increase the surface area through which to absorb oxygen (Douglas 1979). Their walls may be thinner and more porous, with less ornamentation.

Within a single species the foraminifers may have thick ornamented walls under normal oxygen concentrations, and thin, less-ornamented walls under low oxygen conditions. In a study of Pliocene foraminifers (probably post-flood), Hendrix (1958) broke open rocks containing both non-laminated massive and thinly laminated mudstone and examined the foraminifers exposed on the fresh surfaces. He found that the foraminifers in the massive sediments had thicker walls with more ornamentation, such as longitudinal ribs and keels, than specimens of the same species from the laminated sediments. Although many factors could influence the formation and preservation of laminae, they are often interpreted to indicate an environment with low oxygen levels (<0.3 ml/l water; Bernhard 1986).

If the changes are a response to the change in environment and do not permanently alter the genetic make-up of the species, the generations after

FIGURE 1. A representation of pre-flood environments as proposed by Clark (1946). The gradual erosion/burial of these ecologic zones by flood waters is used to explain the fossil sequence in sedimentary deposits. Representation not to scale.



the environment returns to normal will have their normal characteristics. Temporary changes in the morphology of a species resulting from changes in its environment are called ecophenotypic variation (Kennett 1976).

Foraminiferal Variability

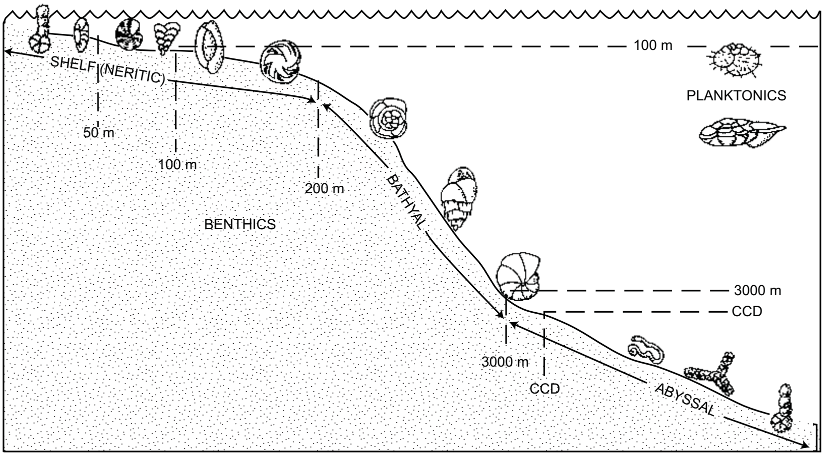
Because of the many examples of variation in living and fossil forms, foraminifers are considered to be extraordinarily plastic (Kennett 1976). A foraminifer may contain enough genetic information to express many different forms, depending on the conditions. The effect on gene expression (shape and function) of environmental factors such as oxygen levels is a subject requiring further research.

Many of the so-called species in the fossil record were probably not separate biological species. A species is defined as a potentially interbreeding group. Fossil species can only be defined based on the characteristics of the preserved remains.

Species may be defined because of their stratigraphic utility. If a group of fossil foraminifers contains a continuum of morphologic forms and one form is found consistently lower in the geologic column than the other, separating them into two or more species would increase the precision of the biostratigraphy based on their ranges.

It is quite possible, therefore, for a few types of created foraminifers to have developed different forms to fill the various ecologic niches in the

FIGURE 2. Representative foraminiferal types in the ocean today. Depth data from Brasier (1980) for planktonic and nearshore environments, Bandy (1953) for bathyal depths and Schroder et al. (1988) for abyssal depths.



pre-flood seas without the necessity of genetic changes requiring long periods of time.

PLAUSIBILITY OF A FLOOD MODEL

Number of Fossil Foraminifers

The first question which must be asked of the fossil record to determine if it could have been formed in a flood scenario is quite simple. Are there too many fossilized foraminifers for them all to have lived and died within the short time allowed?

Answering this question quantitatively would require a detailed analysis of the entire geologic column to estimate the number of foraminifers preserved. Although foraminifers are found throughout the geologic column, they are actually quite sparse in most sedimentary rocks. In Paleozoic and early Mesozoic strata, most specimens are recovered from small fossiliferous areas. A micropaleontologist studying the Triassic, for example, may process samples from a dozen localities before finding any specimens.

The number of foraminifers that could have lived between creation and the flood is also difficult to estimate. The reproductive capability of foraminifers is among the highest on Earth, with a doubling time of 3.65 days (Berger 1976). The pre-flood conditions were likely good for rapid growth and reproduction. During and after the flood the turbid waters would have included high levels of organic matter and other nutrients needed to fuel growth.

Number of Species

The oceans today contain species which are zoned by depth and other factors. If the pre-flood world contained several seas at different levels, as was proposed by Clark (1946), separate morphological species could have developed to fill the niches in those seas (Figure 1). Intensive differentiation could also have occurred during and after the flood events as conditions changed. With the inherent plasticity in foraminifer species discussed above, the many morphological species found in the fossil record could have developed in thousands rather than millions of years.

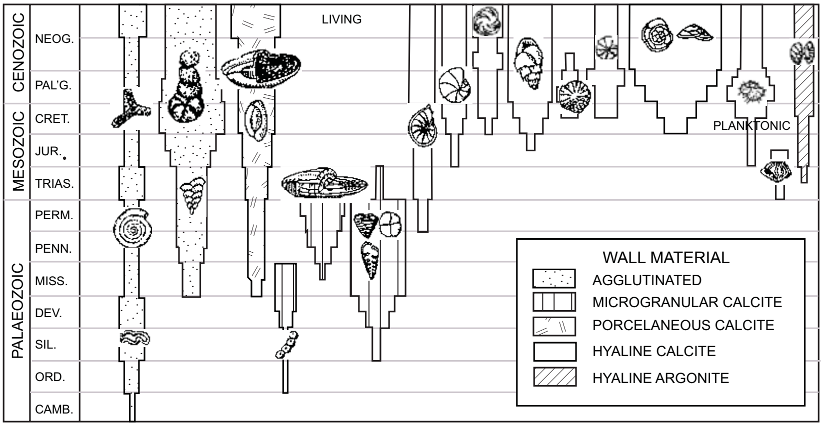
Distribution in the Fossil Record

The stratigraphic distributions of foraminiferal taxa are fairly well described in the literature, but determining if that distribution could be the result of a catastrophic flood is another subject which would require years of research.

A significant problem arises because similar forms are classified differently if they occur at different stratigraphic levels. These cases are explained as iterative evolution, that is, the same form evolved repeatedly through geologic history. Thus classification is subjectively influenced by evolutionary theory. Repeated occurrences could be explained as easily by a catastrophic flood model. If the foraminifers found fossilized at various levels in the geologic column were living at the same time in different ecologic zones, species common to several ecologic zones would be found at several levels. Gaps in the record only indicate that the species was not present in the source area or the ecologic zone being buried at that time, not that it was totally extinct. No coincidence of repeated extinction and identical evolution is required.

Ecologic zonation as developed by Clark (1946) would mean that foraminifers living in the lower seas or deeper parts of the ocean would be buried first as the sediments were redeposited by the gradually rising flood waters, while those from higher ecologic zones would be buried later The fossil record seems generally consistent with this model. Figures 2 and 3 show the distribution of foraminifers today and of fossils in the geologic column. Simple agglutinated forms that now live in environments ranging from the deep sea to estuaries, are found fossilized in Early Paleozoic and younger strata. Calcareous benthic species now predominate both in bathyal environments (Figure 2) and in Mesozoic strata of the past, and

FIGURE 3. Stratigraphic distribution of foraminiferal groups. Width of bar represents number of families. (Modified from Brasier 1980).



presently floating planktonic forms from a higher ecologic zone are abundant in the higher Cenozoic strata of the past.

In the oceans today, calcareous material is dissolved below the carbonate compensation depth (CCD) — usually at a depth of about 4000 m, depending on carbon dioxide concentration. Neither benthic nor planktonic calcareous foraminifers are generally found below that depth on the abyssal plains or in deep sea trenches, because their calcareous shells would be dissolved. Agglutinated forms are dominant (Figure 2). Agglutinated species are common in the Lower Paleozoic, and the benthic calcareous foraminifers found generally have thicker walls than forms higher in the geologic column. They could have lived near the pre-flood CCD where most calcareous forms, especially thinner-shelled planktonic species, would have been completely dissolved. Lower Paleozoic foraminifers are consistent, therefore, with the distribution expected by a catastrophic flood.

The fusulinids in the Upper Paleozoic, however, are an anomaly. Some species of fusulinids grew to volumes of more than 100 m^3 (Ross 1979). Foraminifers which grew that large today have symbiotic photosynthetic algae living in their tests, and so must live within tens of meters of the ocean surface where sunlight is available. Large foraminifers from other groups live in shallow water tropical environments today; therefore, the fusulinids are interpreted also to have lived in a similar environment (Ross 1979), yet we do not find them at the top of the geologic column. Possibly they grew at the surface of pre-flood bodies of water of low altitude (Figure 1).

Planktonic foraminifers are not found in Paleozoic or Lower Mesozoic deposits. Even though living planktonic foraminifers float and would not be expected to be found in the early flood deposits, tests of those which had died before the flood should have been on the sea floor and should have been buried with those living there. Either they were not present in those ecologic zones, or they were not preserved as fossils. Because they have thinner, more porous tests than benthic forms, they could easily have been dissolved preferentially on the sea floor before the onset of catastrophic flooding, if their shells sank below the CCD.

Benthic hyaline calcareous foraminifers become abundant in the Mesozoic. Triassic and Jurassic foraminifers are generally not as well preserved as later forms. In Cretaceous strata, both benthic and planktonic forms are diverse and abundant, making it correlative with the upper bathyal zone of the ocean today.

Foraminifers older than the Cretaceous are generally widely distributed. A Triassic species may be found in both Australia and Idaho, but nowhere in between (Tosk & Andersson 1988). Cretaceous and younger foraminifers have distribution patterns correlative with modern assemblages (Sliter 1972). Under the prevailing paradigm, this would mean that the pre-Cretaceous seas were more cosmopolitan because modern hydrographic patterns and ecologic distributions had not yet developed. Continental fragmentation and sea-floor spreading during the Cretaceous are used to account for the development of modern oceanic patterns at that time.

In a flood model, however, this pattern is what would be expected. During the more violent stages of the flood events, foraminifers from a small area would be scattered widely over the earth. As the violence of the flood died down, foraminifers would not be transported as far and might even begin developing their own ecologic distribution patterns. Major deposition during and after the Cretaceous could have become localized in basins and at continental margins. Life for foraminifers may have returned to normal in less affected areas.

Post-Flood Foraminifers

Some foraminifers must have lived through the flood. Those that could survive such a catastrophe would be forms tolerant of turbidity and strong wave action, and possibly the juveniles of more delicate forms.

All major groups of foraminifers in the fossil record are represented by living forms except the complex fusulinid group which dominated the Paleozoic. As discussed above, they are interpreted to have lived in a tropical-type environment with low sediment output, and they may have had little tolerance for storm conditions. The agglutinated forms found in Paleozoic strata are found in many extreme environments today. They may have been better able to withstand the flood events.

No particular biogeographic distribution would be expected of foraminifers, unlike the animals which were saved in the ark and would have dispersed afterwards. Foraminifers would have continued living wherever they happened to be after the flood events subsided. With the availability of the many open niches and much organic material stirred up by the flood, foraminifers could have multiplied rapidly. Roth (1985) discussed the volume of biogenic sediments, especially foraminiferal oozes, on the ocean floor and showed that it is plausible that the foraminiferal deposits found on today's ocean floors could have been formed in the time since the flood.

CONCLUSIONS

The abundance, diversity and distribution of foraminifers in the fossil record exemplify many of the problems of fitting the fossil record into a short chronology, such as the multitude of species, large numbers of organisms, and apparent evolutionary sequences of simple to complex forms. Living species of foraminifers exhibit diverse morphological forms under varying environmental conditions, raising the possibility that many of the nominal species in the fossil record are actually ecophenotypes. In this case, a long time for evolution to take place would not be required. Presumed evolutionary sequences could then represent populations living in different environments or in the changing conditions during the flood and as it subsided.

Foraminifers are sparsely represented in the fossil record up through the Triassic, with most specimens found in small fossiliferous deposits. With this in mind, and the fact that foraminifers can multiply rapidly, it seems plausible that the number of organisms found in the geologic column could have been produced in the time since creation.

The distribution of foraminifers in the fossil record seems to bear some resemblance to their ecological distribution in the oceans today. Fossil benthic species are found in most Phanerozoic strata, and similar forms are found living in ecological zones ranging from the deep sea to brackish estuaries. Fossil planktonic species are found only in Jurassic and younger strata, while living planktonic species are found floating in the upper parts of the water column. These distributions seem consistent with an ecological zonation model. The extinct large fusulinids in the Upper Paleozoic are anomalous, however. They are interpreted to have had symbiotic algae, so must have lived in shallow environments, perhaps in the upper ecologic zones of a low elevation sea.

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ARTICLES

IMPLICATIONS OF C-14 AGE VS DEPTH PROFILE CHARACTERISTICS

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WHAT THIS ARTICLE IS ABOUT

Intensive analytical treatment of C-14 age profile data indicates that during prehistoric time either the biosphere C-14/C-12 ratio has increased, or the world average sedimentation rate has increased, while peat accumulation rates have decreased. A model based on biosphere C-14/C-12 ratio increase is suggested by the biblical chronologic data in the book of Genesis, and is favored by paleoclimate considerations against a model based on sedimentation rate increase. The currently accepted dendrochronologic framework requires a biosphere C-14/C-12 ratio decrease, and therefore supports a model based on sedimentation rate increase. Aside from dendrochronologic considerations, there is a basis for proposing that sediment, soil, and peat accumulation rates have generally decreased during the prehistoric period following glaciation. Biblical chronologic data taken together with recent Accelerator Mass Spectrometry C-14 data provide a basis for postulating that the biosphere C-14/C-12 ratio has increased more than 70-fold, but less than 500-fold since the global catastrophe described in the 7th and 8th chapters of Genesis. This increase could be due to an increase in the rate of C-14 production and a decrease in the carbon inventory in the carbon exchange system.

INTRODUCTION

The relationship between radiocarbon age data and the chronological data in the fifth and eleventh chapters of Genesis has been examined in previous issues of ORIGINS [2:6-18, 58 (1975); 6:30-44 (1979); 7:9-11 (1980)]. The first of these treatments utilized a crude quantitative description of C-14 age versus depth profile shape and concluded that the deeper portions of these profiles are most likely to be concave toward the C-14 age axis, showing less sediment per C-14 time unit than shallower deposits. Such profile shape could be due to an increasing C-14/C-12 ratio in the biosphere during the early (prehistoric) stages of sediment accumulation and peat growth, increasing accumulation rates as sediment and peat features developed, or a combination of these circumstances. The conclusion in the 1975 treatment, that "C-14 ages in the prehistoric range should be expected to be progressively in excess of the real time involved," was strongly supported by the sediment data set of 60 profiles, and mildly supported by the peat data set of 39 profiles.

DATA BASE

The purpose of this presentation is to acquaint ORIGINS readers with a more extensive and more rigorous investigation reported in *Radiocarbon* (Brown 1986). The report in *Radiocarbon* is based on 170 sediment, 114 peat, and 25 soil profiles. All sediment and peat features that provided the data base for the 1975 report in ORIGINS are included in the data base for the 1986 *Radiocarbon* report. An attempt was made to include in the 1986 report all C-14 age vs depth profiles that have been reported in the scientific literature up through most of 1984. I am confident that this goal was adequately, though not fully, realized except for the scientific literature that was produced within the U.S.S.R. and its satellite countries.

ANALYTICAL TREATMENT

Each set of C-14 age versus depth data in the recent investigation was analyzed using cubic regression for a smooth curve representation of the average data trend. The analysis was limited to profiles which were described by at least 7 data pairs, with the exception of 3 continental sediment and 2 peat profiles, each of which has 6 well-spaced, precisely determined data points. Profiles for which a cubic regression with a Coefficient of Determination (CRCD) of at least 0.70 could not be obtained were not included in the group analysis. Six continental sediment and 5 soil profiles failed to meet the 0.70 CRCD criterion. Sixteen continental sediment, 5 soil, and 9 peat profiles that met the 0.70 CRCD criterion

TABLE 1

Adequacy of Cubic Regression Fit. Coefficient of Determination = 1.0000 represents a "perfect" fit to the C-14 age versus depth data. The ± limits specify the range which includes 67% of the coefficients of determination.

