SEDIMENTATION AND THE FOSSIL RECORD: A STUDY IN HYDRAULIC ENGINEERING[1]

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Since the fossil record in sedimentary rocks of the earth's crust supposedly provides documentary evidence of organic evolution throughout geologic time, it is of considerable importance to know how these fossil-bearing sediments were originally deposited. A study of these phenomena in light of modern knowledge of sediment hydraulics and fluid mechanics indicates that the sediments must have been laid down very rapidly, even catastrophically, rather than slowly over long ages. Furthermore, the evidence favors one single major depositional epoch rather than a large number of individual and localized sedimentary catastrophes spread over great expanses of *time.*

Introduction

The relationship of the field of hydraulic engineering to the evolution-creation question at first may seem somewhat tenuous. There is, nevertheless, a very real and significant connection.

Hydraulic engineering is that profession which seeks to devise and build systems and structures for the most effective control and utilization of the earth's water resources. It is necessarily based on a thorough understanding of the sciences of hydrology and hydraulics.

Hydrology is the science dealing with the earth's natural waters and their distribution, especially in the forms of precipitation, streamflow and groundwater. Hydraulics deals with the forces, velocities, and frictional resistances associated with flowing fluids.

One of the most important functions of the earth's natural waters is that of erosion, transportation and deposition of sediments. Mechanics of sedimentation phenomena control formation and development of river systems. Rivers not only carry the waters back to the ocean from whence they came, but also serve to carry off large quantities of sediment eroded from their drainage basins, depositing them finally along their flood plains or in deltas near their mouths. Deltaic sediments are gradually re-worked by wave action and by littoral currents until finally deposited more or less permanently along the continental shelves and slopes. Thus land surfaces are gradually being cut down and ocean basins filled.

These sedimentation processes are highly important to both the geologist and the hydraulic engineer. Most geologic processes involve water in one way or another, but the processes of sedimentation are by far the most important, since most of the earth's land surface consists of sediments, either still loose and unconsolidated or else compacted and hardened into sedimentary rocks. In order to understand and explain geologic formations and phenomena, therefore, the geologist should have a thorough understanding of the processes of sedimentation.

The hydraulic engineer has a more immediate and practical need for such knowledge. He is concerned with the silting-up of canals, reservoirs and harbors, with the stability of structures built along river channels, with erosion of valuable lands, with bank-caving and channel-shifting in alluvial rivers, and with numerous other practical and costly problems associated with the hydraulics of sedimentation as connected with the design of hydraulic structures and systems.[2]

Hydraulic engineers, therefore, have been engaged for the past four decades, especially, in intensive laboratory and analytical studies dealing with the processes of sedimentation. These phenomena are extremely complex, but much has been learned and will continue to be learned concerning them.

Geologists, on the other hand, with a few noteworthy exceptions, have continued to favor a qualitative and descriptive, rather than quantitative and mathematical, approach to sedimentation. It should be obvious, however, that the degree of confidence that can be placed in their interpretations of sedimentary deposits of the past is directly dependent upon their understanding of sedimentary processes in the present. The present state of knowledge of sedimentation mechanics, even of those hydraulic engineers who are most actively involved in such studies, is certainly not such as to warrant placing overmuch confidence in interpretations of the sedimentary deposits of the past by anyone, and especially by anyone not thoroughly conversant with modern studies in sediment hydraulics.

Now the bearing of this discussion on the subject of evolution is simply that the sedimentary rocks laid down in the past constitute the repository for the fossilized remains of former living plants and animals. And this fossil record of life during earth's past history is really the *only* non-circumstantial, historical evidence supporting the theory of organic evolution.

The question, therefore, of *how* the fossil-bearing sediments were originally laid down is

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thus of extreme significance to the evolution-creation controversy. Can the sedimentary processes of the earth as now constituted adequately explain them? Were they deposited very slowly, over long ages, or rapidly and violently? Under what circumstances, and in what kinds of environments, were they originally eroded, transported and deposited?

Such questions can never be fully resolved scientifically, for the simple reason that events of the past are not reproducible. However, the goal of obtaining the most reasonable and probable answer clearly requires, as a minimum prerequisite, a thorough understanding of all sedimentation phenomena, environments and processes as they exist at present. And until paleontologists and historical geologists have acquired such knowledge and have demonstrated its consistency with their uniformitarian and evolutionary interpretation of the fossil record, we are fully warranted in rejecting the entire concept of organic evolution.

The various contentions in the foregoing general discussion will now be discussed and documented in somewhat more detail.

Role of Water in Geologic Interpretation

Of all physical factors involved in the study of geology, one of the most obvious and certain facts is that water has been the primary geologic agent in shaping the earth's surface. The planet Earth, uniquely among all bodies in the universe in so far as any real knowledge goes, has been equipped with an abundant supply of water, and this fact is profoundly important in the understanding of earth history.

This water supply is intricately associated with almost all the physical processes and structures of the earth. Approximately 71% of the earth's surface is, in fact, covered with water. Plant and animal life is composed mainly of water; the human body, for example, is more than two-thirds water! Most chemical processes of importance involve water, as do biologic processes. No wonder the Apostle Peter said:

> . . . heavens came into existence long ago by the word of God, and an earth also, which was formed out of water and by means of water. (II Peter 3:5b, Amplified Bible).

It is also obvious that even the 29% of the earth's surface which is dry land has in the past been covered with water, and that most of the rocks on the surface were originally laid down by moving water. Rock formations are usually classified as igneous, metamorphic or sedimentary, with the latter formed primarily by deposition of sediments out of water after transportation from some source area. It is significant that most surface rocks are sedimentary rocks.

> By volume, sedimentary rocks are about one-tenth as abundant as igneous rocks in the earth's crust; but when it comes to the rocks exposed at the earth's surface, sedimentary rocks or sediments, as they are sometimes called, cover nearly three-fourths of the land surface.[4]

Furthermore, many of the igneous rocks at the earth's surface are underlain by sedimentaries, upon which they flowed after eruption through volcanic vents or fissures. Similarly, many of the metamorphic rocks at the surface represent rocks which once were sedimentary rocks (e. g., marble, transformed from limestone by processes of metamorphism).

