HYDRAULICS, SEDIMENTATION, AND CATASTROPHISM

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PART 1

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 geophysical 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. Practically all 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 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 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.[1]

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.

This, of course, 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 accomplish on the earth's crust by the waters, as affirmed in II Peter 3:5, 6.

But modem geologists have been unwilling to accept such an apparently simple explanation for the earth's sedimentary rocks, especially since it involves a worldwide catastrophe with supernaturalist 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.
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> 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.[2]

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 yearlong 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 the writing of the secular records of human history (excepting, of course, the Biblical record in the early chapters of Genesis). The events which formed the sedimentary strata are non-reproducible events and, since the very essence of the scientific method is experimental reproducibility, it is impossible to prove, scientifically, whether catastrophism or uniformitarianism provides the true explanation (unless, of course, we are willing to accept as trustworthy the apparently eye-witness accounts of the catastrophic events described in Genesis 7 and 8; this would be a valid scientific approach, but one which is nevertheless arbitrarily rejected by most historical geologists).

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. A deposit which seems to one student to give overwhelming evidence of rapid deposition will be explained by another as having been laid down very slowly and gradually. It may well be impossible to delineate, *scientifically,* which is ultimately right, for the simple reason that the deposits cannot be reproduced experimentally.

The use of laboratory models to study such large-scale and long-duration phenomena as these must always be of very limited and doubtful value, and comparison with modern sedimentary phenomena is likewise a very difficult and subjective procedure. Our purpose here, therefore, is simply to show that aqueous catastrophism provides a very reasonable explanation for the sedimentary rocks, and that uniformitarianism, on the other hand, is beset with exceedingly serious difficulties. The conclusions one may draw from this fact will depend largely upon his own philosophic preferences, or perhaps prejudices.

Difficulties in Uniformist Theories

We shall consider first some of the difficulties encountered by uniformitarian explanations of the ancient sediments. It is incumbent upon the uniformitarian, of course, to explain the formation of these sedimentary rocks in terms of the same processes of sedimentation (including the erosion, transportation, deposition, and lithification of sedimentary materials) that are now taking place in nature.

One of the major difficulties encountered in accomplishing this is the fact that we do not even understand much about how these processes operate right now! Processes of sedimentation are highly complex phenomena and do not yield very readily to any kind of rational, quantitative formulation. One leading hydrologist says:

> It is difficult to imagine a recognized field of science which is broader and more complex than sedimentation . . . In the process between erosion and deposition, soil particles are acted upon by many forces which are difficult to measure and evaluate. Sediment rates are highly variable because the many inter-related factors themselves vary in time and space.[3]

Because of the great practical importance of sedimentation in reservoirs, canals, rivers, and the like, a great deal of research has been devoted during the past few decades to an attempt to obtain a quantitative understanding of the process. But these have been only partly successful and in a very preliminary sort of way.[4]

Now if we do not even understand the nature of sedimentation as it occurs at present, how can we be justified in confidently extrapolating to the tremendously vast sedimentary deposits of the past on the basis of an arbitrary application of the principle of uniformity? Any use of present rates of erosion or deposition, for example, as an index to the time required for the deposition of a certain formation is utterly meaningless, if not indeed quite deceptive.

Even to attempt to identify ancient environments of sedimentation (as deltaic, lagunal, lacustrine, geosynclinal, etc.) on the basis of an imagined similarity with deposits of the present is, in very large measure, arbitrary and unrealistic. Most sedimentary rocks are believed to have been deposited in shallow marine waters.

The attempt to discover the characteristics of such deposition as it exists at present is quite difficult and has barely scratched the surface so far. Dr. Bruce Nelson, formerly at V. P. I., and now Geology Department Head at South Carolina, who for several years conducted field studies on sedimentation processes in Chesapeake Bay, says:

> A review of the various aspects of our recent sediment program as it has been conducted during the last year will show that we have come into contact directly with over a dozen separate scientific disciplines in an effort to decipher our geological problems . . . Our understanding of the geological processes leading to the production of recent sediments and their conversion into sedimentary rocks, therefore, will depend upon how thoroughly we, as geologists, can understand and master these bordering sciences.[5]

A good example of the inadequacy of the uniformity concept in the interpretation of sedimentary rocks is found in the geosynclinal theory. A geosyncline is conceived of as a tremendous near-shore trough, into which sediments are continually poured by the rivers carrying them to the sea. However, the trough is never very deep, so that the sediments are deposited in fairly shallow water.