Feature Type	Number of Features	Mean Coefficient of Determination ± one standard deviation	
Deep Ocean Sediment	10	0.991	+0.007 / -0.058
Continental Sediment	160	0.986	+0.011 / -0.045
Soil	25	0.973	+0.017 / -0.046
Peat	114	0.985	+0.011 / -0.033

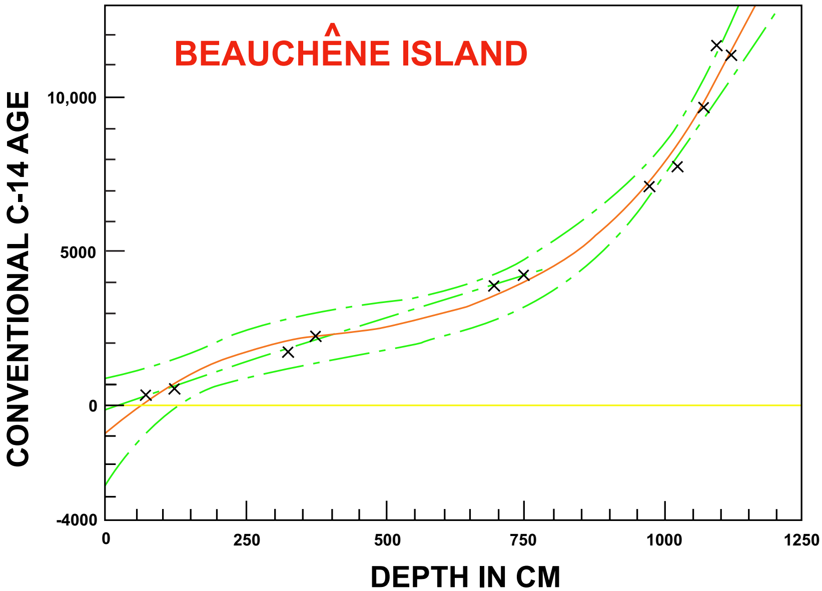
were rejected on the basis of clear evidence that the feature had been disturbed during or since emplacement, or because the data range was too restricted to establish adequately a representative trend. Of the profiles, 170 sediment, 114 peat, and 25 soil survived these restrictions.

Some readers may question the adequacy of a relatively simple cubic regression (second-order nonlinearity) to represent the raw C-14 age profile data. Table 1 gives the mean CRCD together with the range of this coefficient that includes 67% of the data set.

All profiles for which the smooth curve representation was only mildly curved were fitted with both a cubic regression and a linear regression. If the linear regression (straight-line fit) gave a lower Standard Error of Estimation than did the cubic regression, the profile was represented in group analysis by its linear regression. No deep ocean sediment profiles, 19 continental sediment profiles, one soil profile, and thirty peat profiles were better represented by a linear regression.

For each profile a plot was made showing the raw conventional C-14 age (5568 year Libby half-life) vs depth data points, the best-fit regression

FIGURE 1. Peat profile from Beauchêne Island, Falkland Islands (data from Smith & Prince 1985). Dashed adjustment to regression line provides most reasonable estimate of slope and curvature at 2500 ^{14}C yr (see also Smith & Clymo 1985).



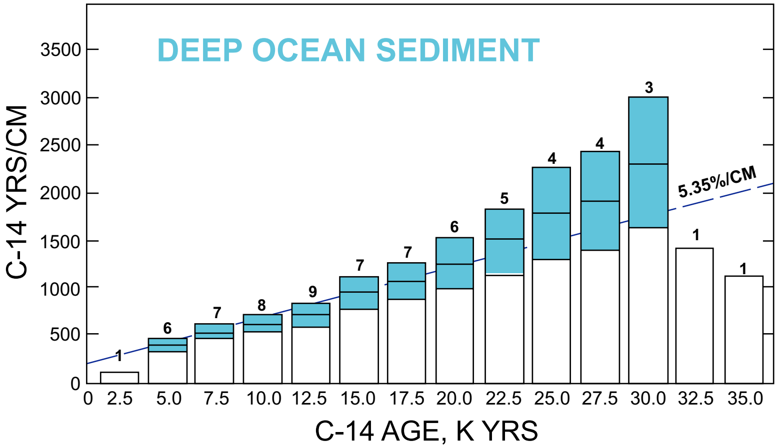
line for the raw data, and the 95% confidence boundaries for the regression line, as illustrated in Figure 1. The slope of the regression line in C-14 years/cm was calculated for 2500-year intervals. If the slope (C-14 years/cm) at either of the extreme data points appeared questionable, the regression line was extrapolated as a straight line of slope compatible with the interior section. (The regression curve fitting process gives the best fit to the input data points, but may yield an incorrect slope of the regression line at the extreme points where there is constraint in only one direction. See Figure 1 for an example.)

For each of the four feature types (deep ocean sediment, continental sediment, soil, and peat) the mean regression line slope in C-14 years/cm was determined for intervals of 2500 years. These mean values are represented by vertical bars in Figures 2-5. The filled portion of these bars represents the range within which the respective mean value has a statistical expectation of failing with 67 chances out of 100. The numbers at the top of each bar are the number of profiles in the data represented by the bar. Figures 2-5 represent only data for profile sections bounded by C-14 age determinations, i.e., no data from extrapolated regions are included. The line designated %/cm represents the average increase in C-14 years/cm between adjacent bars.

DISCUSSION

The data represented in Figures 2-5 clearly establish a global tendency for C-14 age increment per unit of depth to increase with depth, i.e., for

FIGURE 2. Graphic summary of global slope characteristics of deep ocean sediment profiles.



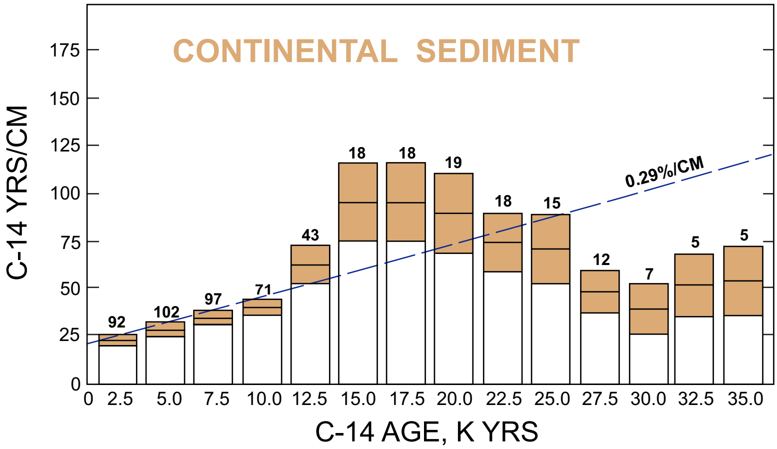
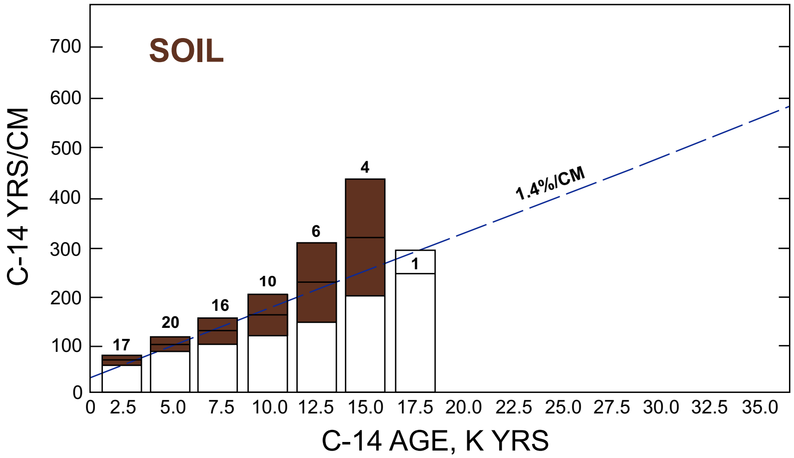


FIGURE 3. Graphic summary of global slope characteristics of continental sediment profiles.

FIGURE 4. Graphic summary of global slope characteristics of soil profiles.



the C-14 age profile to be concave toward the C-14 age axis, as in Figure 1. The three peat bog data sets which include 15,000, 17,500, and 20,000 C-14 years are an inadequate sample for determining global characteristics. Since there are such a large number of samples over the 0-10,000 C-14 year range, it is most reasonable to conclude that within the limits of the currently available data an average peat deposit profile should be expected to be linear. Accordingly, the profile represented in Figure 1 does not represent the most probable C-14 age versus depth (thickness) relationship

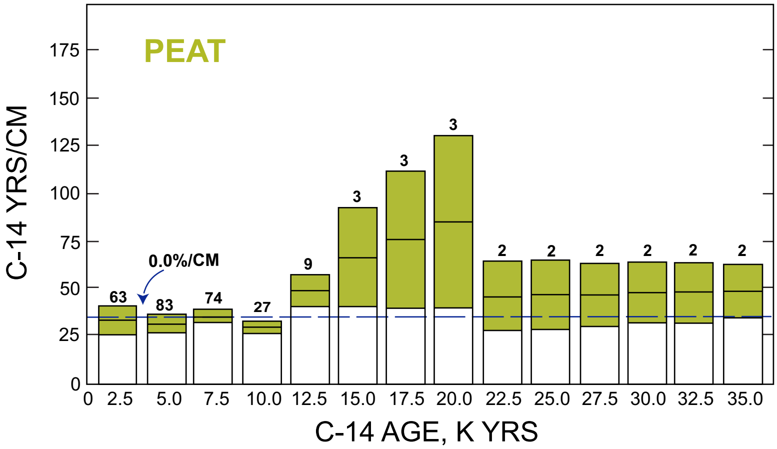


FIGURE 5. Graphic summary of global slope characteristics of peat profiles.

for a peat deposit. Several factors that might affect the shape of a profile are discussed below.

Compaction may be expected to increase the C-14 age span per cm of depth in the lower portion of a deposit and produce a C-14 age profile concave toward the C-14 age axis. If compaction is an adequate explanation for the profiles depicted in Figures 2-4, the average density at profile depths associated with 15,000-year C-14 age must be 3.2, 4.2 and 4.8 times the average density at profile depths associated with 2500-year C-14 age for deep ocean sediment, continental sediment, and soil, respectively (ratio of C-14 years/cm ordinates). Such ratios are unreasonable since they require a sediment density greater than that of either granite or basalt. Furthermore, if compaction is a significant factor, it should be more pronounced among a group of thicker features than among a group of relatively thinner features. The average increase in C-14 years/cm per cm of depth should be greater (correlate positively) for relatively thick features than for relatively thin ones. Table 2 lists the Coefficient of Correlation between average increase per cm in C-14 years/cm and maximum depth for the profiles in the feature types described in Table 1.

The small negative correlation for sediments probably has no significance. The negative 0.47 correlation for soil profiles indicates that shallower soil profiles have a distinctly greater tendency to be concave toward the C-14 age axis than do deeper soil profiles. I have no explanation for a difference between soil and sediment profiles in this respect. The more positive correlation for peat profiles with respect to sediment profiles

TABLE 2

Compaction Analysis. Coefficient of Correlation between average increase per cm in C-14 years/cm and maximum depth for the profile groups described in Table 1.

Feature Type	Range of Maximum Depth(cm)	Correlation Coefficient
Deep Ocean Sediment	14-55	-0.18
Continental Sediment	35-8010	-0.10
Soil	75-285	-0.47
Peat	78-1770	+0.16

indicates that compaction has been a significant, but not major, factor in peat accumulations.

Another possible cause of C-14 age profile concavity toward the C-14 age axis is contamination (Nambudiri et al. 1980), providing the degree of contamination by more ancient material progressively decreases with time. While allowance should be made for such possibility at some locations over some periods of time, it does not appear to provide a universally adequate explanation. Contamination by material of greater than contemporary age as a feature builds up by natural processes most reasonably should be negligible, uniform in time, or episodic. A uniform rate of contamination would have no effect on the C-14 age profile shape. Episodic contamination would produce a profile discontinuity that gives data points which do not fit the general profile trend. Such anomalous data are occasionally encountered and are easily recognized.

A universally adequate explanation for the sediment and soil C-14 age profile shape tendency seems to require a progressively increasing C-14/C-12 ratio in the supporting environment and/or progressively more rapid accumulation rates. Considerations relative to a C-14/C-12 ratio increase have been presented earlier (Brown 1979). Dendrochronologic correlations with C-14 age (e.g., Kromer et al. 1986) appear to limit changes in C-14/C-12 ratio to only a minor, rather than a dominant, role. The classical grammatical-historical interpretation of the Hebrew scriptures provides constraints on historical time that disallow the currently accepted dendrochronologic models for time prior to around 2000 B.C. (Hasel 1980a,b), and favor an increasing C-14/C-12 ratio as the dominant factor in sediment and soil C-14 age profile shape tendency. The evidence concerning paleoclimate does not indicate a steadily increasing global trend for sedimentation, erosion, and soil buildup rates throughout the late Pleistocene and early Holocene epochs. This is contrary to the possible explanation that the dominant factor in sediment and soil C-14 age profile shape might be changes in accumulation rate (Hecht 1985). The choice between increasing C-14/C-12 ratio and increasing accumulation rate will depend largely on the relationship between one's confidence in a chronology based on the data in the first eleven chapters of Genesis and his confidence in the models for paleoclimate and dendrochronology that are in vogue. An additional factor that could produce a C-14 age versus depth profile concave toward the C-14 age axis for peat accumulations is decomposition (Clymo 1984). Decomposition allows organic material to be carried away in solution by percolating water. The older (lower) portions would be more depleted than the younger (upper) portion. Also compaction should be a more significant factor for peat profiles than for sediment and soil profiles. The Correlation Coefficient data in Table 2 is consistent with these considerations. Since the group average profile for peat deposits is essentially linear over at least a 10,000 C-14 year range (Figure 5), the global average peat *accumulation* profile (excluding the consequences of compaction and decomposition which produce a profile convex toward the depth axis) must be concave toward the depth axis over the same range of time. Such a characteristic specifies declining peat accumulation rates, at least over the early portion of the time covered by the last 10,000 C-14 years.

If the C-14/C-12 ratio increases with time, a C-14 age based on a recent C-14/C-12 ratio will be increasingly greater than the corresponding real-time age. Consequently, an accumulation profile of C-14 age versus depth would be less concave toward the depth axis than the corresponding real-time age versus depth profile, and could be reversed to appear convex, as in Figure 1. Accordingly, the actual decline in a peat accumulation rate could be greater than might be inferred from a C-14 age versus depth profile.

To eliminate an increasing C-14/C-12 ratio as a major factor in producing the profile characteristics displayed in this analysis, it would be necessary to have a world-wide climate trend favoring an increase in average sediment and soil accumulation rates. Since most of the peat bogs described in the literature are located in formerly glaciated areas, it seems to me more reasonable to presume that the global averages of both sediment accumulation rates and peat accumulation rates have declined over at least the early part of the Holocene.

C-14/C-12 RATIO INCREASE LIMIT

If there has been a C-14/C-12 ratio increase in the biosphere, is there a basis for determining a probable value for this increase? Such a determination can be made if one has appropriate samples of known real-time age, equipment capable of determining the residual C-14/C-12 ratio in these samples, and techniques for determining the amount of C-14 contamination in them. Contamination could be due to a mixture of carbonaceous material older than the real-time age of the sample (C-14/C-12 ratio lower than the "true" value), or to transfer from contact with younger carbonaceous material (C-14/C-12 ratio greater than the "true" value).

The data in the first eleven chapters of Genesis specify a major global catastrophic event that occurred within about ±500 years of 5000 years ago. Remains of organisms buried during this catastrophe would now be characterized by 51-58% of the C-14/C-12 ratio that characterized them at death. Since the C-14 in Earth's biosphere is formed by interaction of cosmic ray protons with nitrogen atoms in the upper atmosphere, it is most reasonable to presume that the C-14/C-12 ratio in the pre-flood biosphere was greater than zero, specifically 72-96% greater (since 1/.51 = 1.96 and 1/.58 = 1.72) than that which now characterizes the remains of organisms buried during the Noachian flood.

The Twelfth International Radiocarbon Conference featured reports from seven laboratories on the present capabilities of the nuclear accelerator mass spectrometry (AMS) technique for direct counting of C-14 atoms [*Radiocarbon* 28(2A):177-255 (1986)], the most refined and sensitive technique for C-14 age determination. Table 3 summarizes the C-14 age

TABLE 3

AMS Data for "Infinite" C-14 Age Samples. Data from seven laboratories reporting in *Radiocarbon* 28(2A):177-244. Column four is derived from column three.

Sample	Equivalent C-14 Age	C-14/C-12 Ratio re 1950 A.D. Standard	Excess Over Machine Background
Machine Background without a sample	60,000 - 73,000	.00070 - .00015	—
Unprocessed Finland Bedrock	63,500 ± 2,000	.00046 ± .00011	0
Unprocessed Meteorite	56,500 ± 1,500	.00108 ± .00020	ca. .00040
Unprocessed Natural Graphite	54,000 - 64,000	.00146 - .00043	.00080 - 0
"Infinite" Age Samples:anthracite, bone, calcite, graphite, limestone, shell, wood	40,000 - 52,000	.00792 - .00185	.0072 - .0011

threshold data in these reports. Since column 4 combines data from seven different laboratories, the numbers given therein should be considered as only rough estimates of what might be expected in any particular laboratory. The meteorite listed in Table 3 would be expected to contain a trace of C-14 formed by spallation reactions with cosmic rays before its entry into Earth's atmosphere.