Thus it is evident that probably all of the earth's surface either now is, or has been, at some time or times, completely submerged by water, and that these waters have been profoundly effective in the very formation of the rocks themselves, as well as the surface features of the earth's physiography.

Of course, this is not surprising to the student of scripture. According to Biblical revelation, there have been two periods in earth history when the surface of the earth was completely submerged by water. The first was immediately after the Creation of heaven and earth, when the earth is said to have been covered with water (Genesis 1:2,3). Second, the earth was again fully inundated at the time of the Great Flood, in the days of Noah (Genesis 6-9). In both cases, it is certain that much geological work must have been accomplished on the earth's crust by the waters (as affirmed in II Peter 3:5,6).

But modern geologists have been unwilling to accept so simple an explanation for the earth's sedimentary rocks, especially since it involves a worldwide catastrophe with supernatural overtones. Instead, it has, for more than a hundred years, been assumed more "scientific" to explain the great masses of sedimentary rocks, sometimes several miles in thickness, in terms of the ordinary processes of sedimentation which are in operation in the present world.

> Biblical and other ancient literature of the Middle East is dominated by a tradition of universal deluge. Characteristic of this view is an extremely short time scale for the duration of our planet—measured in thousands rather than in billions of years. One flood during this period sufficed to explain all evidences of former seas on land . . . . Little by little, the excrescences of the Middle Ages were shaken off by the developing science of geology. . . . By the end of the nineteenth century, only religious fundamentalists . . . refused to accept the overwhelming evidence that not once but many times the seas have crossed where land lies now.[5]

Uniformitarian versus Catastrophic Sedimentation

There thus seem to be two possible types of explanations for the fact that essentially all of the earth's surface has been, at some time or times in the past, beneath the sea. One is that of catastrophism, the other that of uniformitarianism.

In the one, a tremendous cataclysm of water, pouring down from the skies and up from the subterranean deeps, produced a year-long debacle of erosion and deposition of sediments that could have accounted for at least most of the sedimentary deposits in the earth's crust.

In the other, the very slow processes of weathering, denudation, river flow, delta deposition, land subsidence and emergence, and similar geomorphologic processes, acting over many hundreds of millions of years, have combined to produce these formations.

In both cases, the amount of geologic work accomplished is the same, but the power required--the time-rate of work accomplished—is vastly different. It is a question of whether great forces and energies were at work during a short period of time, or small energies operating over great expanses of time.

In either case, the bulk of the work was accomplished prior to recorded human history, and therefore the process is not subject to scientific examination. It is completely impossible to *prove* scientifically, whether catastrophism or uniformitarianism provides the true explanation.

The best that can be done is to examine the ancient sediments and compare them with modern processes of sedimentation, to see whether the latter are producing deposits which are comparable in character to those of the geologic column, and also, on the basis of what we know about hydraulics, to try to estimate the possible type and extent of sedimentation that could occur in a world flood, in order to evaluate the sedimentary rocks in terms of this possibility.

The decision between the two alternatives will very likely be, to some extent, subjective. This kind of study is necessarily bound up with probabilities and presuppositions. The very same deposit will seem to one student to give overwhelming evidence of rapid deposition, and to another it will seem to have been laid down very slowly and gradually. The true explanation is not necessarily determined by majority vote!

It is salutary to keep constantly before us, in deciphering geologic history, the fact that we are outside the domain of true science. The viewpoint favored here, of course, is that of catastrophism. The deposits can be understood quite adequately in this context, but this is not the same as saying that catastrophism can be proved scientifically (which means, experimentally). By the same token, it should be clearly recognized that neither can uniformitarianism be proved scientifically.

Our purpose here, therefore, is simply to show that aqueous catastrophism provides a possible and reasonable explanation for the sedimentary rocks, and that uniformitarianism is beset with serious difficulties. The conclusions one may draw from this fact will depend largely upon his own philosophic preferences, or perhaps prejudices.

Sedimentation, Paleontology and Evolution

The importance of the study of the processes of sedimentation as related to the geological record lies mainly in its contribution to the theory of evolution. The fossil record, as preserved in the sedimentary rocks of the earth's crust, is by all odds the most important of the so-called evidences for evolution. As Kerkut has said:

> The most important evidence for the theory of Evolution is that obtained from the study of paleontology. Though the study of other branches of zoology, such as Comparative Anatomy or Embryology, might lead one to suspect that animals are all inter-related, it was the discovery of various fossils and their correct placing in relative strata and age that provided the main factual basis for the modern view of evolution.[6]

That is, the earth's vast areas and thickness of sedimentary rocks, comprising as they do about three-fourths of the earth's land surface, are supposed to have been laid down over aeons of geologic time, each layer in turn containing fossils typical of the life of the period of its own deposition. Older rocks contain only primitive forms of life, and the fossils become increasingly complex and modern in more and more recent deposits. Thus, although other evidences of evolution are circumstantial in nature, and may be explained either in terms of evolutionary kinship or in terms of direct creation, the fossil record purports to provide an actual documentary history of organic evolution.

But at the same time, the rock layers themselves are dated as to their relative antiquity by the fossils they contain!

> Vertebrate paleontologists have relied upon 'stage-of-evolution' as the criterion for determining the chronologic relationships of faunas. Before the establishment of physical dates, evolutionary progression was the best method for dating fossiliferous strata.[7]

Rocks containing simple fossils are thus assumed to be old and those with complex fossils are young. The physical dates referred to are not by any means as yet considered determinative in establishing geologic age, since any radioactive dating which appeared to contradict the pre-

viously determined geologic age would be discarded immediately as erroneous.

> The standard time scale is derived directly from the standard column and from no other source, except for late Pleistocene details. The fossils of the units in the standard column and of other units in other columns are still our principal guides in stratigraphic correlation, although we cordially welcome the statistical calibration of the standard column, in years, from radiometric data.[8]

There is thus clearly a very subtle circle of reasoning involved in the stratigraphic interpretation of the sedimentary rocks of the earth's crust. The basis for their relative dating is entirely paleontological, on the assumption of evolutionary progression over the geologic ages.

But then, the only real evidence for this evolutionary progression is the fossil record. And, as a matter of fact, even this is only true in small part. Dating is accomplished not by the fossil assemblages as a whole, but only by certain "index fossils," which are supposed to be sure criteria of the various specific stages in evolutionary history.

> The best example of how *qualitative* and *non-statistical* paleontological correlation is, is provided by the already-mentioned fact that only a minority of fossils of most faunas (and this often amounts to the minority of one fossil species or genus only!) are reliable time indices or index fossils. The great majority of fossils are, conversely, either inferior (parachronological) time indices or have little or no practical biochronological value (ecostratigraphical indices). Any single, readily identifiable specimen or fragment of a known diagnostic ammonite, belemnite, planktonic foraminifera, graptolite, trilobite, etc., is, therefore, often more significant for the dating and correlation of the rock units concerned than all the rest of their faunas taken together.[9]

The most trustworthy indicators of evolution and geologic age, therefore, seem to be a relatively restricted number of simple marine organisms. These were presumably of worldwide provenance, so that they can be used for correlation on a worldwide basis, and are found in rather clearly distinguishable vertical series, with the simpler and less specialized forms in the lower layers, and the more complex and differentiated forms in the upper layers.

And these marine indicators, of course, are all found in stratified rocks, which originally were deposited as sediments by moving water, most probably in fairly shallow marine environments. This latter is confirmed by Krumbein and Sloss:

> Taken as whole, the sublittoral environment is perhaps the most important from the viewpoint of stratigraphic analysis. Twenhofel (1950) estimated that about 80 per cent of the sediments in the geologic column were deposited in water less than 600 feet deep.[10]

Dr. Walter E. Lammerts, in a personal communication, has called attention to an important example of a specific index fossil and how its occurrence might well be better interpreted in terms of sedimentary sorting during deposition rather than in terms of its unique occurrence during a particular geologic age. He says:

> The foraminifera group called fusulinids are considered excellent index fossils indicating the middle Pennsylvanian in distinction from the schwagerinids which are indicative of the Permian. But these schwagerinids, such as the genus *Schwagerina, Pseudoschwagerina* and *Parafusulina,* are quite different in both wall structure and shape. Accordingly one would expect them to be segregated into different strata strictly on this basis alone! Furthermore they may well have occupied ecologically distinctive niches and thus been buried in different places.
>
> Many of the foraminifera are arenaceous and so would not in general be found mixed with the calcareous forms. Though unfortunately the fusulinids and schwagerinids seem to be extinct, it would be most interesting if tests could be run on the comparative rapidity with which these various genera sink in water. It is very likely, if not certain, that they would show different rates of settling, which is thus an obvious reason why they should now be found segregated into distinctive strata.

The reasonableness of this suggestion is pointed up by the fact that decanting is, right today, used as an effective method for sorting out different foraminifera specimens. Joseph Cushman, probably the greatest authority on "forams," says:

> Another method by which rough sorting can be done is by decanting. If the material is shaken up in a tall vessel of some sort, the lighter specimens will stay in suspension for a short period and can be poured off, leaving the heavier ones on the bottom. Successive stages will separate most of the calcareous tests from the sand and heavier foraminifera.[11]

The effectiveness and significance of hydrodynamic sorting, as a mechanism for producing particular assemblages which seem superficially to be chronological markers or index fossils will be discussed further in a later section. Here we merely note that even those relatively few organisms which have served as index fossils

may themselves really have a hydraulic basis, rather than genuine evolutionary or chronologic significance.

In summary, the real basis for the theory of evolution seems to consist mainly of the series of marine index fossils found in the geologic column. These are found in hardened, stratified sediments deposited originally in shallow epicontinental seas, supposedly over hundreds of millions of years of geologic time, and then uplifted in more recent times to form in many cases our present mountainous regions. The processes of sedimentation by which these great fossiliferous beds were originally formed thus become of great interest and significance.

Inadequacy of Uniformitarianism

For over a hundred years, the dogma of uniformity has been the pride and backbone of geologic interpretation. Geologic processes in operation in the present era —*especially those of sedimentation*, which are obviously the most important of all geologic processes since they have produced the rocks whose fossils form the basis of geologic analysis—are supposedly capable of accounting for all these sediments in the geologic column. In the familiar catch phrase of James Hutton, "the present is the key to the past."

However, the principle of uniformity turns out to be entirely inadequate right at this most important aspect of geologic interpretation. Modern processes of sedimentation are in general quite incapable of accounting for the sedimentary rocks of the geologic column. This is true whether the environment of deposition is thought to be geosynclinal, deltaic, lagoonal, or some other.

As a matter of fact, it is increasingly being recognized by modern geologists that uniformitarianism has failed. It is, of course, still tenaciously held in opposition to any form of Biblical catastrophism or creationism, but it is widely acknowledged that it is not at all adequate when it comes to correlating the geologic formations with modern processes and their rates. In a recent article, a California geologist has said, for example:

> The doctrine of uniformitarianism has been vigorously disputed in recent years. A number of writers, although approaching the subject from different directions, have agreed that this doctrine is composed partly of meaningless and erroneous components and some have suggested that it be discarded as a formal assumption of geologic science.[12]

Similarly, David Kitts, of the University of Oklahoma, has noted this problem:

> There is widespread agreement among geologists that some special principle of uniformity is a fundamental ingredient of all geologic inference. . . . Despite this general agreement about the importance of the principle, geologists hold widely divergent views as to its meaning. So divergent are these views, in fact, that one is led to conclude that there has been little or no resolution of the problems which gave rise to the famous controversies between the 'uniformitarians' and the 'catastrophists' in the nineteenth century. Though the problems have not been solved, the controversy has subsided.[13]

It is thus admitted that, although uniformitarianism has not proved adequate to account for the strata, and that catastrophism has not been proved false, yet nevertheless "the controversy has subsided." Of course, this is because the forces of naturalism and evolutionism have attained essentially universal dominance in science and any form of supernatural catastrophism is excluded from further discussion. As Valentine says:

> Frequently the doctrine of uniformitarianism is used fruitfully to explain the anti-catastrophist viewpoint of history, and to illuminate the practical working method of consulting nature for clues to natural history.[14]

Or, as George Gaylord Simpson has put it:

> It is a necessary condition and indeed part of the definition of science in the modern sense that only natural explanations of material phenomena are to be sought or can be considered scientifically tenable. It is interesting and significant that general acceptance of this principle (or limitation, if you like) came much later in the historical than in the non-historical sciences. In historical geology it was the most important outcome of the uniformitarian-catastrophism controversy. In historical biology it was the still later outcome of the Darwinian controversy and was hardly settled until our own day. (It is still far from settled among non-scientists.)[15]

One might note, in passing, the self-serving assumption by Professor Simpson that all who might disagree with his naturalistic presuppositions are "non-scientists," especially since it is certainly true that neither catastrophism nor creationism can possibly be disproved "scientifically." One can invent his own definition of "science," of course, and frame it so as to exclude any possibility of teleological explanation, and this is what Simpson and others have done. It still remains true that uniformitarianism has proved sterile as far as much of historical geology is concerned:

> It seems unfortunate that uniformitarianism, a doctrine which has so important a place

> in the history of geology, should continue to be misrepresented in contemporary texts and courses by 'the present is the key to the past,' a maxim without much credit.[16]

The Biblical creationist, of course, has no objection whatever to the concept of the uniformity of *natural law*, as prevalent in the present cosmos. It is the assumption that present *processes* (which operate within the framework of uniform natural law) must always operate at the same rates as at present with which he takes issue. This latter assumption is even bold enough to claim that the processes, and even the laws, produced themselves, by means of themselves!

The basic distinction between the laws of nature and the processes which operate within the framework of those laws, and between a valid and a fallacious uniformitarianism, have been discussed in a previous article.[17] In general it can be argued quite persuasively that the very existence of natural laws presupposes a Creator by Whom such laws were brought into existence. Since this is so, the permanence and inviolability of such laws is dependent upon the will of the Creator, and our knowledge of these characteristics is contingent upon His revelation to us concerning them.

Even within the framework of the semi-permanence of natural law and basic cosmic processes which has been established and revealed by God (Genesis 8:22), it is still true that process rates may and do vary tremendously. Each process, and the rate at which it operates, is found to depend upon many different parameters, and a change in conditions for even one of these may materially change the process rate.

For example (and this is obviously the example most pertinent to our present discussion), sediment erosion, transportation and deposition is a process that may take place very slowly or exceedingly rapidly. A very large number of variables go into the determination of sedimentation rates. An incomplete list would include:

(a) **hydraulic factors,** such as channel slope, shape and size; quantity of water available; roughness of channel bed and sides; variability of water flow; and water temperature;

(b) **topographic factors,** such as shape and size of watershed, slope and aspect of the terrain, nature of the soil and its vegetal cover, tributary network and groundwater conditions;

(c) **meteorological factors,** such as frequency and intensity of storm rainfall, direction of air mass movements, and duration of rainfall;

(d) **sedimentary factors,** such as size, shape, variability, specific gravity, and chemical character of the sediment being transported.

Other influences could be added, but even this list will indicate how futile it would be to try to establish any kind of *average rate* of sedimentation, and then to extrapolate such a rate for hundreds of millions of years into the past to try to explain the immense sedimentary formations of the earth's crust! There is no *a priori* reason whatever why rapid (or catastrophic) formation of these beds would not provide as satisfactory an explanation—and as fully in accord with the assumption of uniform natural law—as would slow deposition over millions of years.

Mechanics of Sedimentation

In principle, it should be possible by induction to examine the character of a given sedimentary deposit; and, therefrom, to determine (1) the nature of the source area from which the sediment had been eroded initially, (2) the magnitude and nature of the water flow which had transported it, and (3) the character and extent of the basin into which it had finally been dropped. In actuality, however, owing to the excessive number of variables which may have contributed to the phenomenon, as above enumerated, it is normally quite impossible to make such extrapolations with any degree of assurance.

It is customary to consider sedimentation under the three stages of erosion, transportation and deposition. Since the first and last of these necessarily involve non-uniform conditions (either degradation or aggradation), it is easiest to consider the transportation phase first, as an equilibrium, or quasi-equilibrium, state. That is, it is assumed that the sediment transported by the flow is constant with time and distance, with any localized erosion being offset by localized deposition. Non-equilibrium conditions are then characterized either by a net erosion or a net deposition of sediment.

A great many studies have been made in laboratory flumes, and a smaller number in actual streams, of rates of sediment transport. Numerous empirical formulas have been derived and some have been employed with fair success in engineering problems. Typical of these formulas is the following,[18] attributed to M. L. Albertson and R. L. Garde, of Colorado State University:

$$G_s = \frac{1.36\ W\ V^4 n^3}{k^3 d^{1.5} D\ (10^{15})}$$

In this formula, G_s represents the total number of pounds of sediment being transported each second past any given point in the stream. W is the stream width, V is the velocity of flow in feet per second, and n is a channel "roughness coefficient," which measures the hydraulic resistance to flow. The depth of flow, in feet, is D, and the diameter of sediment particles is d, also in feet. The effect of temperature is measured by the "kinematic viscosity" of the water, k. Typical values of k and n might be, respectively,

about 0.00001 square feet per second, and 0.035, although they can vary over a wide range.

The formula applies only to a uniform channel, with flow at constant velocity, for sediment composed predominantly of sand grains of only one size. Even with these limitations it is able to give only very approximate answers. Many formulas attempt to distinguish between the suspended sediment load, the saltional (rolling and bouncing) load, and the bed load. Also, depending upon the velocity and other factors, the form of dunes on the bed may change materialy, thus changing the hydraulic roughness and modifying the flow.

The problem of course is compounded if any of the factors become non-uniform. If there is a change in the channel cross-section, velocity, or roughness, or if the sediment is of varying sizes, then it becomes almost impossible to make calculations of sediment transport which are quantitatively accurate, although it may be possible to determine whether there will be scour or deposition.

And calculations become necessarily still more complex if non-equilibrium conditions exist—that is, if material is being eroded or deposited, instead of simply transported. It is thus quite clear that any truly quantitative understanding of the processes and rates of sediment deposition, even in the environments of the present, is still far from being attained. Consequently, the idea that the sedimentary rocks of the earth's crust, with their fossil contents, can be explained in terms of present processes of sedimentation on the application of uniformitarian principles is nothing but wishful thinking.