Assuming that "infinite" age samples are components of deposits made during the flood episode, and adding 72-96% to estimate C-14 activity at the time of burial/formation, the .0072-.0011 range in column 4 of Table 3 becomes .014-.002, or $^{1}/_{71}$-$^{1}/_{500}$. The $^{1}/_{71}$-$^{1}/_{500}$ range fraction of modern C-14 concentration could be entirely contamination during sample handling and preparation. There is also a possibility that it could be largely residual C-14. If residual C-14 is present, the ^{1}/71-^{1}/500 range probably represents varying proportions of residuum and contamination. From the perspective of a C-14 age model that includes the historical and chronological data in the first eleven chapters of Genesis, one can postulate that since the Noachian flood the biosphere C-14/C-12 ratio has increased more than 70-fold, yet probably less than 500-fold. Modeling considerations for such an increase have been discussed in Brown (1979).

CONCLUSIONS

In the opinion of the writer, the extended and more intensive investigations reported here provide increased credibility for the conclusion offered in my 1975 treatment, viz., that C-14 ages in the prehistoric range should be expected to be progressively in excess of the real time involved. While confidence in the historical and chronological data in the first eleven chapters of Genesis must be based on considerations which are independent of radioisotope-age data — and accessible to individuals who are not in a position to understand such data —, every effort should be made to develop a composite view (model) which harmonizes the data from these two sources. Those who seek such harmonization on a soundly logical and broad scientific base may find in the quantitative analysis presented here encouragement for assignment of the total range of C-14 dates for plant and animal remains to a 5000-year span of real time since the world cataclysm portrayed in Genesis 7 and 8.

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ANNOTATIONS FROM THE LITERATURE

ANTHROPOLOGY

Lewin R. 1987. Bones of contention. Controversies in the search for human origins. NY: Simon and Schuster. 348 p.

Summary. Described as the most "insightful and most controversial" book on paleoanthropology, the volume chronicles the never-ending saga of investigations on fossil man and his assumed ancestors. The book not only examines the scientific aspects of the most famous relevant controversies, but also concentrates on the humanness of the investigators involved. Probably no branch of science has been subject to more contention and change than has paleoanthropology, and in this discipline the author, a well-known scientific writer, has found a fruitful area to discuss the "bones of contention". This is a fascinating volume that is well-documented and provides pertinent details of the controversies.

PALEOMAGNETISM

Courtillot V, Besse J. 1987. Magnetic reversals, polar wander, and core-mantle coupling. Science 237:1140-1147.

Summary. The rate of reversal of Earth's magnetic field was lowest during the Permian and Cretaceous periods. Each of these periods was preceded by a reduced amount of polar wander, and each was followed by continental drifting, an increase in vulcanism, and a major mass extinction. The Deccan flows in India erupted at the end of the Cretaceous, and the Siberian flows apparently originated at the end of the Permian. The authors suggest that thermal instabilities originating in the core-mantle boundary initiated a series of events causing crustal instability. Crustal instability resulted in plate movements and extensive vulcanism, which in turn caused the mass extinctions at the ends of the Permian and Cretaceous periods, respectively.

Comment. The possible linkage between magnetic reversals, vulcanism, continental drifting, and mass extinctions might be useful in developing a model of the catastrophic flood described in the book of Genesis.

SPECIATION

Meyer A. 1987. Phenotypic plasticity and heterochrony in *Cichlasoma managuense* (Pisces, cichlidae) and their implications for speciation in cichlid fishes. Evolution 41:1357-1369.

Summary. The relationship between diet and morphology in a species of cichlid fish was tested. Three groups of fish were used. One group was fed Diet A, and a second group was fed Diet B. A third group was fed Diet B for the first 8½ months, then switched to Diet A. The fish were x-rayed at intervals, and measurements of the proportions of the head and jaws were taken from the x-rays. The results showed that fish fed with Diet A and those fed with Diet B had different head shapes. When the diet of the third group was switched, the jaw morphology also changed. By 16½ months, the group originally fed Diet A and the group that was switched to Diet A were statistically indistinguishable, while the group on Diet B was morphologically different.

Summary. This experiment indicates that the environment has the potential to significantly affect morphology. The species flocks of East African cichlids should be studied more to see whether they have been properly classified.

LITERATURE REVIEWS

Readers are invited to submit reviews of current literature relating to origins. Mailing address: ORIGINS, Geoscience Research Institute, 11060 Campus St., Loma Linda, California 92350 USA. The Institute does not distribute the publications reviewed; please contact the publisher directly.

EXAMINING RADIOHALOS

CREATION'S TINY MYSTERY. 1988. R. V. Gentry. 2nd ed. Earth Science Associates, Knoxville, Tennessee. 347 p.

R. H. Brown, H. G. Coffin, L. J. Gibson, A. A. Roth, and C. L. Webster, Geoscience Research Institute

This book is an account of Robert Gentry's efforts to defend creation, particularly his model of creation. The author has spent many years studying and promoting pleochroic halos [microscopic rings in rocks formed by radioactive decay in the center of the ring] as evidence of instantaneous creation. His hard work and commitment are commendable.

The first edition of *Creation's Tiny Mystery* was published in 1986. The second edition (1988) is essentially the same as the first, but contains additional material concerning exchanges between the author and various individuals who have challenged his interpretation of the data he has collected. The book is published in paperback and contains eleven color plates of radiohalos. For the purpose of discussion, it can be divided into three parts.

The first four chapters of the book are an autobiographic account of how Gentry became involved in the investigation of radiohalos, together with a description of the kind of data he found. The remaining eleven chapters are largely reports of reactions of various individuals to Gentry's interpretation of his data. The last third of the book is an appendix containing a collection from Gentry's published papers and some correspondence relating to his discoveries. After a brief commentary on each of these sections, this review will evaluate Gentry's conclusions in some detail.

The first four chapters, together with the color plates of radiohalos, are the most interesting and useful part of the book. The way in which radiohalos are formed is explained, and the author's view of their significance is outlined. Anyone interested in radiohalos — and in Gentry's views — would benefit from reading these chapters.

The remaining eleven chapters are largely a record of Gentry's efforts to promote his views, along with his concern over their nonacceptance. Several chapters are devoted to the 1981 Arkansas evolution/creation trial, at which Gentry testified in support of creationism. This material is largely of historical interest. Gentry claims that his creationistic beliefs have resulted in discrimination against him; but the reader may be unable to tell whether this discrimination has been due to his philosophical beliefs or to his methods of promoting them. An example is seen in his challenge to the National Academy of Sciences that is reproduced on p 196-198, 322-324 of *Creation's Tiny Mystery*. The president of the Academy is to be commended for his restrained response.

The appendix contains copies of several of Gentry's published papers which present the technical details of his investigation of radiohalos. Most of these papers are in readily available sources, but it will be helpful to some readers to have them so conveniently accessible. The appendix also contains records of some of Gentry's exchanges with various individuals who have questioned his conclusions.

It is regrettable that the author did not expend more effort in organizing and presenting the evidence and the basis for his interpretation of that evidence. Those who are interested in the validity of Gentry's interpretations will find material of substance primarily in the first four chapters, the radiohalo catalogue, and the copies of his published papers. The remainder of the book is more polemic than many readers would wish, and contributes little to an understanding of Gentry's creation model. His model of earth history is partially described, especially on p 184-185 and 280-281. He proposes at least three "singularities" (short periods of time in which God supernaturally intervened in natural processes). These are the *ex nihilo* creation of Earth and the Milky Way galaxy, the fall of man, and the Noachian flood. Between these singularities, Gentry believes, natural laws continued in operation as they do today. During these singularities, the operations of natural law were superseded. In particular, the rates of radioactive decay for uranium and some other kinds of atoms were accelerated; however, the polonium decay rates were not altered.

Gentry's conclusions seem to be based on two propositions which he believes are supported by the evidence from radiohalos The first of these is his belief that rocks containing halos, especially granites, are rocks that were directly created by God, presumably during the Genesis creation week. Gentry's second proposition is that polonium radiohalos were created in the rocks as evidence that the rocks did not form naturally, but were created. The basis for the first proposition seems to be that when granite is melted and then allowed to cool, it does not reform with the same crystal structure, but instead cools to form rhyolite. This suggests to Gentry that granite cannot form naturally, but must be the result of supernatural activity. Both propositions will be evaluated in the succeeding paragraphs of this review.

Before proceeding, it should be pointed out that belief in *ex nihilo* creation, the fall of man, and the Noachian flood does not rest on the acceptance or rejection of the thesis presented. If Gentry is wrong in his understanding of the evidence, the validity of biblical creationism is not in jeopardy. Biblical creationism is supported by many other kinds of evidence.

The key to understanding the technical aspects of many problems is the dividing of that problem into as many known parts as possible, thereby isolating the unknown parts for further study. Such a division of the "mystery" of the polonium pleochroic halos results in several known aspects and very few unknown aspects.

The basic "tiny mystery" of the halos is as follows:

1. There exists in the biotite (mica) of some granites and some pegmatites certain pleochroic halos identified as arising from the radioactive decay of three polonium isotopes.
2. The specific isotopes of polonium are Po-210, Po-214 and Po-218. Gentry's observations have suggested that these halos are independent of other radioactive elements, i.e., are not derived from the systematic radioactive decay of U-238.
3. The "mystery" is: If these polonium halos are independent of U-238, how did they get into the mica within solid granite when the polonium half-lives may be only 138 days, 3 minutes or 164 millionths of a second?! (Polonium halos are also found in the hydrothermal mineral fluorite, although less frequently than in mica.)

Seven principal questions need to be answered in attempting to understand this "mystery":

1. How are the halos formed?
2. How are the halos identified as polonium halos?
3. Where are the halos found?
4. How did the halos get into the micas or fluorite?
5. Where did these halos form?
6. Are there other halos present in the micas in addition to those produced by polonium?
7. If the initial independence from a uranium-source assumption is incorrect, what happens to the "mystery"?

On the question of halo formation, Gentry and other scientists are in agreement. Pleochroic halos are the result of crystal lattice damage due to the impact of alpha particles from radioactive decay occurring at the center of the halo.

Halo identification is achieved through the measurement of the halo diameter. The size of the halo and the half-life of the isotope producing it are related. Assuming that the half-life of the parent isotope has remained constant throughout the formation of the halo, the initial energy of the alpha particles that produced the halos can be determined, and hence the parent radioactive isotope identified. In making this identification, Gentry assumes, as do other scientists, a constancy of radioactive decay rate for polonium. However, Gentry also wants to invoke periods of time that "...may have been accompanied by an increased, nonuniform radioactive decay rate" (p 134). If there were periods of nonuniform decay rates, identification of any pleochroic halo from its ring diameter would be questionable at best! All available data indicate that halo ring diameter increases with increase in decay rate. Either the rates remain constant or they do not. Evidence from other sources[1] suggests that the decay rates have remained constant for all radioactive isotopes. Several problems arise when one attempts to invoke increased decay rates while at the same time keeping the halo diameters constant! Such inconsistency cannot be considered as a satisfactory argument.

Questions 3 and 4 are the areas in which there is some of the most open contention between Gentry and other scientists, creationists and non-creationists alike. Throughout *Creation's Tiny Mystery*, Gentry claims that primordial polonium halos are found only in Precambrian granites, pegmatites and possibly some flood rocks. Moreover, Gentry claims that these polonium halos are the "fingerprints of the Creator" and can therefore have no other origin. On the other hand, Gentry recognizes that the polonium halos in coalified wood are of secondary origin, i.e., due to transport into the wood of polonium derived from uranium, rather than arising by instantaneous fiat creation.

A careful examination of some of the geologic settings where polonium halos are found reveals that at least some of the minerals containing the polonium halos are not found in primordial Precambrian granites.[2,3,4] More will be said about the geologic setting later.

Irrefutable laboratory evidence as to the geochemical processes involved in polonium halo formation is lacking. However, a systematic study of the geologic and geochemical data strongly suggests one or more transport models for the emplacement of polonium halos in biotite, fluorite and other minerals. The polonium or polonium precursors, in the form of aqueous solutions, are transported into the minerals along crystal lattice planes, cracks and conduits. Gentry's "spectacle halo" (p 218, Plate 9-B) is an excellent example for solution transport along conduits.

One of the best papers addressing transport mechanisms for polonium halos is that of Meier & Hecker.[5] They suggest that polonium halos are associated with uranium deposits either by hydrothermal processes or supergene (downward enrichment) processes. Without invoking unknown processes, Meier & Hecker — and others — can account for the polonium isotopic pattern and abundances as well as the geochemical and geologic setting in which the polonium halos are found.

The question as to when the pleochroic halos formed in the rocks — or more basic yet, when did the rocks that contain the pleochroic halos form? — evokes open confrontation between the position that Gentry adopts and the views held by the majority of the scientific community. In *Creation's Tiny Mystery*, Gentry repeatedly states (p 25, 36, 65, 66, 98, 117, 153, 184) that the Precambrian granites represent the primordial creation rocks. Part of the reason for this statement is the presence of pleochroic halos found in them. However, Wakefield[6] and Wilkerson[7] challenge this interpretation, pointing out that the localities where the pleochroic halos are found represent secondary rocks, specifically dikes of granite and even calcite veins that intrude older rocks; hence, they are at least secondary in origin. Wise,[8] who has reviewed the literature on the localities where pleochroic halos have been reported, indicates that a majority (15 out of 22) appear to come from veins or dikes (pegmatites), and hence represent secondary and not primary rocks.

Without entering into the argument as to the absolute age of the rocks (either primary or secondary), it would be safe to state that the majority of halo-containing minerals are younger than the host rock and therefore do not represent primordial material.

The presence of non-polonium pleochroic halos found near polonium halos in biotite, fluorite or other minerals weakens Gentry's case even further. This is especially true when Gentry must invoke a nonuniform increased radioactive decay rate to account for the presence of U-238, Th-232 and Sm-146 halos, while leaving untouched the polonium decay rates! Gentry must invoke a nonuniform rate increase for some of the halos, because at present the half-lives of these other halo-producing isotopes are on the order of hundreds of millions to thousands of millions of years!

If Gentry's independence assumption (polonium halos formed from polonium which was not produced by the radioactive parent U-238) is found to be incorrect, or even found to be strongly questionable, his whole contention that pleochroic halos are evidence of *ex nihilo* creation becomes suspect. The fact that the polonium isotopes involved in halo formation in the rocks are only those which are daughter products of systematic uranium and thorium decay forces one to suspect immediately that they are derived from uranium rather than a special creation. There are 19 other polonium isotopes, not derived from uranium and thorium, and literally hundreds of *independent*, non-polonium halo-producing isotopes that could give stronger evidence for instantaneous creation of the granite or other rocks.

No review would be complete without addressing Gentry's challenge to evolution. In *Creation's Tiny Mystery*, the author states that he will consider his thesis ("evidence for creation", p 72) essentially falsified if a single hand-sized specimen of granite is synthesized in the laboratory (p 65, 72, 98, 117,120, 123, 128, 129ff, 183, 191, 194). Probably the author derived this challenge from his belief that the pleochroic halos found in granite represent "God's fingerprints" and thus instantaneous creation. There are several problems with this falsification-of-creation test.

1. The ability to synthesize granite in the laboratory may have little to do with creation. The argument is basically a *non sequitur*. Whether we can or cannot synthesize certain rocks or minerals in the laboratory seems to reflect mainly the sophistication of our laboratory procedures. One could likewise say that the synthesis of a one-kilogram (2.2 pound) diamond would disprove creation. But such an argument would not be taken seriously.
2. We can now synthesize many substances that could not be produced artificially in the past. This fact should evoke caution regarding risking belief in creation on whether or not a hand-sized specimen of granite can be synthesized. In the past we were unable to synthesize diamonds or opals, but we can now. Over a century ago, some individuals believed that organic compounds could only be created by God, but many thousands of them have been synthesized since then! In addition, all the basic minerals found in granite have already been synthesized in the laboratory.[9,10,11,12] It seems risky to pose a challenge to evolution on the basis of whether or not a hand-sized piece of granite is synthesized, since none of us can predict the future developments of science.
3. It appears that in a number of instances, granite has formed as the result of natural processes. This seems to be the case when granite penetrates (in the form of veins or dikes) older rocks, some of which contain fossils. Obviously the granite was formed after the intruded rocks. Granite filling cracks in fossil-bearing rocks suggests a natural formation of granite rather than evidence for creation. Even more convincing for a naturalistic origin of

granite is the discovery *within* granite of shells of a number of fossil species of brachiopods.[13] One could hardly argue that God would place fossils in granite He was creating.

Creation's Tiny Mystery represents an interesting approach at a synthesis of science and the Bible; however, the argumentation presented has some serious problems. These include:

1. The inconsistent use of radioactive disintegration rates;
2. The fact that polonium halos appear to be derived from uranium;
3. The evidence for the origin of polonium halos by aqueous transport; and
4. The fact that polonium halos are found in secondary rocks.

Because of these and other problems, readers of *Creation's Tiny Mystery* should be cautious in accepting its argumentation and claims of evidence for *ex nihilo* creation.

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GENERAL SCIENCE NOTES

THE UPPER LIMIT OF C-14 AGE?

By R. H. Brown, Geoscience Research Institute

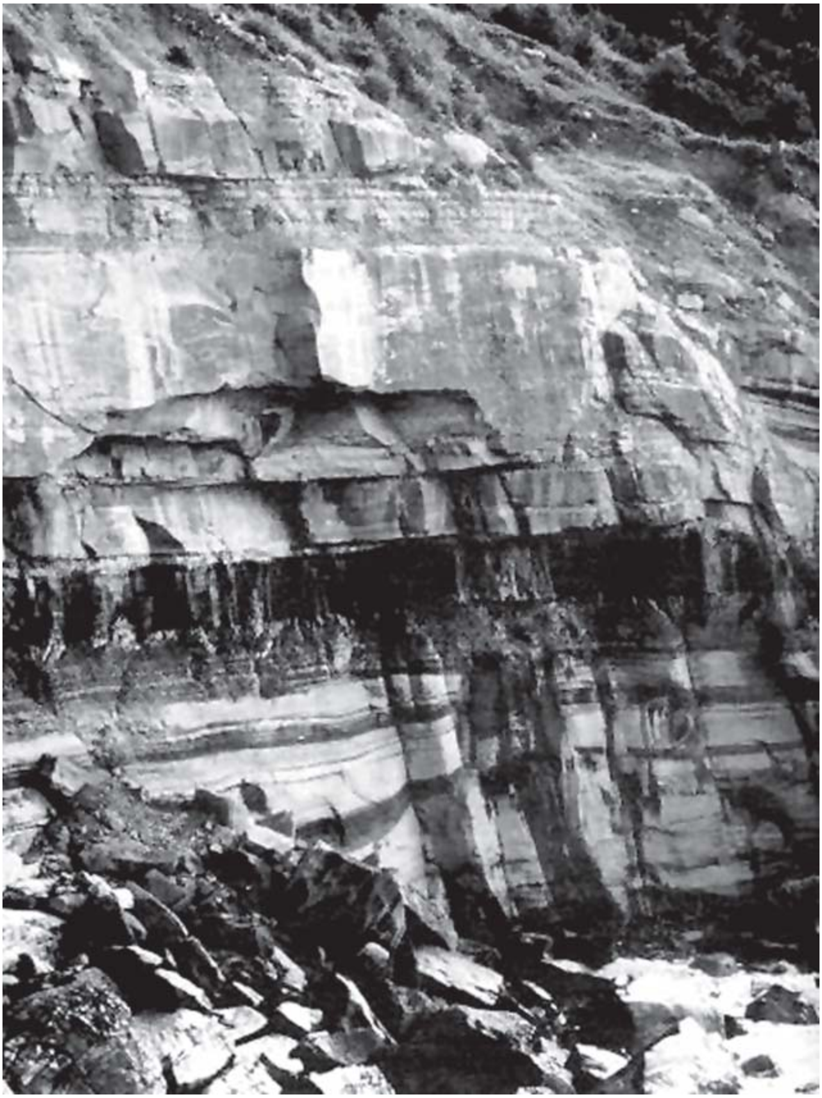
WHAT THIS ARTICLE IS ABOUT

Some recent radiocarbon dates derived from sources assumed to be geologically very old give dates in the 40,000-year range. These relatively young dates may reflect the concentration of Carbon-14 in the antediluvian atmosphere. Implications related to the antediluvian Carbon-14 production rate and the size of the biosphere are considered.

The development of the Accelerator Mass Spectrometry (AMS) technique for measurement of radiocarbon (C-14) activity has renewed interest in the C-14 activity levels of "infinite" age samples. Infinite age samples are those considered too old to be dated by radiocarbon techniques. Over a period of time equal to ten half-lives, the activity of an isolated radioactive specimen will diminish by a factor of 2^{10} or 1024. For 5730-year half-life C-14 this time period is 57,300 years. The sensitivity of the AMS technique is such that samples from a biosphere such as that which is now characteristic of planet Earth should exhibit detectable residual C-14 activity into the 60th millennium after isolation (i.e., over about 12 C-14 half-lives). As far as this technique is concerned, samples with a real-time age greater than 70,000 years would be in the "infinite age" classification.

"Infinite age" samples such as anthracite coal from deep mines in Carboniferous geologic formations (270-350 millions years conventional age assignment) have yielded AMS C-14 ages in the 40,000-year range at laboratories in Europe, Canada, and the U.S.A. (Brown et al. 1983; Jull et al. 1986; Beukens, Gurfinkel, & Lee 1986; Grootes et al. 1986; Nelson et al. 1986; and Bonani et al. 1986). The ready explanation for this unexpected result is contamination from the contemporary biosphere. *Radiocarbon* [Vol. 29, No. 3 (1987)] contains reports of two attempts to determine the limits of such contamination, one at Simon Frazer University in British Columbia (Vogel, Nelson & Southon 1987), and the other at the University of Toronto in Ontario (Gurfinkel 1987).

The Simon Frazer University study indicates that machine background and sample preparation procedures do introduce uncertainty in C-14 age



Coal seam (black layer) from the Permian deposits along the east coast of Australia south of Sydney. See this article regarding the unexpected presence of Carbon-14 in such seams.

determinations on samples of anthracite smaller than about 400 micrograms. Forty-three samples of anthracite from Pennsylvania, U.S.A., that had been given the best-known pretreatment to remove contamination by modern carbon, and ranged in size from 0.5 to 20 milligrams, yielded a 43,000-year C-14 age, regardless of sample size. According to the authors' Table 1, less than 30% of the C-14 activity associated with this 43,000-year age limit could be assigned to machine background and contamination during sample preparation.

The University of Toronto investigator (Gurfinkel 1987) stated that "One of the major problems encountered in this study was the apparent presence of ^{14}C contamination in samples that were assumed dead....it could not be assumed that even the oldest samples were necessarily ^{14}C free" (p 342). Her meticulous investigation using graphite, calcite, limestone, and anthracite samples concluded that "infinite age" samples should be expected to have "contamination" up to as great as that represented by a conventional 43,000-year C-14 age, similar to the results obtained by the Simon Frazer University group.

These findings are of particular interest to individuals who are looking for models that relate the historical data in the Bible to modern scientific observations. Chapters 6-8 of the book of Genesis describe a universal catastrophe that reasonably may be expected to have produced most of the coal and shell fossil material, much of the limestone, and some of the calcite accessible today. Since terrestrial C-14 is produced almost entirely by the interaction of cosmic rays with atmospheric nitrogen, C-14 should have been present in the antediluvian biosphere as well as in the immediate postdiluvian and the contemporary biosphere.

The C-14 production rate (R) and the active biosphere carbon inventory (I) may not have been the same in antediluvian time as at present. Consequently the equilibrium activity level (A) which is proportional to the ratio R/I may not have been the same then as that which characterizes the modern environment (13.6 spontaneous C-14 disintegrations per minute per gram of carbon).

The precise date for the Deluge of Genesis 6-8 cannot be determined because of variations in the source documents (Samaritan, Septuagint, and Masoretic manuscripts). The best we can affirm is that the source material specifies a universal destruction and reorganization of planet Earth's surface most probably sometime within the range 2500-3500 years BC (Brown 1987). Accordingly, organic material buried in this catastrophe would now have a real-time age since burial in the range 4500-5500 years, and should now exhibit about 55% of the C-14 activity level that characterized the antediluvian world. Any C-14 age in excess of about 5000 years for such material could be attributed to a lower R/I ratio than that which characterizes the modern biosphere — a lower C-14 production rate (R), and/or a larger active biosphere carbon inventory (I).

According to the two research reports reviewed here, carbon from the antediluvian biosphere should now have a radiocarbon age of at lest 43,000 years. Allowing 5000 years since the Deluge leaves 38,000 years for the radiocarbon age characteristic of this material at the time of the Deluge. A 38,000-year C-14 age is equivalent to a C-14 specific activity 1.01% of the contemporary reference standard. This could indicate C-14 production at 1/99 of the present production rate, an active biosphere carbon inventory 99 times greater than that of the modern world, or any combination between these extremes as required for an R/I ratio of 1/99.

If the sample preparation procedures introduce unidentifiable contamination by modern carbon, or do not remove all contamination that may be developed naturally, the radiocarbon age indicated for material at the time of the Deluge would be greater than 38,000 years. With a contamination effect as great as 30%, as possibly indicated by the Table 1 data supplied by the Simon Frazer University group, the C-14 age of Deluge deposits would be increased from 43,000 to about 46,000, or about 41,000 at the time of the Deluge. Such increase would lower the R/I ratio relative to that of the modern world to about $^1/_{143}$.

The approximate equivalence of C-14 age with real-time age over at least the last 3500 years indicates that C-14 concentrations in the upper biosphere (all but the deep ocean and ocean sediment) have been essentially at R/I equilibrium levels over this period of time. If for some reason C-14 levels had not reached equilibrium by the time of the Deluge, the antediluvian biosphere could be modeled on the basis of an R/I ratio higher than the $^1/_{99}$-$^1/_{143}$ range [antediluvian biosphere carbon inventory lower than 99-143 times the current value, assuming the C-14 generation rate (R) was the same for both epochs].

Individuals who wish to develop a model for the carbon content of the antediluvian biosphere within the constraints of the available data have considerable latitude. Without exceeding the constraints provided by paleomagnetic intensity data, the C-14 generation rate might be postulated to have been as low as $^1/_4$ the modern value as a consequence of a higher geomagnetic field intensity that reduced the hazard of damage to organisms by cosmic radiation. The active carbon exchange inventory in the antediluvian biosphere then needs to be postulated in the range of only 25-40 times the present value, rather than 99-143. Since the total "fossil" organic carbon inventory on planet Earth is estimated to be roughly 250 times the carbon inventory in the present carbon exchange system (Olson 1985; compare 175-fold in Rubey 1951), and most of Earth's surface is now desert (combined marine, arctic, temperate, and tropical deserts), an antediluvian world that is consistent with both modern C-14 data and biblical chronological data does not appear unreasonable.

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EDITORIAL

TRUTH — AN ENDANGERED SPECIES

Molière, the famous French author, wrote an incisive comedy entitled "The Forced Marriage."[1] The play, which had been written at the request of King Louis XIV, was an immediate success, and occasionally France's most opulent king even participated in its presentation. This comedy addresses some of the foibles of humanity in a humorous, but instructive and not so subtle, context. In the story, a rich, mature gentleman wonders whether he should marry a young maiden who is primarily interested in his wealth. He seeks the advice of several individuals, including two philosophers. The first philosopher is Aristotelian and is so concerned about his own opinions, his philosophy, and the definitions of terms that the poor gentleman cannot communicate to him the reality of his practical problem. He departs disappointed and seeks advice from a skeptic philosopher. In introducing himself he informs this philosopher that he has come for advice; whereupon the philosopher replies: "Pray change this mode of speaking. Our philosophy enjoins us not to enunciate a positive proposition, but to speak of everything dubiously, and always to suspend our judgment. For this reason, you should not say, I am come, but it seems that I am come." An extended discussion follows as to whether the gentleman has really come or if it only appears that he has come. Further factual statements from the gentleman are met with deprecating comments such as "it may be so," or "it is not impossible," and "that may be." The philosopher refuses to address the gentleman's real question. Tension arises, and compelling reality suddenly appears when the exasperated "gentleman" attacks the philosopher who responds with yells and vexed comments. Informing the gentleman that it is an insolence and outrage to beat a philosopher like him, he threatens to appeal to the magistrate. The gentleman appropriately answers: "Pray, correct this manner of speaking. We are to doubt everything; and you ought not to say that I have beaten you, but it seems I have beaten you." Subsequent argumentation provides the gentleman with further opportunity to reply to the philosopher with the same uncertain statements he has just heard. The philosopher, who is positive that he has been beaten, rehears comments such as "it may be so" and "it is not impossible." The gentleman is proudly instructing the philosopher about the foibles of skepticism.

Our present intellectual milieu does not appear to be all that different from some of the foibles of Molière's time. Relativism, agnosticism, and skepticism are respected, while certainty and truth appear to be endangered.

It is fashionable to question almost anything. Doubts appear to be encouraged for their own sake, even when they have little else to contribute except further doubts.

This attitude, without doubt, in part encouraged Mark Twain to quip, “Researchers have already cast much darkness on the subject, and if they continue their investigations, we shall soon know nothing at all about it.”

Absolute truth, i.e., that which is — in other words, actuality or reality—, is degraded by the presently accepted philosophy of relativism which holds that no absolutes exist. Agnosticism — the idea that the answer to ultimate questions is “I don’t know” — scarcely fares better. This philosophy runs the risk of missing any ultimate reality, because of refusal to come to any conclusion. It may seem wise to keep an open mind on ultimate issues, but “many an open mind has revealed a vacant lot.” More significant is the avoidance of disagreeable or painful decisions by resorting to agnosticism. This is sometimes referred to as the convenience of agnosticism. Skepticism, which encourages an attitude of doubt towards much, can also paralyze the truth-searching-and-finding process. When we come to a point of decision between two views, we can do one of three things. We can opt for one view or for the other, or we can decide not to decide. Skepticism encourages the latter, and when no decision is made, progress can be hampered.

A recent article in the journal *Nature* entitled “Where Science Has Gone Wrong”[2] bemoans the loss of certainty in science. An attitude has developed that science is not an objective search for truth but more of a transient sojourn through ever-changing ideas. The authors attribute the loss of financial support for science in England and the rise of the creation movement in the United States to this lack of certainty. As soon as a new idea is proposed, it is usually challenged. If science is not finding truth, what is its ultimate value? My personal opinion is that science does discover truth, albeit a number of false pathways may be taken along the way, but current agnosticism, relativism and skepticism would tend to deny this, and scientific truth is endangered.

In academic pursuits, how often we are satisfied with just presenting several views and not bringing our study to a conclusion. Too often our research ends up with a plurality, of possibilities. This is doubtless part of the basis for the traditional satirical “maybe” as the final conclusion of the typical doctoral dissertation.

There is no question that a firm case can be made for not accepting many ideas and that in the presence of a plethora of concepts, investigation and caution are virtues. Also, there is room for legitimate suspension of judgment because of lack of information. In working out truth, we should be reasonable and balance our acceptance of ideas with careful inquiry. There is room for questioning, but everything does not have to be questioned forever, and the all-important task of sorting out truth from error should not fall a victim to fruitless skepticism. Sound scholarship can afford to make room for truth. We do not need to relegate ourselves needlessly to that realm of the "maybe" where everything seems, but nothing is.

Sometimes our doubting game comes face to face with the reality of plain cold facts, such as the collision between an iceberg and the Titanic. If our car is stolen, its existence and concepts of ownership become real; if we are late and miss a plane, time also becomes very real. Our fashionable questioning can also be jarred by the reality of having someone physically attack a skeptic philosopher! (Incidentally, in Molière's comedy, the relatives of the young lady forced the rich man to marry her!) A divorce or the pardoning of the criminal can remind us that moral values, integrity and forgiveness are also a part of reality. Sometimes in the midst of all our doubts reality confronts us and commands our respect, and if there is reality, there is truth.

Truth exists, and we will not arrive at it by doubting everything. The one who doubts everything certainly does not have as much to offer as the one seeking for truth.

Relativism, agnosticism, and skepticism reduce truth to uncertainty while assuming exceptions for themselves. These ideas cannot claim any degree of assurance of being correct, while their own tenets would enjoin that we be uncertain about almost everything significant, which would include these propositions themselves. If you do not believe in anything, can you be consistent and believe that you do not believe in anything?

Reality is there, truth exists, and a satisfying degree of certitude is possible. While we must be cautious in not accepting as true that which will not bear careful scrutiny, truth should not fall a victim to prevalent concepts of uncertainty. Truth is so important that we should actively protect its right to exist.

Ariel A. Roth

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REACTIONS

Readers are invited to submit their reactions to the articles in our journal. Please address contributions to: ORIGINS, Geoscience Research Institute, 11060 Campus St., Loma Linda, California 92350 USA.

Re: Hodges: Fossil Binding in Modern and Ancient Reefs (ORIGINS 14:84-91)

Lance Hodges has reported evidence indicating that the use of the term “reef” is inappropriate as applied to some ancient (Paleozoic level) facies in the Great Lakes region. A similar conclusion apparently applies to Mesozoic level “reefs” here in the northwest U.S.A. Orr and Orr in *Handbook of Oregon Plant and Animal Fossils* (1981, p 82) say: “The tendency in the geologic literature in the past has been to call rich accumulations of fossils ‘reefs’. More often than not what is called a bioherm (reef) is in fact a ‘biostrome’ or fossil rich lense without form or internal structure.” Two examples from early 20th century geologic literature (second and fourth decades) of stuctureless accumulations mislabeled reefs are then cited. The reef discussion’s concluding sentence states, “Although biostromes are not uncommon in the State [of Oregon] true bioherms or reefs are unknown.”