The Necessity of Catastrophism

Since we have no scientific basis for quantitative evaluation of ancient sedimentary processes, it is obvious that the question of catastrophism versus uniformitarianism in sedimentary interpretation is still very much an open question. If it then begins to appear that many of the present geologic formations could not have been formed at all by modern, slow, rates of deposition, the presumptive evidence for catastrophism as the most likely explanation is rendered all the stronger.

As a matter of fact, even most modern sedimentary phenomena must be attributed to brief, intense periods of sedimentation, rather than normal, slow, uniform periods. More than half of all sediments transported and deposited by modern rivers, are carried during flood periods, when the river is overflowing its banks.

There are a number of remarkable phenomena characterizing the sedimentary rocks of the earth's crust that seem to be clear evidences of catastrophic deposition and which thus belie the evolutionist's assumption of uniformitarianism. These include among them the following:

(1) **Fossil Graveyards** It is well known that when a living organism dies, especially one of the larger animals, its remains soon disappear, because of the efficiency of scavenger organisms and the decay processes which immediately go to work on it. Yet, in the earth's sedimentary rocks, there are buried vast numbers of plants and animals of all kinds, often in great fossil "cemeteries," where thousands, even millions, of organisms may be found crushed together and buried by the sediments. Even after centuries of collecting great quantities of fossils all over the world, new "graveyards" continue to be found.[19]

It is a matter of the most elementary scientific logic to recognize that phenomena such as these must be attributed to very rapid burial, or otherwise they could never have been preserved. And since most such fossil graveyards have been buried in water-laid sediments, they clearly give witness to the fact of aqueous catastrophism.

(2) **Polystrate Fossils** Stratification (or layered sequence) is a universal characteristic of sedimentary rocks. A stratum of sediment is formed by deposition under essentially continuous and uniform hydraulic conditions. When the sedimentation stops for a while before another period of deposition, the new stratum will be visibly distinguishable from the earlier by a stratification line (actually a surface). Distinct strata also result when there is a change in the velocity of flow or other hydraulic characteristics. Sedimentary beds as now found are typically composed of many "strata," and it is in such beds that most fossils are found.

Not infrequently, large fossils[20] of animals and plants—especially tree trunks-are found which extend through several strata, often 20 feet or more in thickness. A young Dutch geologist, N. A. Rupke, has suggested that these be called "polystrate fossils" and has documented[21] numerous remarkable examples of this phenomenon. (See Figure 1.)

It is beyond question that this type of fossil must have been buried quickly or it would not have been preserved intact while the strata gradually accumulated around it. And since the strata entombing these polystrate fossils are no different in appearance or composition from other strata, it is probable that neither was there any significant difference in the rapidity of deposition.

(3) **Ephemeral Markings** Another evidence of very rapid deposition is the preservation of what Rupke[22] calls "ephemeral markings." These constitute a special type of fossil originally formed as a transient marking on the surface of a re-

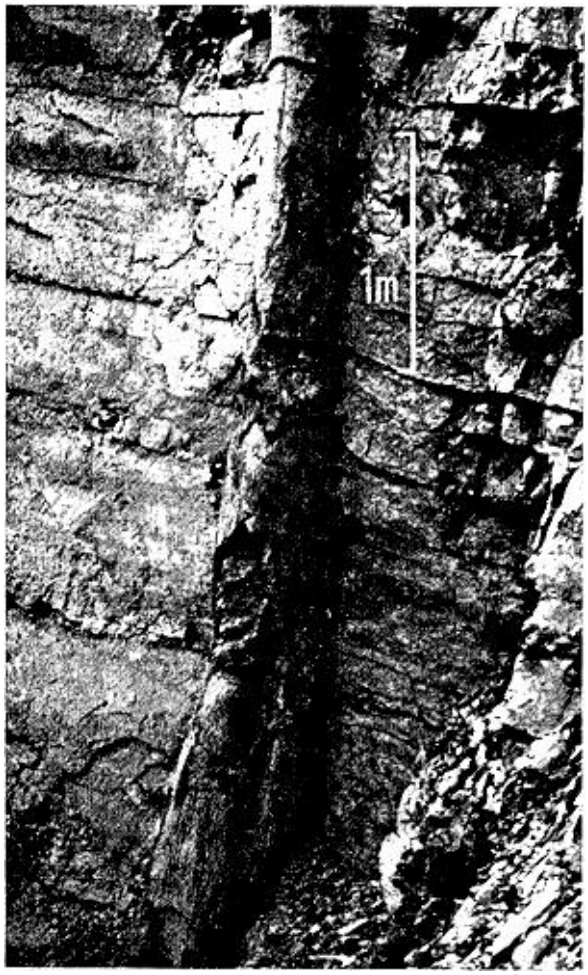

Figure 1. Polystrate tree-trunk near Essen-Kupferdreh (Germany). (Photo by Klusemann).

cently deposited layer of sediment. These include such phenomena as: (a) ripple marks; (b) rain prints; (c) worm trails, and (d) bird and reptile tracks.

It is a matter of common observation that such fragile structures, once formed, are very quickly obliterated by subsequent wind or air currents or by later erosion and sedimentation. The only way they could be preserved is by means of abnormally rapid burial (without concurrent erosion), plus abnormally rapid lithification.

It would indeed be difficult, if not impossible, to point to examples of such fossils in the process of formation at present. Sudden burial by turbidity currents is frequently suggested. For example, Adolf Seilacher, Geologisches Institut University of Frankfurt, Germany, says:

> The post-depositional sole trails of Flysch psammites occur only in thinner beds up to a thickness particular to each species. This proves instantaneous deposition of the individual beds, as postulated by the turbidity-current theory. The majority of the sole trails are predepositional mud burrows washed out and sand cast by turbidity currents. Thus erosion of an unusual type must have preceded every turbidite sedimentation.[23]

But the remarkable fact is that "ephemeral markings" of this type are found in great abundance in the ancient sedimentary rocks of practically all geologic "ages," including the most ancient. Furthermore, they appear equally fresh, when exposed in the present time, regardless of what the particular geologic age is supposed to be, whether Proterozoic or Tertiary or anywhere in between. It seems quite clear that only some kind of overwhelming catastrophic sedimentary phenomenon can really account for these markings and their preservation.