Please supply more identifying information on locales. It took this reader awhile to track down the Richvalley, Indiana, and Formosa, Ontario, sites on maps. For other curious readers, Richvalley, Indiana, is in north central Indiana (Wabash County) close to the Wabash River, approximately five miles west of the city of Wabash. Are we readers to infer that the “reef complex near Richvalley (Fig. 2, p 86) is part of “the classic Silurian reef at Wabash” (p 90)?

Richard Kutsch
Florence, Oregon

Editor’s note:

The reef complex near Richvalley is not part of the classic Silurian reef at Wabash. Interested readers should contact Dr. Hodges regarding the specific locations of the various reefs. He can be contacted through the Geoscience Research Institute.

Incidentally, another classic “reef” appears to have succumbed to the scrutiny of additional investigation. The famous Steinplatte reef of the Austrian Alps, a classic upper Triassic reef, is now considered to be a “platform-edge sandpile.” See: Stanton RJ, Jr., Flügel E. 1988. Geological Society of America Abstracts with Programs 20(7):A201, #11494.

ARTICLES

EXPANDING EARTH?

Bill Mundy
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Pacific Union College
Angwin, California

WHAT THIS ARTICLE IS ABOUT

Plate tectonics, which suggests that the crust of the earth is composed of a few plates fitted together like pieces of a puzzle, has been very successful in explaining surface features of the earth, such as mountains, ocean trenches, volcanos and earthquakes. However, some of the evidence to support it is ambiguous and the source of plate motion has not been unequivocally identified. Motivated by these problems, a few earth scientists have proposed an alternative model, the expanding earth. This article first considers satellite and interferometry measurements which were supposed to provide a definitive test of the two models. However, despite phenomenal accuracy, the error associated with these measurements is still too large to distinguish between the models. Additional evidence favoring the expanding earth is discussed, including the superior fit of the continents that it allows. This is followed by some of the problems that are associated with it, such as the source of expansion. Finally, some of the problems of plate tectonics are considered, most significant of which may be the mechanism that moves the plates.

In summary, there are difficulties with both models. Currently, plate tectonics seems to be the more adequate of the two models, but that may reflect the time invested in it. Perhaps a more acceptable model would involve the synthesis of the two concepts. Unfortunately, it appears that such a combination would import the difficulties of finding suitable causes for both expansion and *plate motion.*

Plate tectonics has been a very successful model in describing and synthesizing information about the kinematics of the crust of the earth (Lithosphere 1983, p 1; Loper 1985). Briefly, it suggests that the surface of the earth is composed of a few plates which fit together like pieces of a spherical puzzle (Tarbuck & Lutgens 1984, p 400-406). The edges or boundaries of these plates are typically characterized by volcanoes and epicenters of earthquakes. Some of the boundaries, such as the mid-Atlantic ridge, are identified as spreading ridges, where birth is given to new crustal material; other boundaries, such as the trench of the west coast of South America, are identified as subduction zones where old crust is being pulled or pushed back into the interior of the earth; still other boundaries, like the San Andreas fault, are slip-strike faults where one plate slides past another; and others, such as the Himalayas, are interpreted to be places where plates are colliding. As suggested by the processes occurring at the boundaries, the plates are moving with respect to each other. Since the plate-tectonic model assumes a constant-sized earth (Tarbuck & Lutgens 1984, p 403), the sea-floor spreading that occurs at the ridges has to be compensated for by subduction and collisional compression.

However, a small but persistent group of earth scientists argue that the spreading sea floors and wandering continents are best explained in terms of an *expanding earth* (Carey 1976, Carey 1983a, Carey 1988, Crawford 1986, Glikson 1980, King 1983, Owen 1983a, Steiner 1977). In its most radical form this model assumes that sea-floor spreading is entirely compensated by the increasing area of an expanding earth so that no subduction occurs (Carey 1976, p 14; Carey 1988, ch 13; Crawford 1986). Some variations on this incorporate modest subduction and collision along with the expansion of the earth (Owen 1983b). In spite of the fact that a number of times the expanding earth is said to have been discredited (Kerr 1987; Smith 1976, 1977, 1978; Wood 1979) the expanding earth remains as an alternative model to plate tectonics.

S. Warren Carey, who can be considered the dean of the expanding-earth model, feels that all the apparent plate motion is due to the crust of the earth accommodating itself to an earth that is increasing in size. In his 1976 book, *The Expanding Earth* (Heirtzler 1977, Irving 1978, Karig 1978, Mundy 1985), Carey proposed three experimental tests to verify if the earth is expanding (Carey 1976, p 443). Variations on two of these suggestions have now been done: a) satellite laser ranging (SLR) and b) very long base interferometry (VLBI) (Anderson & Cazenave 1986, Stein 1987). Doppler satellite measurement techniques are also being developed.

VLBI AND SLR RESULTS

VLBI consists of a pair of receivers, at different locations on the earth, looking at the same quasar (Carter & Robertson 1986, Herring et al. 1986). Quasars are so far from the earth that parallax is negligible even over the distance of the diameter of the earth. These quasars are also radio sources which can serve as a random “universal bar code” (Stein 1988). When two receivers are oriented as shown in Figure 1, receiver A will receive a code before receiver B. Using the time delay and a little

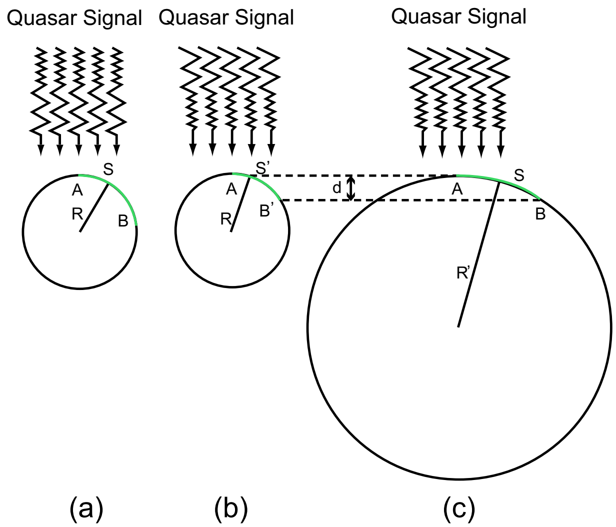

FIGURE 1. R, the radius of the unexpanded earth, the same in (a) and (b); S, the arc length between stations A and B, the same in (a) and (c); d, the difference in distance from stations A and B to the quasar, the same in (b) and (c).

geometry, the distance between the two stations can be determined. Now, at a later time, when station A is again oriented with respect to the quasar as before, if B has moved so that it is closer to A the delay time between the reception of a code will be less than before. But notice that if the distance between receivers A and B has remained fixed but the earth has expanded in the mean time, this would also reduce the delay time between the two receivers.

SLR consists of beaming lasers toward satellites that have been fitted with reflectors (Christodoulidis, Smith & Kolenkiewicz 1985; Tapley, Schutz & Eanes 1985). This provides independent but similar measurements to VLBI, with the same ambiguity as to whether there has been surface movement or earth expansion.

Measurements made over the last ten years using VLBI and SLR have yielded similar results (Kolenkiewicz, Ryan & Torrence 1985; Stein 1987). Amazingly, these plate speeds and directions also correspond nicely within measurement error (correlation of 0.91 for SLR data), with the geotectonic calculations of Minster and Jordan (1978) which are based on paleomagnetic, earthquake and fault azimuth data, which are presumed to be averaged over geologic periods of time (Christodoulidis et al. 1986, Herring 1986, Minster & Jordan 1978). There are some tantalizing, though

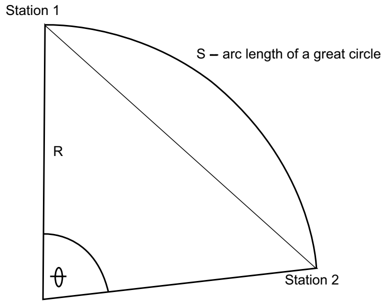

FIGURE 2. Geometry for intercontinental measurement on a great circle.

marginally significant, differences: across the “stable” North American plate for which Minster and Jordan naturally calculate a relative velocity of zero, the VLBI measurements indicate that the two locations are *approaching* each other at a rate of about one centimeter per year (-1.0 cm/yr); or this could be explained by an earth expansion of about two centimeters per year (2.0 cm/yr) while the actual surface separation remains constant. If measurements are made between three stations that lie on a great circle of the earth then we can dispense with the requirement that any of them be located on stable plates but can in fact make intercontinental (interplate) measurements (Carey 1988, p 168-170). Using the geometry shown in Figure 2, we can relate the chord length C between two stations, the radius R of the earth and the enclosed angle θ by the expression, $C = 2R\sin(\theta/2)$. Taking the time derivative, we get

$$dC/dt = 2dR/dt \sin(\theta/2) + Rdh/dt \cos(\theta/2).$$

Solving this equation simultaneously for each of the three pairs, Australia-Hawaii (-7 cm/yr), Hawaii-USA (+4 cm/yr), and Australia-USA (-3 cm/yr), Carey got dR/dt = 2.8 cm/yr (negative numbers mean moving closer; positive numbers moving apart). But the error associated with the measurements that he used are such that this could be zero! And, unfortunately, it is proving difficult to improve the accuracy of these measurements, so it may be several more years before more definitive results can be obtained (Herring 1986, Parsons 1988, Smith & Christodoulidis 1985). At this time the results may be consistent with an expanding earth, but they are ambiguous. However, it is expected that these measurements will provide the final evidence whether or not continental drift is occurring (Martin 1987).

EVIDENCE FOR EXPANDING EARTH

Maps are what initiated the development of plate tectonics. And maps provide motivation for the expanding-earth model (Carey 1988, p 93, 166, 167). A casual glance at a globe of the earth suggests that the east coasts of North and South America might nicely fit against the west coasts of Africa and Europe. Such fits have been made, first of all by sliding cutouts of continents around on a globe, now by computer simulations. Good fits can be obtained. The differences obtained by different cartographers are due to such considerations as how much of the continental shelves are included with the continents and different interpretations of paleomagnetic data (Chatterjee & Hotton III 1986; Hartnady 1988; Jackson 1988; Lawver 1984; Powell, Johnson & Veevers 1980; Rickard & Belbin 1980; Stock & Molnar 1987). Typically, even with the best fits, there are some overlaps and/or gaps between the continents when the fits are made on a globe scaled to the present size of the earth. Carey, Owen and others have noticed that they could improve the fits and avoid a questionable Tethys ocean if the continents were cut out and fitted on a smaller globe (Carey 1976, p 27,40; Carey 1988, p 143, 164-167; Crawford 1986; Harland 1979; Owen 1979; Owen 1983a, p 3; Owen 1984; Schmidt & Embelton 1981; Vogel 1984). This suggests an earth that has expanded over time. Carey, who has been most aggressive with this argument, suggests that the earth had a radius of about 60% of its current value during the Jurassic era, and hence no subduction need to occur. Owen starts with an earth with a Jurassic radius of 80% of its current value, so he has to allow for some subduction in his model. In a critique of Owen's work, Hallam allows that Owen's strong point is geometric but goes on to argue that the edges of the continents are not well defined and that there is evidence that some continental pieces have "subsided" or been "attenuated" (Hallam 1976). However, Harland states that "Owen's work is so thorough that it cannot be ignored" (Harland 1979).

Another argument for an expanding earth is that all the present ocean floors are geologically young (Carey 1976, p 53; Carey 1988, p 147, 186; Glikson 1980; Vogel 1984). With the plate-tectonic model, it is presumed this is because older oceanic crust has been subducted (Scholl & Vallier 1983, Smith 1985). So an area equivalent to the Pacific Ocean is usually assumed to have been subducted under the Americas since the Jurassic with no debris or remnants of older oceanic crust left behind. Glikson states, "I am unaware of any constant radius models capable of accounting for the nature of about three fourths of the earth's crust during Precambrian time" (Glikson 1979). The expanding earth provides a natural explanation: the ocean floors are just the new surface that has emerged during the expansion process.

The distributions of fossil plants and animals have been used as indications of the past locations of continents and oceans (Ahmad 1983;

Davidson 1983; Fallow 1983; Shields 1979). A recently reported study of brachiopods concludes that “the balance of evidence seems to require an expanding earth” (Ager 1986).

PROBLEMS WITH EXPANDING EARTH

But the expanding-earth concept is not without its problems. A natural question is, how do mountains form on an expanding earth (Stocklin 1983)? In the context of plate tectonics, mountains are understood to be the consequence of colliding plates. But colliding plates would not be expected to be a prominent feature of an expanding earth. Carey has developed a “diapiric extension model” of “orogenesis” (Carey 1986). This model (see Figure 3) proposes that as the earth expands, the lithosphere thins at various locations and mantle material, with the reduced pressure, experiences phase changes, expands and rises sufficiently to maintain an isostatic balance. In the resulting break-up of the crust and elevation of mantle material, gravity spreading (downslope motion of overlying material) occurs. There are some similarities between the diapiric process and a very slow motion volcano. Characteristic patterns of mountains can thus be obtained. Carey has detailed the Himalayan tectonics and other mountain ranges using his model. See Figure 4. On the basis of faunal and floral elements, Ahmad concludes that “the Himalayas could neither have been born of collision nor of subduction, but resulted from vertical uplift” (Ahmad 1983). And while Stocklin does not feel that Carey’s model of diapiric deformation is sufficient to account for the “general Himalayan style”, he does allow that the “structure of the Himalaya is in no contradiction to an expanding earth” and that a previously smaller Earth radius would allow India, Africa and Eurasia to be positioned as required by paleomagnetic data without detaching India, which is just what geology requires (Stocklin 1983). Even advocates of standard plate tectonics recognize that Himalayan orogeny and the associated Tethyan paradox (lack of evidence for postulated Tethys ocean) are complex and elusive of interpretation, providing evidence that often leads to diverse and very incompatible models (Funk et al. 1987; Jiwen et al. 1987; Lemoine, Tricart & Boillot 1987; Searle et al. 1987; Sengor 1987; Srikantia 1987; Valdiya 1984; Verma & Kumar 1987).

Also, an expanding earth would suggest an increase in the moment of inertia of the earth, which would mean that the rate of rotation of the earth would have to decrease in order to conserve angular momentum. But the retardation that the earth does experience seems to be more than adequately explained by tidal friction (Bursa 1984, Bursa 1987, Van Diggelen 1976). However, Talobre claims that an expansion of the radius of the earth of

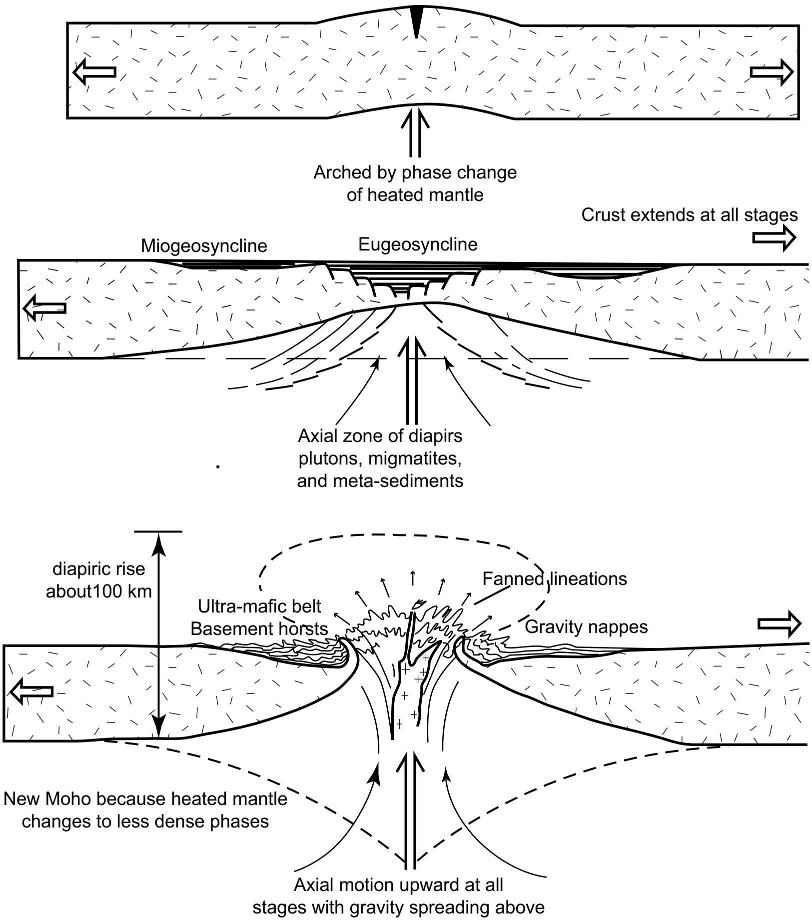

FIGURE 3. Model of the development of a geosyncline and orogen during continuous crustal extension and continuous diapiric rise of about 100 km. Figure 1 in: Carey SW. 1986. Diapiric krikogenesis. In: Wezel F-C, editor. The Origin of Arcs. The Netherlands: Elsevier Science Publishers, p 6. Reproduced by permission of the publisher.

about two centimeters per year is necessary to account for the increased duration of the day (Talobre 1983). On the other hand, it is possible to have a constant-mass object expanding and differentiating in such a way that the moment of inertia stays constant or even decreases (Carey 1988, p 196).

Burrett has also noted that "no reconstruction of the Early Paleozoic hypothesis [based on the expanding-earth model] has yet been produced

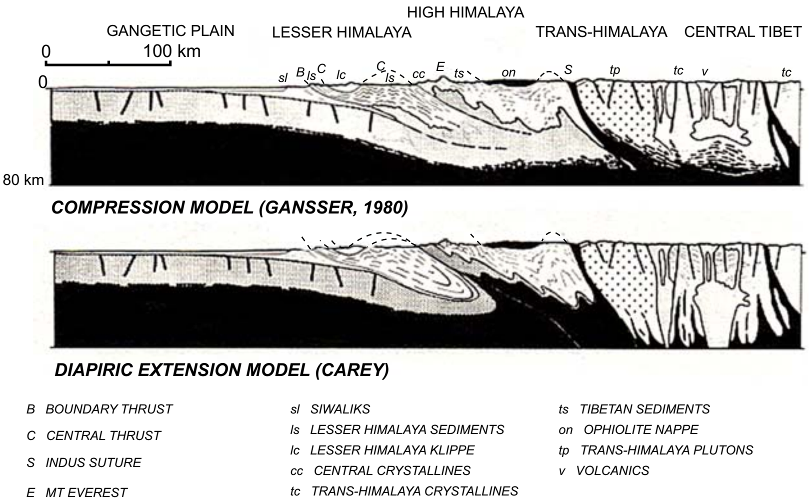

FIGURE 4. Compressional and diapiric models of the Himalaya. Figure 8 in: Carey SW. 1986. Diapiric krikogenesis. In: Wezel F-C, editor. The Origin of Arcs. The Netherlands: Elsevier Science Publishers, p 15. Reproduced by permission of the publisher.

that places the north pole in any paleomagnetically or paleoclimatically reasonable position" (Burrett 1983).

But the main problems associated with the expanding earth are the mechanism of expansion and some of the consequences associated with some of the most commonly suggested mechanisms (Taylor 1983). The most frequently mentioned mechanism is a structural or a chemical phase change that involves an increase in volume with constant mass (Carey 1976, p 124, 450; Stewart 1983). (The development of ice from liquid water, for example, involves a structural change in which there is an increase in volume.) This could be occurring at the core/mantle interface. In this process the mass of the earth would remain essentially constant while its volume is increased. Consequently, if the radius of the earth doubled, the force due to gravity on the surface of the earth would now be only one fourth of what it was prior to the expansion. But paleogravity studies indicate that the force of gravity has never been significantly greater than it is now (Stewart 1983).

Another suggested phenomenon is a change in Newton's universal gravitational constant, G (Van Flandern 1979). This possibility was earlier suggested by Dirac to explain an expanding universe (Heirtzler 1977, Stewart 1983). As applied to the earth, the idea is that if G decreases, then the earth would expand due to reduced interior gravitational pressure. But, of course, if such expansion happened for the earth it would also happen for other planets, moons and the sun. And most astrophysicists see little evidence that such expansion happened on other planets such as Mars (McElhinny, Taylor & Stevenson 1978). Also, any significant change in G during the existence of the solar system would noticeably change the planetary distances which would change the thermal environment of the earth. Finally, calculations of the equation of state for the earth have been made in the context of general relativity (Einstein's gravitational theory) which shows that a changing G would not affect the size of the earth (Canuto 1981). Some scalar models of gravity would even have the earth shrink if G were to become smaller.

Perhaps the most radical suggestion is Carey's "null universe" in which it is envisioned that matter is continuously created (Carey 1983b; Carey 1988, p 338-342). (Carey rejects the "big bang" in favor of this continuous process.) The "null" is motivated by the assumption that all conserved quantities (momentum, energy, etc.) have net values of zero. That this could be true for momentum, for example, is evident. That this could also be true for energy becomes apparent when it is realized that the positive mass energy, mc^2, of an object can be offset by its negative gravitational potential energy, $-GMm/R$, where M is the mass of the universe and R is its radius (the Hubble radius). Tryon has shown that within observational uncertainties, $mc^2 - GMm/R \approx 0$ which is consistent with the suggestion that the net energy of the universe is zero (Tryon 1973, Tryon 1983). (Actually, the general theory of relativity, as currently understood, allows only an ambiguous concept of net energy.)

Although conservation of the standard conserved physical quantities is a high-lighted feature of the model, the "null universe" does not conserve baryon number, which would require, under present conditions, the creation of an equal number of particles *and* anti-particles. Other difficulties of the "null universe" that Tryon points out are:

1. Typically, only elementary particles are created in particle production which might possibly eventuate in simple atoms such as hydrogen. But currently hydrogen is only a minor constituent of the earth.
2. If particle creation is responsible for earth expansion, then it ought to cause other planets to expand also. But there is evidence that the earth's moon and Mercury have not expanded. Furthermore, if stars, including the earth's sun, have similarly expanded, then many of them should have become massive enough to have become blackholes.

3. Such expansion of the stars would alter their luminosities dramatically, which cannot be reconciled with observations that the distant and near galaxies look similar to each other.

Tryon also critiques the idea that the earth may be participating in a fundamental process that would also explain the Hubble expansion of the universe. This type of expansion would affect the entire earth, surface as well as core, uniformly and there would be no cracks or other surface evidence of expansion.

PROBLEMS WITH PLATE TECTONICS

Now let us consider some of the problems of the standard plate-tectonics model that, in fact, have motivated the search for an alternative model such as the expanding earth. One problem is how to move continents around (Kundt & Jessner 1986, Loper 1985, Lowman 1985a, Pavoni 1986, Runcorn 1980, Walzer & Maaz 1983). No good mechanism has been devised to push or pull them about. Further, recent evidence suggests that some of the continents have deep roots, going down as deep as 700 km (Kerr 1986, Lay 1988, Lowman 1985a). The movement of plates with such deep roots seems so incredible that a fixed-earth plate-tectonic model has recently been proposed that requires subduction zones which have not been suspected heretofore and for which there is little evidence (Lowman 1985b, Lowman 1986, Martin 1987, Schmidt & Embleton 1986).

Another difficulty is that both the African and the Antarctic tectonic plates are almost completely surrounded by spreading ridges with no significant subduction zones on their boundaries (Bevis & Payne 1983; Carey 1976, p 57; Carey 1983c; Carey 1988, p 174-176; Karig 1978). Consequently, the subduction zones available to accommodate the spreading are not near by; and these expansion ridges themselves would have to migrate toward distant subduction zones. In fact, models of relative plate motions have not been unambiguously established yet, particularly for the circum-Pacific (Kamp & Fitzgerald 1987).

Finally, Carey has been most critical of the very concept of subduction (Carey 1976, p 16, 50, 54; Carey 1988, ch 13). He has argued that typically slabs that are presumed to be thrust under plates show characteristics of tension rather than compression. And he has noticed that frequently there is little evidence of sediment accretion in subduction trenches. Chudinov also argues that evidence for subduction is weak and the phenomena observed in active marginal oceanic zones are best explained by “eduction” (extrusion of mantle material at the edge of the continental block) (Chudinov 1981). However, current plate-tectonic theory suggests that slabs are being pulled down by their own weight more than they are being pushed from the expanding ridge or by the force of plates gravitationally "sliding downhill" across the ocean floor from ridges to subduction zones (Jurdy 1987, Sekiguchi 1985, Spence 1986, Spence 1987). This can explain tensional characteristics frequently found in subduction zones. But, this does assume that oceanic plates which were less dense than the mantle when they emerged from the ridges have cooled sufficiently to become more dense than the mantle into which they are being reintroduced (Grow & Bowin 1975, Kerr 1988, Park 1988). Also it leaves unanswered what causes the low-density continental slab to descend under the Alps (Mueller & Panza 1986). Additional problems have been raised by Uyeda (1986). Subduction is a complex process involving an interplay of various forces that are difficult to quantify (Jarrard 1986). Unequivocal subduction models are difficult to affirm because subduction destroys most of its evidence; so little is yet known about its mechanics (Anderson 1981, Rea & Duncan 1986).

With respect to this problem, subduction models have been developed that let sediments be dragged under with the slab and even allow the downgoing plate to erode the overriding plate (Scholl et al. 1980, Scholl & Vallier 1983, Wortel & Cloetingh 1986). Recent surveys of the Japan Trench using Seabeam mapping, gravity and geomagnetic measurements, and seismic reflections seem to justify these models (Cadet et al. 1986; Cadet et al. 1987a,b; Kobayashi et al. 1987; Le Pichon et al. 1987). Little evidence of accretion was found, although a fractured seamount was discovered that appears to be "falling" into the trench. The landward plate seems to be "lifted" by the front edge of the seamount in such a way that suggests the seamount is being pulled under, i.e., subducted. Bivalve communities along the continental shelf indicate that water is being pressed from the subducted material, and this may "lubricate" the contact between the plates so that the oceanic slab with the seamount can slide under the continental plate with relatively little friction.

Still other difficulties with the standard plate-tectonics model have been published. For instance, "the geotectonic phenomena operating in the island arc regions are rather different from those assumed to now" (Wezel 1986b). Rocks rather than oceanic sediments in trenches, old material rather than young sediments in trench slopes, subsistence rather than uplift observed during subduction in trench margins, including the Japan Trench, and tensional rather than compressional characteristics in subduction zones are listed as evidence to support the above assertion. Also, "the origin of volcanism and high heat flow and the origin of back-arc basins are still 'basic unsolved problems' in the context of the subduction model" (Wezel 1986b). So Wezel claims that "the tectonic processes hypothesized by the present [tectonic] models do not correspond to the geological reality of the arc systems" (Wezel 1986b).

Studies on the lithosphere have noticed the paradox of a model that seems to require the continental crust to be like a "thick elastic plate" in the neighborhood of mountains yet in other contexts it is required to be weaker than the oceanic crust (McNutt 1987).

Finally, a week-long workshop on the lithosphere convened by the U.S. Geodynamics committee in 1982 noted that "no generally accepted models exist for the initiation of [subduction]", "rates and mechanisms of assimilation of models for the heating of subducted slabs...[are] wholly inadequate...", and "gravity profiles across subduction zones and the published geoid data do not reflect the thermally predicted excess mass" (Lithosphere 1983, p 28, 29).

SUMMARY

Despite the success that standard plate-tectonics theory has enjoyed, there are phenomena that it currently is not able to model. Perhaps the most adequate model would incorporate Owens' suggestion that there is both subduction and expansion. This would allow the earth to expand at a modest rate with reasonable changes in surface gravitation and also require some subduction for which the evidence seems convincing. But such a model presents the difficulty of finding suitable mechanisms for expansion, plate motion and subduction!

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ANNOTATIONS FROM THE LITERATURE

ANTHROPOLOGY

Stringer CB, Andrews P. 1988. Genetic and fossil evidence for the origin of modern humans. Science 239:1263-1268.

Summary. Two models are compared to explain the origin of anatomically modern humans. The "multiregional" model states that modern man evolved from a widespread species, with relatively small differentiation between populations, and with fossil intermediates expected anywhere in the world. The "single origin" model places the origin of modern humans in Africa, with dispersal from that point of origin. The greatest genetic variation within populations should occur in Africa, and fossil intermediates would be expected only from Africa.

Comment. The authors favor the "single origin" mode, with reasons based on genetic and fossil evidence. The question is interesting, but the discussion seems somewhat speculative.

ANTI-EVOLUTION BIBLIOGRAPHY

McIver T. 1988. Anti-evolution: an annotated bibliography. Jefferson, NC: McFarland & Co. 385 p.

Summary. This unusual volume should prove to be very useful to anyone interested in the creation-evolution controversy. The author lists 1852 references which are considered to be "anti-evolution." Though most of the references are books, some are booklets or pamphlets. Both contemporary and historical references are included. It is highly regrettable that the author did not include articles from the many creation journals to make a more comprehensive volume. However, considering the volume of material available, such an omission is understandable. It is also regrettable that the number of pages for each reference is not given, leaving the reader without any idea of the extent of coverage for each reference.

The volume concludes with three indices: name, title, and subject. Most of the entries are annotated, some quite extensively. The author who "disagrees with anti-evolution arguments and conclusions" presents the viewpoint of the various references themselves. The annotations make interesting and instructive reading.

Summary. In the introduction the author states, "My intention is to illustrate the enormous range and depth of the opposition to evolution." This goal has been impressively achieved, even with the exclusion of articles from the creation-oriented journals.

DARWINISM

McCann LJ. 1986. Blowing the whistle on Darwinism. Published by the author, St. Paul, Minnesota. 124 p.

Summary. This book is another of the many anti-Darwinian documents to appear in recent years. Its approach is scientific. Darwinism is viewed in its broader meaning, including both the origin of life and the production of new species. The main part of the text presents a logical and factual outline of the main scientific problems with Darwinism. Consideration is also given to the implications of the spread of Darwinism and the incongruity between so-called scientific rigor and the acceptance of the Darwinian concepts by the scientific community. The author proposes that fundamental scientific principles have been violated. Some of the sociological implications of Darwinism are discussed. Intelligent design for the origin of living organisms is suggested as an alternative.

Rusch WH, Sr, Klotz JW. 1988. Did Charles Darwin become a Christian? Williams EL, editor. Norcross, GA: Creation Research Society Books. 38 p.

Summary. An interesting and informative review of the evidence relating to the alleged deathbed Christian confession of Charles Darwin to Lady Hope. Based on several lines of convincing evidence, the author (Rusch) concludes that the anecdote must be apocryphal. The last part of this booklet, written by Klotz, reviews Charles Darwin's religious beliefs. The conclusion is that while he had some lingering doubts about the non-existence of God, he considered himself to be an agnostic.

EVOLUTION

Cairns J, Overbaugh J, Miller S. 1988. The origin of mutants. Nature 335:142-145.

Summary. Conventional evolutionary theory is based on the belief that variation is produced by random mutations, and that the environment acts in such a way that those individuals best adapted for survival are favored over those less well-adapted. The randomness of mutations seems intuitively obvious, but the experiments described in this paper bring this assumption into question.

In the laboratory, bacteria (*E. coli*) with a mutation disrupting the function of the enzyme for utilizing lactose somehow mutated to restore the lactose gene to normal function, but did so only when under selection for ability to utilize lactose. In another experiment, a bacterial strain was used that could grow in lactose only if a short DNA segment were deleted, and if grown in the presence of arabinose. Again, mutants were discovered only if lactose was present. In a third experiment, bacteria were used that lacked the normal gene for the lactase enzyme. *E coli* possesses a cryptic gene which can utilize lactose if two rare mutations occur together. Lactose-using colonies formed in this situation, but the process whereby this may occur is not understood.

Comment. These results are based on only one species and one enzyme system, and it is not certain whether the results have a more general application. Nevertheless, this paper promises to stimulate a great deal of discussion among evolutionary theorists, and will encourage those who favor some kind of environmental influence on genetic change. If the phenomenon of non-random mutations is found among eukaryotes, it may be used to explain directionality in evolution. (For a related discussion, see: Opadia-Kadima GZ. 1987. How the slot machine led biologists astray. Journal of Theoretical Biology 124:127-135, reviewed in *Origins* 14:26.)

EXTRAORDINARY GEOLOGY

Moores EM, Wahl FM, editors. 1988. The art of geology. Geological Society of America Special Paper 225. 140 p.

Summary. The stated purpose of this unusual volume is “to celebrate the 100th anniversary of the Geological Society of America and to convey the visual beauty of Earth and its neighbors as seen from a geologic perspective.”

It consists mostly of 133 pages of color photographs of geologic features selected primarily for their natural beauty. Scenic features dominate, but the photographed objects vary from minerals under the microscope to a radar image of folds on Venus. The message of the book seems to be that there is much beauty to be seen in the geologic features of the world. Those familiar with field geology have been highly aware of this, but it is interesting to find a publication that emphasizes this point. It speaks of the "humanness" of geologists.

Comment. Strangely, the introductory comments place special emphasis on the development of the geologic time scale. Likewise, the captions of many of the photographs emphasize their assumed age. One wonders why a volume that is supposedly devoted to the "visual beauty of Earth" should concentrate on geochronometry. Another criticism is that while a number of the pictures are dramatic, and many of them are good, too many are very poor. Especially annoying are a number of out-of-focus pictures.