(4) **Preservation of Soft Parts** Numerous instances are known where the fossil remains do not consist of petrification or molds or the like, but where the actual soft tissues of the organism have been preserved. This is true even in very "ancient" strata, and often such fossils are found massed together in large numbers.[24] Not only do these deposits speak plainly of very rapid burial by the sediments, but they also make the contention that they have remained unaffected by decay, erosion, etc., for many millions of years exceedingly difficult to believe.

(5) **Phenomena of Stratification** Not only do the fossils contained in the sedimentary strata demonstrate the necessity of catastrophic deposition, but the very strata themselves indicate this. As already noted, most of the earth's surface is covered with sediments or sedimentary rocks, originally deposited under moving water. This in itself is *prima facie* evidence that powerful waters once covered the earth. Furthermore, as already mentioned, even under modern conditions most sedimentary deposits are the result of brief, intense periods of flood run-off, rather than slow, uniform silting.

Laboratory evidence that a typical sedimentary deposit may form quite rapidly is found in the work of Alan Jopling at Harvard, who made a long series of studies on delta-type deposition in a laboratory flume and then applied the results to the analysis of a small delta outwash deposit, supposedly formed about 13,000 years ago. His conclusion was as follows:

> It may be concluded therefore that the time required for the deposition of the entire delta deposit amounted to several days . . . Based on the computed rate of delta advance and the thickness of individual laminae, the average time for the deposition of a lamina must have been several minutes.[25]

The fact that many sedimentary formations in the stratigraphic column consist of gravels or conglomerates, or even boulders, is further testimony to hydraulic activity of high intensity, as is the frequent occurrence of "cross-bedding" phenomena, indicating rapidly changing current directions.

(6) **Alluvial Valleys** Practically all modern rivers course through valleys that once carried far greater volumes of water than they do now. This is indicated not only by the universal presence of old river terraces high on the valley walls but even more by the vast amounts of sands and gravels lying beneath the present flood plains, which now fill what were formerly the stream channels.

> Subsurface explorations of meandering valleys in the Driftless Area of Wisconsin, by means of a refraction seismograph, reveal large filled channels similar to those previously determined in English rivers where the augering technique was used. The channels are asymmetrical in cross profile and attain their greatest depths at valley bends. In cross-sectional area at probable bankfull they are some 25 times as large as the present stream channels.[26]

This sort of thing is practically universal. The Mississippi Valley, for example, consists of alluvial deposits extending to depths of 600 feet! All of this indicates that the rivers of the world, in very recent times (probably during and after the continental uplifts terminating the year of the Great Flood) carried tremendous volumes of water and sediment.

(7) **Incised Meanders** Another universal characteristic of alluvial streams is the phenomenon of meandering. Many analytical and experimental studies have been made to determine the cause and mechanics of meandering, but these have only been partially successful. It is well accepted, however, that stream meandering requires relatively mild stream gradients and easily eroded banks. If the slopes are steep and the sides resistant, then erosion will occur primarily at the beds and the stream will cut down essentially vertically, forming a canyon section.

Most remarkable, therefore, are the intricate meandering patterns found frequently incised in deep gorges in high plateau and mountainous areas. These would seem to defy any explanation in terms of the ordinary hydraulics of rivers, and geologists' suggestions (superposed meanders, for example!) seem to be oblivious of such hydraulics.

Clearly some kind of catastrophic origin is indicated. Great regions of horizontal sedimentary beds, still relatively soft and erosible when uplifted following the Deluge, riven by great fissures during the uplift process, possibly provide a realistic model of conditions suitable for formation of these structures. The initial cracks could have been rapidly widened and deepened into the present meandering gorges as great volumes of water were being rapidly drained off the rising plateaus.

Evidence of a Single Depositional Epoch

The above is not of course a complete, but only a representative, list of evidence of aqueous catastrophism. Neither does the scope of this paper allow for discussion of various types of formations which superficially may seem to require very slow process rates. This has already been done to some extent elsewhere.[27]

It can be said that in general catastrophism provides a very adequate framework of interpretation for most, and probably all, the features of the known geologic column. Uniformitarianism, on the other hand, while satisfactory as a framework for some parts of the data, seems utterly inadequate to account for most of them.

There is one question, however. Even though admitting the validity of the concept of aqueous catastrophism to explain many of the geologic phenomena, as many geologists readily are doing today, there is still almost universal resistance to the idea of one, single, catastrophic epoch such as described in the Bible. Historical geologists still prefer a general framework of uniformitarianism and great ages, even though they are willing to recognize any number of intense and widespread floods and other local catastrophes occurring within that framework.

Thus the question is whether the numerous evidences of catastrophic sedimentation, including those discussed in the preceding pages, were caused by one great cataclysm or by a great number of lesser catastrophes.

If it were not for the religious implications, and were it only a matter of seeking a logical explanation of the actual physical data, the application of the principle of Occam's Razor (which cautions against the unnecessary multiplication of hypotheses) would lead quickly to a decision in favor of the one great cataclysm.

To insist that there have been great numbers of violent geologic catastrophes (in all parts of the world and through all the aeons of geologic time) sufficient to explain the many evidences of catastrophism; and further knowing (a) that many of these catastrophes must have been far greater than anything ever observed in the modern world, and (b) that uniformitarianism is utterly inadequate to incorporate them within any kind of experimentally quantitative framework, would surely seem to suggest a strong religious bias against the concept of the Biblical record of the great Deluge and favoring an evolutionary interpretation of history.

The various evidences for catastrophism cited previously—the fossil graveyards, polystrate fossils, ephemeral markings, and others—are generally found more or less indiscriminately among strata throughout the entire geologic column. There are no evidences of progressive changes in the characteristics of catastrophism throughout the supposed geologic ages, such as should be expected in response to changing climatic and geophysical regimes as postulated throughout the earth's evolution. Sedimentary deposits of the Proterozoic Era have essentially the same physical characteristics as those of the Tertiary, or any others, the only significant difference being the fossil assemblages, especially the index fossils, contained in them.

And of course the fossil assemblages themselves are better explained in terms of aqueous cataclysm than of evolutionary uniformitarianism. They are supposed to show increasing complexity, and therefore evolution, with the passage of geologic time, but this interpretation is belied by the fact of the great gaps which exist between all the major kinds of creatures in the fossil record, which gaps are essentially the same as the gaps between the same kinds of plants and animals in the modern world.