Aside from these shortcomings, this very enjoyable volume illustrates in a simple way many dramatic geologic features.

PALEOMAGNETISM

Loper DE, McCartney K, Buzyna G. 1988. A model of correlated episodicity in magnetic-field reversals, climate, and mass extinctions. Journal of Geology 96:1-15.

Summary. Noting the correlation between mass extinctions, climate, and magnetic-field reversals, the authors suggest these events are caused by thermal anomalies in the core-mantle boundary. As the boundary layer cools, it thickens, reducing the flow of heat from the core to the mantle. This causes the layer to absorb more heat, eventually resulting in convection and thinning of the boundary material. A hot plume is released from the boundary material into the mantle, and rises to the top, where it disrupts the stability of the crust. The effects on the crust depend on the nature of the crust in the particular region affected. Polar wander would be the first to be affected, followed by changes in magnetic field and climate, and mass extinction.

PALEONTOLOGY

Rigby JK, Jr, Newman KR, Smit J, Van der Kaars S, Sloan RE, Rigby JK. 1987. Dinosaurs from the Paleocene part of the Hell Creek Formation, McCone County, Montana. Palaios 2:296-302.

Summary. Dinosaur fossils have been found in six Paleogene localities in Montana. This is higher in the geologic column than their traditional demise proposed for the end of the Cretaceous. Evidence that they are truly Paleogene deposits, and not simply reworked Cretaceous deposits, is given. This evidence includes the unabraded appearance of the fossils, their association with other fossils that seem definitely not to have been reworked, and their segregation from other Cretaceous fossils that should have been included if the Cretaceous deposits had been reworked. Since the stratigraphic range of the dinosaurs extends beyond the Cretaceous-Tertiary boundary, the significance of the mass extinction event at the boundary is reduced.

PHILOSOPHY OF SCIENCE

Stenger VJ. 1988. Not by design. The origin of the universe. Buffalo, NY: Prometheus Books. 203 p.

Summary. The thesis of this interesting, albeit erroneous, book is that order can emerge from chaos, and nothing that we see illustrates an omnipotent, supernatural Creator. The world, including man, is the result of chance, and the concept of an overriding plan or design is considered to be archaic. The argumentation, which is mainly at the nuclear-physics level, is well-explained and easily grasped.

Comment. One wonders what can prompt someone to take such a strong reductionistic position and with ease and logical arrogance reduce all of the universe to his understanding of it. Significant aspects of science and other aspects of reality are blatantly ignored, and man's uniqueness is not considered. The philosophical diffidence that one might expect from the author in view of the important questions posed is lacking. To him, selected interpretations of science have all the answers. One also wonders about the objectivity of the author when he entitles his last chapter, "We will become God." This chapter concludes with an appeal to the prowess of computers.

PLATE TECTONICS: HISTORY

Frankel H. 1988. From continental drift to plate tectonics. Nature 335:127-130.

Summary. The history of the development of plate-tectonic theory over the past 25 years is outlined in this paper. The men whose ideas changed the course of geology are named and their ideas described. The way in which one idea prepared the way for the acceptance of other ideas, finally resulting in a new perspective, makes interesting reading. Anyone interested in how ideas change, or more specifically in the discoveries that contributed to the acceptance of the theory of plate tectonics, will want to read this paper.

GENERAL SCIENCE NOTES

THOSE GAPS IN THE SEDIMENTARY LAYERS

By Ariel A. Roth. Geoscience Research Institute

WHAT THIS ARTICLE IS ABOUT

The layers of sedimentary rock that we see over the surface of the earth usually appear as parallel features that are often spread over wide areas. What does not appear to the casual observer is that between some of these layers major portions of the stratigraphic (geologic) column are missing. These gaps between the layers tell a story related to the age of these layers.

Geologists can tell that a portion of the layers is missing because in other parts of the word layers with characteristic fossils are found between the layers represented at the gaps. For instance, near the bottom of the Grand Canyon, the Ordovician and Silurian portions of the geologic column are missing between some of the parallel layers present. The missing portion represents an assumed 100 million years of layers found elsewhere.

The crucial question is: Is there evidence of that 100 million-year gap, or does it appear that the layers were laid down rapidly, as would be expected during the flood described in the book of Genesis? If there really is a 100 million-year gap, evidence of this in the form of erosion should be abundant. In fact, current rates of erosion are so rapid that erosion would completely eliminate layers below the gaps in the time span assumed.

These gaps are common, and it appears that the erosion and other features expected during these long gaps in deposition are not there. This suggests that the layers were laid down rapidly. The absence of the expected evidence for long ages challenges the standard geologic time scale of thousands of millions of years for the formation of the strata of the earth.

THE GAPS (HIATUSES)

In the Panhandle region of Texas one can drive for many miles on the flat plain called the Llano Estacado or “staked plain.” The origin of the name is somewhat obscure. Possibly it came from marker stakes left on the plain by pioneers or from cactus plants that resembled stakes.

Dramatic geologic features come to view at the edge of the Llano Estacado. In Palo Duro Canyon, which has been eroded from the south-east, the layers below the staked plain are well-exposed (Figure 1). The top layer is the prominent, mostly light-colored Ogallala Formation, which is sometimes up to several hundred meters thick, although only about 30 m thick here. It extends for some 1200 km from South Dakota to well-south of the Texas Panhandle. Economically the Ogallala is very important, because it harbors water for the towns and farms of the region.

Fossils that have been found in the Ogallala include horse teeth, plant roots (Maxwell 1970), a giant tortoise, fossil seeds (WTSU n.d., p 18), and remains of mastodons, camels and sloths (Matthews 1969). Just below the Ogallala is the darker Trujillo Formation. Fossil wood, leaves and bones of an extinct amphibian have been found in this formation (Maxwell 1970). The upper arrow in Figure 1 points to the somewhat-indistinct boundary between these two formations.

According to the standard geologic time scale, the Ogallala is considered to be a very young formation about 2-5 million years (Ma) old (Pliocene). The Trujillo Formation is considered to be over 208 Ma old (Triassic). The top arrow in Figure 1 points to a gap of some 200 Ma of missing layers.

Approximately 150 km to the west (Figure 2), south of the town of Tucumcari, New Mexico, the same assumed 200 Ma gap is found. The arrow in Figure 2 points to the contact between the Triassic Chinle Formation and the Pliocene Ogallala above. Three-hundred km further south near the town of Big Springs, Texas, the same relation can be seen.

FIGURE 1. View of Palo Duro Canyon in northern Texas. The upper arrow points to an assumed 200 Ma gap in the sequence of sediment deposition. The lower arrow points to a 16 Ma gap.

FIGURE 2. View of cliff south of Tucumcari, New Mexico. The same 200 Ma gap shown in Figure 1 is indicated by the arrow.

To the north the assumed gap decreases gradually as layers younger than the Trujillo and Chinle underlie the Ogallala.

The proposed ages of these formations can raise a question about the validity of the geologic time scale. If there is a 200 Ma hiatus of layers between the Ogallala and the layers below, the effects of that extended time period should be noticeable. If not, one may wonder if it ever took place. Evidence for time should be especially manifest in the form of gullies, canyons, and valleys produced by erosion; weathering; plant growth; and soil formation. Sometimes there is evidence of slight erosion, but not what would be expected over the purported time suggested and is graphically demonstrated by Palo Duro Canyon itself. Could the Trujillo Formation remain so flat or be eroded to such flatness during these assumed 200 Ma, or has much less time been involved? As can be seen, the Ogallala lies very flat on top of the Trujillo. The Trujillo has many soft units that should be eroded away in relatively short periods of normal weathering and erosion. The question is especially pertinent when one realizes that this flat contact extends over approximately 150,000 km^2.

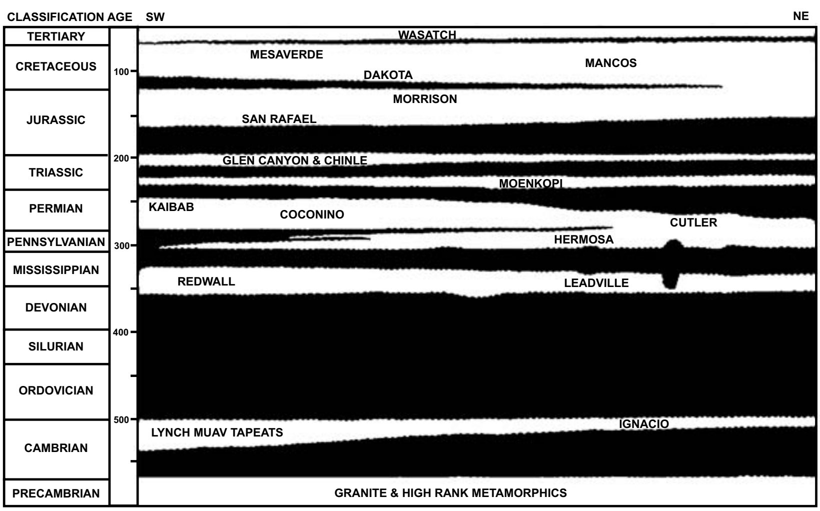
A little lower in Palo Duro Canyon are two other formations that also have an assumed time gap between them. The lower arrow in Figure 1 points to that contact line. Above the arrow is the Late Triassic Tecovas Formation and below is the Permian Quartermaster Formation. The middle and lower Triassic layers are missing. While this represents only a 16 Ma gap in contrast to a 200 Ma gap above, it does represent a considerable time span during which much could have happened.

All of this raises a more fundamental question, namely: Do the assumed time gaps between sedimentary layers show the effects of time, or do they suggest rapid deposition as would be expected if they were laid down during the catastrophic flood described in the book of Genesis?

Missing divisions (gaps) of the standard geologic column are a common feature of the sedimentary layers of the earth. Figure 3 is an example, with the main missing portions represented in black. Charts for the Western United States (Molenaar 1973, p 156; Molenaar 1978, p 4; WGA 1980, inside front cover) suggest that about $^{1}/_{3}$ or more of the major subdivisions (e.g., upper Triassic) are missing between various parts of the sequences. On a smaller scale much more is assumed to be missing. The "age" scale in Figure 3, which is in millions of years, gives an estimate of the time (black portions) between these layers. Surprisingly, the layers lie one on top of the other in orderly fashion without evidence of the extensive erosion expected during the purported time represented by the gaps. It should be noted that the vertical scale in this diagram is exaggerated approximately 16×. We are dealing with relatively thin, widespread features.

The question often arises as to how one determines the length of time involved at these gaps. It is based mainly on the absence of layers that are present elsewhere and have been dated with characteristic fossil types. It is assumed that much time is involved in the evolution of these characteristic fossils, as well as the deposition of the layers containing them. It is mainly by correlating and comparing with composite, complete sequences of the

STRATIGRAPHIC HIATUSES IN SOUTHEASTERN UTAH



geologic column that conclusions are drawn concerning missing portions. Radiometric dating is also used, especially in establishing a broad time framework for the layers.

Geologists who have long been aware of these gaps usually designate them as “unconformities.” In Great Britain the tendency is to frame the terminology on the basis of structural features, instead of assumed time; hence, the term “unconformity” has somewhat of a different meaning there.

There are several types of unconformities. If the layers above and below are at an angle to each other, the term *angular unconformity* is used; if they are generally parallel but with some evidence of erosion between the layers, the contact is sometimes called a *disconformity*; and if the contact is not visible or there is no evidence of erosion, it is called a *paraconformity*. We are especially interested in the latter two types, bearing in mind that terminology is not well-standardized. Related to these contacts is the term *conformable*, which is often used to designate the parallel union of different formations.

The question of erosion at these gaps is illustrated in Figure 4. The top diagram (A) illustrates a cross-section of the deposition of sedimentary layers with no appreciable time between the layers.

Figure 4B illustrates what happens when there is no deposition and there is ample time for erosion. This creates the gullies, canyons and valleys common to the eroding surfaces of our world.

Figure 4C shows this irregular erosion pattern covered by subsequent layers. The topography left by past erosion is easily seen. This type of pattern should be common within the sedimentary layers of the earth where significant parts of the geologic column are missing; yet, only rarely do we see ancient valleys and canyons in the sedimentary layers of the continents.

Figure 4D illustrates the effect of a subsequent cycle of erosion, followed by deposition over the pattern in the third diagram. The pattern of distribution of layers would become more complex as more episodes of erosion and deposition are envisioned.

FIGURE 3. Stratigraphic representation of the sedimentary layers in SE Utah. The clear areas represent sedimentary layers, while the black areas represent the main gaps (hiatuses). The main divisions of the geologic column are given in the left column, followed by their assumed age in millions of years. Names in the sedimentary portion represent only the major formations. Vertical exaggeration is about 16×. The horizontal distance represents about 200 km, while the total thickness of the layers (clear part) is about 3½ km. Diagram modified from Molonaar (1975, p 4) to emphasize a more linear time scale.

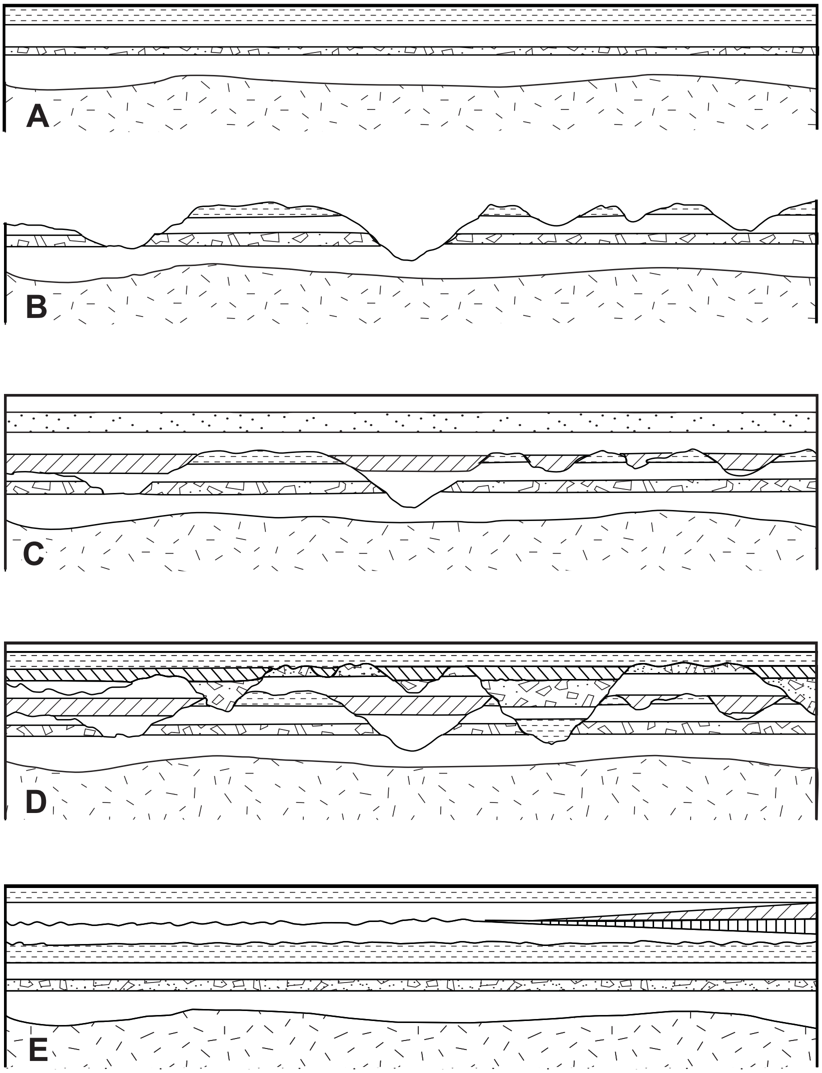


FIGURE 4. Erosion-deposition patterns. A: Pattern of continuous deposition. B: Erosion. C: Resumption of sedimentation. The old erosion surface is still visible. D: A second cycle of erosion and deposition further complicates the pattern. E: The more normal pattern seen. One would expect significant erosion between layers 2 and 3 from the top on the left side, if extensive time was involved in laying down layers 3 and 4 wedged in on the right. Hypothetical diagram with variable vertical exaggeration depending on erosional conditions.

Figure 4E illustrates the more normal pattern that is seen (e.g., Figures 1-3), with little or no erosion between layers. If millions of years were involved between these layers, one would expect a significant amount of erosion, for instance, between the second and third layers from the top on the left side of Figure 4. This time period would be based on the millions of years assumed for the deposition of the third and fourth layers wedged in on the right side.

Numerous other examples of gaps (unconformities) could be given, e.g., Figure 3. Because of space limitations, just a few additional sites will be mentioned.

The Grand Canyon of the Colorado River is one of the geologic showcases of the earth. When one stands on its rim, one is impressed by many things, including how parallel the rock layers are; yet, significant time gaps are assumed between some of these layers. For instance, a little below the major middle cliff called the Redwall, about 100 Ma (Ordovician and Silurian) of deposition are missing (Figure 5 arrow). At the base of the Redwall itself, just slightly above the previous location, there is another assumed 6 Ma (Kinderhook) gap (Breed & Roat 1976, p 54).