The fact that, in general, the fossils are found segregated into assemblages of similar sizes and shapes is exactly what would be expected as a result of diluvial processes, since turbulent water is a highly effective "sorting" agent. In his flume studies at Harvard, Jopling found, for example, that even when the flows were steady and uniform, and when the sediments transported were randomly mixed to begin with, the flow would sort them out.

> Segregation invariably occurs even when uniform conditions of sediment transport prevail, and where the various size grades of the sediment have been thoroughly mixed to begin with. This segregation occurs on either a plane, rippled, or duned bed, and it is evident in both the transverse and longitudinal directions.[28]

This sorting action is basically produced because the amount of hydrodynamic "lift and drag" forces on immersed objects are directly related to the size and shape of the objects. The same applies, of course, to objects falling vertically through water, so that objects which are simpler in shape (and thus, supposedly, more "primitive") would tend to settle out of a decelerating flow more rapidly and thus be buried more deeply than would objects of complex geometry. This tendency would be further augmented by the fact that these simpler organisms (shells, for example) normally are of somewhat greater specific gravity than "higher" organisms.

It would be reasonable to expect, therefore, that the hydraulic activity of a worldwide Flood would tend to deposit organisms of similar sizes and shapes together, and that the depth of burial would be in order of increasing complexity from the bottom up. Furthermore, this is directly parallel to the elevation of the normal habitat of organisms.

Other things being equal, since the simpler organisms dwell at lower elevations, it would be expected that they would be buried at lower elevations. And still further, the mobility of animals is rather closely related to their complexity, so that higher animals would escape burial for longer periods.

All of these factors would contribute toward the preservation of fossils in the Flood sediments in just the order in which they are now usually found, whereas the usual evolutionary interpretation is obviously inadequate.

These three factors,—hydraulic, ecologic, and physiologic--would of course tend to act only statistically, rather than absolutely, so that the very numerous exceptions to the usual order which have been found are not particularly surprising. They *are* an embarrassment to the evolutionist, however, since fossils in the wrong stratigraphic order would indicate a reversal of evolution and thus completely upset the assignment of geologic ages.

It is typical of evolutionary reasoning that such anomalies and contradictions can never be allowed to bring into question the basic assumption of evolution. Consequently, a further multiplication of hypotheses is employed, invoking the possibility of great earth movements as a means of explaining how the fossiliferous strata have been rearranged into the "wrong" order. Vast horizontal "thrust faults" by which great thicknesses of sedimentary strata have been uplifted and then translated horizontally over the adjacent regions, have typically been offered as mechanisms explaining the many areas where "ancient" fossil-bearing formations have been found on top of "recent" formations.

It is interesting that another hydraulic principle has been employed to explain how such movements are possible, since it is well known that ordinary mechanical sliding, even if the sliding planes were lubricated, would be physically impossible on such a large scale without completely destroying the structural integrity of the sliding formations. The presently accepted explanation is that the thrust block was "floated" into place by abnormally high internal fluid pressures along the thrust plane.

These pressures, in order to be effective, would have to be far higher than in ordinary ground water and are supposedly caused by compres-

sion of water trapped in the sedimentary interstices when the sediments were originally deposited. That is, as the original sediments were gradually compressed and lithified, the "connate water" contained in the soil pores was somehow sealed off from any possible escape channels and was eventually so compressed as to develop elastic pressures capable of actually lifting and "floating" the huge rock overburden above it.

This is indeed a remarkable hypothesis. The "seal" around the sides of the thrust blocks (not infrequently hundreds or thousands of square miles in extent) must have been quite elastic itself, permitting great vertical and horizontal motions of the block and yet preventing any escape of the highly compressed water in the process. In a cogent analysis of this hypothesis, Platt has pointed out:

> Obviously an important factor is the quality of the seal that forms in the clay or shale. No matter how small the permeability in the relatively impermeable layer that effectively seals the connate water beneath the thick sequence, some leakage does occur. . . . Hence, if fluid support is to be available to 'float' the rocks, the thrust movement must occur soon (geologically) after the deposition of the final weight of the thick sediments. If the delay is sufficient, the seal of shale becomes very good, but there is no fluid left to seal off.[29]

This requirement for early flotation of the block, suggested by Platt, of course is at cross purposes with the long period of time supposedly required for compression and lithification of the sediments before the fluid could develop the required pressures. The even more important problem of how the necessary seal could be maintained during the period of thrust action is not mentioned at all.

It is concluded, therefore, that the concept of one great hydraulic cataclysm, accompanied by great volcanic and tectonic activities, on a worldwide scope, provides a much more realistic model to explain the sedimentary strata and the fossil record, than does the philosophy of evolutionary uniformitarianism, with its utterly unscientific multiplication of hypotheses and manipulation of data.

References

[1]This paper was originally presented at the Christian Schools Conference, held at the St. Thomas Episcopal School, Houston, Texas, April 15-17, 1967.

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[3]Portions of the following discussion have been taken from an article by the author entitled "Hydraulics, Sedimentation and Catastrophism," *Creation Research Society Quarterly,* Vol. 3, May 1966, pp. 51, 52.

[4]James H. Zumberge, *Elements of Geology*. Second Edition. New York, John Wiley and Sons, 1963, p. 44.

[5]Malcolm C. McKenna, "The Undersea History of America," *Science Digest,* Vol. 57, April 1965, pp. 90-91.

[6]G. A. Kerkut, *Implications of Evolution*. Oxford, Pergamon Press, 1960, p. 134.

[7]J. F. Evernden, D. E. Savage, G. H. Curtis, & G. T. James, "K/A Dates and the Cenozoic Mammalian Chronology of North America," *American Journal of Science,* Vol. 262, February 1964, p. 166.

[8]A. O. Woodford, "Correlation by Fossils," in *The Fabric of Geology*. Edited by C. C. Albritton, Jr. Reading, Mass., Addison-Wesley, 1963, p. 108.

[9]J. A. Jeletzky, "Is it Possible to Qualify Biochronological Correlation?" *Journal of Paleontology,* Vol. 39, January 1965, p. 138.

[10]W. C. Krumbein and L. L. Sloss, *Stratigraphy and Sedimentation*. Second Edition. San Francisco, W. H. Freeman Co., 1963, p. 261.

[11]Joseph A. Cushman, *Foraminifera, Their Classification and Economic Use*. Fourth Edition. Cambridge, Harvard University Press, 1950, p. 27.

[12]James W. Valentine, "The Present Is the Key to the Present." *Journal of Geological Education,* Vol. XIV, April 1966, p. 59.

[13]David B. Kitts, "The Theory of Geology," in *The Fabric of Geology*. 1963, p. 62.

[14]James W. Valentine, *Op cit,* p. 60.

[15]George G. Simpson, "Historical Science," in *The Fabric of Geology*. 1963, p. 32.

[16]James W. Valentine, *Op. cit,* p. 60.

[17]Henry M. Morris, "Science Versus Scientism in Historical Geology," *Creation Research Society Quarterly,* Vol. 2, July 1965, pp. 19-28.

[18]For a discussion of the background of this equation, as well as other methods used in sediment calculations, see *Applied Hydraulics in Engineering* by Henry M. Morris. New York, Ronald Press, 1963, pp. 321-336. This is a standard textbook for senior and graduate courses in hydraulic engineering, currently used at about 75 colleges and universities.

[19]A typical recent example is described by W. W. Dalquest and S. H. Marnay, "The remains of 400 or more Permian amphibians were found in a series of siltstone channels confined to an area 50 feet square . . . . The fossils are mostly or entirely of heavy-bodied, weak-limbed forms that probably could not walk about on land." in "A Remarkable Concentration of Permian Amphibian Remains in Haskell County, Texas," *Journal of Geology,* Vol. 71, September, 1963, p. 641.

[20]N. A. Rupke, "Prolegomena to a Study of Cataclysmal Sedimentation," *Creation Research Society Annual,* Vol. 3, May 1966, No. 1, pp. 16-37. Another instance, not described by Rupke, is mentioned by F. M. Broadhurst in an article entitled, "Some Aspects of the Paleoecology of Non-Marine Faunas and Rates of Sedimentation in the Lancashire Coal Measures," *American Journal of Science,* Vol. 262, Summer 1964, pp. 865-6. He says:

> In 1959 Broadhurst and Magraw described a fossilized tree, in position of growth, from Coal Meas-

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things, evidence from archaeology that the present order of the world began about three thousand years B.C.

There are also two pieces of evidence from population study. The world population of Jews, about 18 millions in say 1930, would be reached from the time of Jacob's marriage, about 1900 B.C., by doubling about every 160 years. Likewise the present population of the world, about 3,500 millions, would be reached from eight people after the Flood, say about 2500 B.C., by doubling at the same rate, about once every 160 years.

There is another piece of evidence, not mentioned in the Pamphlet, which might interest those who live in the Western Hemisphere. It is estimated that the population of the hemisphere in say 1600 was about 15 or 16 millions, about the same as the Jewish population in 1930. So we might expect the population of the New World to have begun, in some sense, about 300 years before Jacob's marriage, viz., about 2200 B.C. (These dates are not Ussher's, but we do not need the dates for the argument, only the intervals.)

Now 300 years before Jacob's marriage would take us back to Peleg's life, and in his time the Earth was divided. If this division separated off the New World, and a very few people with it, the subsequent growth of the population is what would be expected.

Incidentally, any creationists who does not yet know of the publications of the Evolution Protest Movement would find it worth while to find out what the Movement has done. The Secretary of the Movement is: A, G. Tilney, Santhia, Stoke, Hayling Island, Hants., England.

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> tree was preserved as a cast, and the evidence available suggested that the cast was at least 38 feet in height. The original tree must have been surrounded and buried by sediment which was compacted before the bulk of the tree decomposed, so that the cavity vacated by the trunk could be occupied by new sediment which formed the cast. This implies a rapid rate of sedimentation around the original tree . . . . It is clear that trees in position of growth are far from being rare in Lancashire (Teichmuller, 1956, reaches the same conclusion for similar trees in the Rhein-Westfalen Coal Measures), and presumably in all cases there must have been a rapid rate of sedimentation.

[21]Rupke, *Op cit,* pp. 21-25.

[22]*Ibid,* pp. 25-29.

[23]A. Seilacher, "Paleontological Studies on Turbidite Sedimentation and Erosion," *Journal of Geology,* Vol. 70, March 1962, p. 227.

[24]See *The Genesis Flood,* by John C. Whitcomb, Jr. and Henry M. Morris. Nutley, N. J., Presbyterian and Reformed Publ. Co., 1961, pp. 159, 160 for a discussion of various examples of this phenomenon.

[25]Alan V. Jopling, "Some Principles and Techniques Used in Reconstructing the Hydraulic Parameters of a Paleo-Flow Regime," *Journal of Sedimentary Petrology,* Vol. 36, March 1960, p. 34.

[26]G. H. Dury, "Results of Seismic Explorations of Meandering Valleys," *American Journal of Science,* Vol. 260, November 1962, p. 691.

[27]See *The Genesis Flood,* pp. 405-421.

[28]Alan V. Jopling, "Laboratory Study of Sorting Processes Related to Flow Separation," *Journal of Geophysical Research,* Vol. 69, August 15, 1964, p. 3413.

[29]Lucien B. Platt, "Fluid Pressure in Thrust Faulting, A Corollary," *American Journal of Science,* Vol. 260, February 1962, p. 107.

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[10]Desikachary, *Op. cit.,* p. 58.

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[12]Delevoryas, *Op. cit.,* p. 12.

[13]Tilden, *Op. cit.,* p. 50.

[14]Tilden, *Ibid.,* p. 50.

[15]Desikachary, *Op. cit.,* p. 15.

[16]Smith, *Op. cit.,* compare plates on pp. 134 and 560.

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[18]*Ibid.,* p. 142.

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[21]*Ibid.,* p. 48, quoted Dubos, R. J. 1945. The bacterial cell. Harvard University Press, Cambridge, Mass.

[22]*Ibid.,* p. 54.

[23]*Ibid.,* p. 54-55.

[24]*Ibid.,* p. 57.

[25]*Ibid.,* p. 59.

[26]*Ibid.,* pp. 87 and 90.