In eastern Utah one can view the dramatic erosion caused by the Colorado River at Dead Horse Point. The locality received its name because a number of wild horses died there before the turn of the century. The

FIGURE 5. View of the Grand Canyon of the Colorado from the North Rim in Arizona. The arrow points to an assumed 100 Ma depositional gap in the layers.

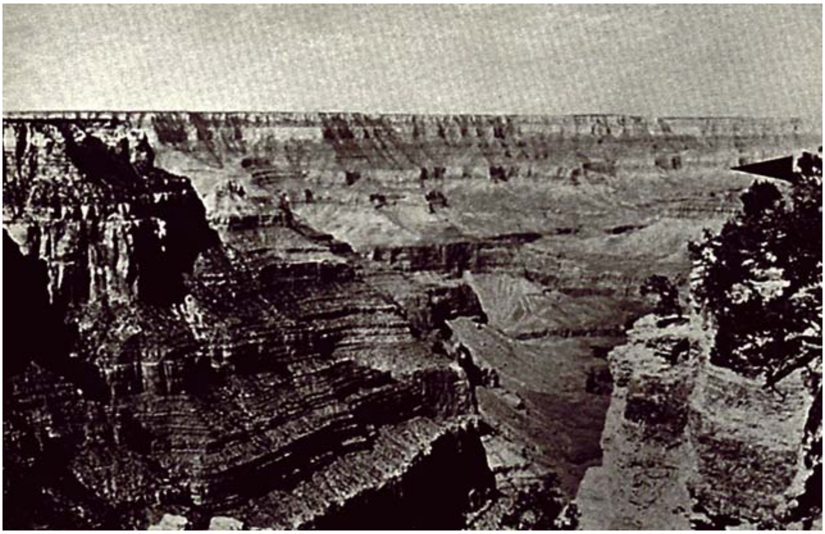


FIGURE 6. Valley of the Colorado River from Dead Horse Point, Utah. The top arrow points to an assumed 10 Ma depositional gap. The lower arrow points to a 20 Ma gap. Note the striking contrast between the flat depositional patterns of the layers at these 10 and 20 Ma hiatuses and the irregular erosion of the canyon by the Colorado River.

contrast between the effects of erosion forming the canyon and the parallel deposition of the layers is again striking (Figure 6). Within these layers are several assumed gaps. The lower arrow (right side) points to about 20 Ma (Ochoa-Guadalupe) assumed to be missing; the upper arrow (left side) points to about 10 Ma (Middle Triassic) of missing layers; yet, the contacts are very flat. This latter gap covers about 250,000 km^2 in the southwestern United States and can be seen at many localities where present erosion has exposed it. These two gaps are also illustrated in Figure 3 and lie respectively just below and above the Moenkopi Formation in the Triassic.

Along the east coast of Australia are excellent exposures of coal seams. At the top of the Bulli Coal (Figure 7 arrow) is another gap. The data given by Pogson (1972) suggest that the gap is about 5 Ma. Herbert and Helby (1980, p 511) point out that this is a "basin-wide hiatus" with probably "world-wide significance." Geological mapping data (Pogson 1972) suggest that this hiatus covers some 90,000 km^2. In the region where the Bulli Coal is present, it is especially difficult to envision this coal seam remaining for 5 Ma without being destroyed many times in that extended period of non-deposition.

The European Alps are in part a complex of gigantic thrusted and folded units called nappes. Between the layers within these nappes are assumed gaps that show the same lack of erosion noted elsewhere. Figure 8 shows part of the Morcles Nappe as seen from the Rhône valley in Switzerland. The arrow points to an assumed gap of 35 Ma or more (Upper Cretaceous). Incidentally, the whole sequence of layers in the region below the arrow and all above it is overturned, having been folded (rolled) over as a unit as the layers were thrust laterally during the early stages of the formation of the Alps.

Some geologists have commented on the lack of evidence for changes expected at these gaps. In referring to the kind of gaps called paraconformities, Norman Newell (1967) comments:

> *A remarkable aspect of paraconformities in limestone sequences is general lack of evidence of leaching of the undersurface. Residual sods and karst surfaces that might be expected to result from long subaerial exposure are lacking or unrecognized.*

While "speculating" on their origin, the author states further that:

> *The origin of paraconformities is uncertain, and I certainly do not have a simple solution to this problem.*

Newell (1984, p 125) also states:

> *A puzzling characteristic of the erathem boundaries and of many other major biostratigraphic boundaries* [boundaries

FIGURE 7. East coast of Australia in New South Wales. The arrow points to an assumed 5 Ma gap above the coal layer.

between differing fossil assemblages] *is the general lack of physical evidence of subaerial exposure. Traces of deep leaching, scour, channeling, and residual gravels tend to be lacking, even where the underlying rocks are cherty limestones (Newell, 1967b). These boundaries are paraconformities that are usually identifiable only by paleontological [fossil] evidence.*

T. H. Van Andel (1981) states:

> *I was much influenced early in my career by the recognition that two thin coal seams in Venezuela, separated by a foot of grey clay and deposited in a coastal swamp, were respectively of Lower Palaeocene and Upper Eocene age. The outcrops were excellent but even the closest inspection failed to turn up the precise position of that 15 Myr gap.*

An additional point of interest related to this question is the fact that present rates of erosion on the earth are so rapid that many of the layers between the gaps should have been eroded away many times during the assumed long time period represented by the missing layers. Present rates of erosion for the United States average about 6.1 cm/1000 yrs (Judson & Ritter 1964), which is 61 m/Ma. In 10 Ma one would expect 600 m of erosion, etc. It is sometimes stated that our present rates of erosion should level the United States in 10 Ma or less.

FIGURE 8. Valley of the Rhône in Switzerland. The arrow points to an assumed 35 Ma or more gap in sedimentation.

It is well recognized that present rates of erosion cannot be easily reconciled with long geologic ages. In referring to some current rates of erosion, Sparks (1986, p 510) emphasizes the problem:

> *Some of these rates are obviously staggering; the Yellow River could peneplain [flatten out] an area with the average height that of Everest in 10 million years.*

Hence, if one assumes long geological ages, this not only raises questions about the lack of evidence for time at the gaps, but also questions about the presence of sedimentary layers between the gaps. Our present average rates of erosion could have long ago eroded many times the sedimentary record found on the continents. Sparks (1986) states further:

> *The student has two courses open to him: to accept long extrapolations of short-term denudation* [erosion] *figures and doubt the reality of the erosion surfaces, or to accept the erosion surfaces and be skeptical about the validity of long extrapolations of present erosion rates.*

I would suggest a third course which could reconcile the dilemma; namely, to accept present rates of erosion in the context of a short period of time for the Phanerozoic record in which one would not need to try to resolve the paradox of long-term effects. The implications of these effects as they relate to catastrophism has been discussed elsewhere (Roth 1986).

In summarizing this section, it can be stated that assumed gaps in the sedimentary layers of the earth are common. The physical evidence for the assumed time of millions of years is missing. Under normal conditions, we expect either erosion or deposition. Surfaces at paraconformities and disconformities seem to show little of either.

One must keep in mind that evidence of time missing in one locality suggests the absence of that time over the entire globe. The lack of evidence for time can be reconciled by a model in which sedimentary layers were laid down rapidly by events associated with the catastrophic flood described in Genesis. This idea is buttressed by the fact that current rates of erosion suggest that over the long assumed ages the layers between the gaps should also be eroded away.

SOME QUESTIONS

We shall now address several questions that can be raised about the suggestion given above.

1. *Are there not very flat areas on the surface of the earth that could represent these gaps?*

Our earth has very flat areas, the flattest being the lake bottoms and abyssal plains on the floor of the oceans. However, there are regions where sediment is being laid down in a flat pattern and do not represent gaps in deposition. They must not be confused at all with regions where sedimentation is not occurring and erosion is taking place. Gaps would be expected at these latter regions. Sediment is usually laid down in a near-horizontal pattern, and there are many broad, flat regions, such as the lower Mississippi Valley of the United States, or the Canterbury plains of New Zealand, where sediment is being deposited in a broad, flat pattern. Areas in which sediment deposition is not occurring are typically very irregular because they are subject to erosion. The usually flat contacts at the assumed gaps do not show the degree of irregularity normal to erosional regions. They also do not show deposition; if they did, there would be no assumed gap.

2. *Can there be flat areas of the earth where neither deposition nor erosion are taking place?*

There may be one or more such areas, but they are the exception and could not account for the abundance of these flat gaps throughout the sedimentary layers of the earth. Some geomorphologists have appealed to the presently arid central Australia as an area where deposition and erosion are very slow. This is an exception that does not represent normal conditions of erosion and deposition on the earth. The fossil evidence found in the layers associated with almost all the gaps does not represent a climate similar to arid central Australia. For instance, the horses and mastodons of the Ogallala demand significant precipitation to produce the vegetation necessary for their survival. In the long time envisioned at these gaps, we would expect much erosion or much deposition under any nearly normal climatic circumstances.

There are a few exposed areas of earth that are assumed to be older surfaces that do not show much of the effects of erosion. Their significance depends on their assumed age. The Llano Estacado mentioned earlier is one of them; however, it is considered to be only a couple of million years old. More significant are such areas as Kangaroo Island and the surrounding Gulfs region in South Australia. Kangaroo Island, which is about 140 by 60 km, has a surface assumed to be 200 Ma old (Daily, Twidale & Milnes 1974). When I visited it, I was impressed by the extreme flatness of most of the island. Figure 9 shows only a small region of this island. Could such a flat surface exist without deposition or erosion for 200 Ma? Ice ages and other climatic factors should have had dramatic effects. Twidale (1976), in assuming long ages, outlines the problem:

FIGURE 9. View of part of Kangaroo Island, South Australia. Across the bay the general flatness of this island can be seen. The surface of this island is assumed to be some 200 Ma old.

> *Even if it is accepted that estimates of the contemporary rate of degradation of land surfaces are several orders too high (Dole and Stabler, 1909; Judson and Ritter, 1964; see also Gilluly, 1955; Menard, 1961) to provide an accurate yardstick of erosion in the geological past there has surely been ample time for the very ancient features preserved in the present landscape to have been eradicated several times over. Yet the silcreted land surface of central Australia has survived perhaps 20 m.y. of weathering and erosion under varied climatic conditions, as has the laterite surface of the northern areas of the continent. The laterite surface of the Gulfs region of South Australia is even more remarkable, for it has persisted through some 200 m.y. of epigene* [surface] *attack. The forms preserved on the granite residuals of Eyre Peninsula have likewise withstood long periods of exposure and yet remain recognizably the landforms that developed under weathering attack many millions of years ago.*

Twidale states further:

> *The survival of these paleoforms* [as Kangaroo Island] *is in some degree an embarrassment to all of the commonly accepted models of landscape development.*

Survival of the flat surface of Kangaroo Island is not an embarrassment if one does not assume the long ages proposed. Twidale (1976) proposes some solutions to the problem, but one is faced with trying to resolve the dilemma that with a conservative erosion rate of 3 cm/1000 yrs, Kangaroo Island should have been eroded down 6 km in 200 Ma. One would have to postulate very odd conditions to explain the survival of the surface of Kangaroo Island for 200 Ma. Extreme conditions can be postulated, but one should be cautious about deriving too many generalizations from the abnormal. It is implausible to assume that neither deposition nor erosion would occur over the millions of years envisioned. Normal erosion rates seem to preclude arguing that present flat surfaces, assumed to be old, represent examples of no erosion.

3. *Is it not possible to have flat erosion?*

We generally think of erosion as accentuating topographic irregularities with time. The longer erosion continues, the deeper our gullies, canyons and valleys become. Twidale, Bourne and Smith (1974) and Twidale (1976) have proposed a landscape model that incorporates this factor. As long as gravity keeps pulling water downward, this kind of activity is to be expected.

On the other hand, to explain the flat gaps we have been considering, some models have proposed lateral erosion down to planar surfaces. The most famous is the peneplain concept proposed about a century ago by the well-known Harvard geomorphologist W. M. Davis. He postulated eventual flat erosion under special conditions, forming a peneplain (almost a plane). His model, which gained considerable acceptance in the early part of this century, is no longer accepted. Garner (1974, p 12) states: “The *peneplain* is Davis’s ‘old age’ landscape. It has been called an imaginary landform. Perhaps it is.” One would expect that any process forming the abundant, widespread, flat gap contacts in the geologic record of the past would be well-represented on the present surface of the earth; yet, Bloom (1969, p 98) states that “unfortunately, none are known” and Pitty (1982, p 77) points out that “although demonstrable unconformities abound, even W. M. Davis admitted that it was difficult to point to a clear present-day example of a peneplain.”

No other generally accepted concept has replaced the peneplain model, although there have been considerable discussions and disputations about laterally directed slope erosion leaving flat surfaces. L.C. King (1950) in South Africa proposed pediplanation, a process that involves both erosion and deposition. These models do little to explain the subsequent erosion expected over long time periods when deposition stops and the time for the gap begins.

One can also ask if flat erosion would occur over a hard surface, such as a tough limestone layer. While limestone appears to degrade about as rapidly as other rocks (see Sparks 1986, p 511), it does at times form resistant layers compared to softer layers such as shale. This will not resolve the problem of flat erosion, since many of the gaps that we are discussing are over softer formations with abundant shale. The Ogallala Formation in Texas and New Mexico mentioned above lies on softer sediment assumed to be 200 Ma older. The Shinarump in the southwestern U.S. lies on the softer Moenkopi assumed to be 10 Ma older. It is difficult to conceive of these relatively soft layers spread over hundreds of thousands of km^2 for these long periods not being eroded away. This raises another question.

4. *Could these time gaps have been protected in the past by resistant or thick layers lying over them?*

This postulation raises the question of why erosion should proceed through a hard or thick protective layer and stop at the softer units mentioned above. These units are relatively thin, widespread and well-preserved. Rapid deposition without the long assumed time between may be a more satisfactory explanation for the data.

5. *Isn't there evidence of erosion at these time gaps?*

It is not surprising that in numerous instances there is evidence of some minor erosion at these gaps. Erosion would occur as water or wind would transport the sediments for the layers above the gaps. Rarely, at these planar surfaces, there is some evidence of deeper erosion, sometimes even several hundred meters of erosion. However, the general pattern shows little erosion, and the contacts are remarkably flat (Figures 1-3, 4-8). Moreover, the presence of erosion is not an argument against rapid action. Erosion can occur very rapidly under catastrophic flood conditions.

6. *If the layers at the top of the gaps were underwater, would this not preclude their being eroded?*

Erosion and deposition proceed under water as well as above. Presently there are no special, widespread, underwater environments where neither deposition nor erosion are occurring. Some of the formations below these gaps, such as the Trujillo and Chinle mentioned above, do not contain the kind of fossils expected in an underwater environment.

CONCLUSIONS

The assumed gaps in the sedimentary layers are not readily noticed, because the layers above and below are in intimate contact with each other and are usually parallel or nearly parallel. Nevertheless, these gaps are abundant. Bloom (1969, p 98) states:

> *The geologic record of sedimentary rocks is full of unconformities that represent long periods of emergence and erosion of continent-sized regions. These unconformities are commonly nearly planar....*

This flat and parallel, or near-parallel, arrangement at these gaps seems to be different from the eroding surfaces of much of our present earth.

The difficulty with the extended time proposed for these gaps is that one cannot have deposition, nor can one have much erosion. With deposition, there is no gap, because sedimentation continues. With erosion, one would expect abundant channeling and the formation of deep gullies, canyons and valleys; yet, the contacts are usually “nearly planar.” Over the long periods of time envisioned for these processes, erosion would erode the underlying layers and much more. One has difficulty envisioning little or nothing at all happening for millions of years on the surface of our planet. The gaps seem to suggest less time.

Our current topography does not represent an extension from the ancient past. Ashley’s (1931) provocative study points out how recent our present topography is and argues that 99% of it was formed in an assumed 15 Ma, which would be very recent on an earth assumed to be thousands of millions of years old. Thornbury (1969, p 25) states that little of earth’s topography is older than Tertiary (67 Ma ago), and most of it is no older than Pleistocene (2 Ma ago).

This raises the question of what happened to the topography for the assumed hundreds of millions of years before that. Our present topography is so dramatic in places that it is difficult to think of ancient topography being so poorly represented. Yet, our Everests and Grand Canyons seem conspicuously absent in the record of the past, while that past is still very well-represented in the older sedimentary layers of the earth. Dramatic topography should be especially noticeable at the assumed long time periods (gaps) between the layers, when there would be ample time for uplift and erosion.

It is often difficult to discern what happened in the past; however, the assumed gaps in the sedimentary layers witness to a past that was very different from the present. In many ways, that difference is readily reconciled with catastrophic models such as the Genesis flood that proposes the relatively rapid deposition of these layers.

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