As the sediments accumulate, the trough gradually subsides, leaving the sediment surface elevation about the same all the time, Eventually great thicknesses of sediment are built up in this way, many miles in depth!

As geologic time goes on, the geosyncline is finally uplifted and folded to become a great continental mountain range. Most of the earth's mountain ranges, such as the Rockies and Appalachians, have been explained largely in this way.

The importance of the geosyncline theory to stratigraphic studies is indicated by Clark and Stearn:

> The geosynclinal theory is one of the great unifying principles of geology. In many ways its role in geology is similar to that of the theory of evolution that serves to integrate the many branches of the biological sciences. The geosynclinal theory is of fundamental importance to sedimentation, petrology, geomorphology, ore deposits, structural geology, geophysics, and practically all the minor branches of geological science. Just as the doctrine of organic evolution is universally accepted among thinking biologists, so also the geosynclinal origin of the major mountain ranges is an established principle in geology.[6]

Now it does seem odd that a theory of such fundamental significance to all branches of geologic science as this one seems to be has not yet been explained in terms of the even more fundamental geological concept of uniformity! The origin, nature, causes of subsidence and causes of uplift of the great geosynclinal troughs are even yet unsettled, although many theories have been put forward at one time or another. Kennedy has discussed the problem as follows:

> The problem of the mechanics of the formation of deep troughs of low density sediments is heightened when their full history is considered. Many are known in the geologic record. In most, sediments accumulate for perhaps a hundred million years and reach a total thickness of as much as 100,000 feet. These thick, highly elongate lenses of sediments may then be slowly folded and uplifted to form mountain ranges which may initially stand as much as 20,000 feet high. Surprisingly, the geologic record shows that a large fraction of the mountain ranges of the world have been formed from rocks of these thick, geosynclinal troughs. Extensive volcanic activity may accompany and continue beyond the time of the formation of the mountain ranges. The mystery, then, of the downsinking of the sedimentary troughs, in which low density sediments apparently displace higher density rocks, is heightened when we note that these narrow elongate zones in the earth's crust, downwarped the most, with the greatest accumulation of rock debris, shed by the higher portions of the continents, become in turn the mountain ranges and the highest portions of the continents.[7]

The only modern crustal feature believed to be comparable to these ancient geosynclines is is the deep trough in the Gulf of Mexico, which is believed to be subsiding at about the same rate as the annual increment of sediment deposited on it by the Mississippi River. Kennedy notes an interesting problem in this connection:

> Each year (the Mississippi) brings to the Gulf of Mexico approximately 750 million tons of dissolved and solid material . . . the rate of erosion for the entire United States approximates one foot in 10,000 years. At this rate, all the land masses of the world would be eroded to sea level in something of the order of 10-25 million years.[8]

This length of time is geologically minuscule, of course, and seems hard to reconcile with the almost universally accepted evidence that the present continents and ocean basins are essentially stable features of the earth's crust. There are supposed to have been many transgressions and regressions of the sea throughout geologic time, but the main continental masses and ocean basins are believed to have remained essentially as they are today for at least the past two billion years.[9]

Kennedy and many others are convinced today that the only possible way of accounting for these anomalies is in terms of "phase changes" of the material in the rocks deep under the surface, at high pressures and temperatures. The level at which such changes occur is the so-called "Mohorovocic Discontinuity." Without entering into the details of the theory, the essence is that the density of rocks under the mountains or under the ocean bottoms adjusts in response to changes in load, as the mountains are eroded or as the troughs are filled. This is not primarily a change of density due to compaction, but due to an actual change of state in the material.

However, the physical evidence that such an explanation is valid is still lacking. In fact, the Gulf of Mexico "geosyncline" (actually this is a misnomer, as there are many discrepancies between the characteristics of this modern geosyncline and those of the ancient geosynclines which have been uplifted to form the present mountain ranges) seems to contradict the theory.[10]

Uniformitarian explanations, therefore, have been unable as yet to account for the most important of all the sedimentary rock deposits. There seems to be no really legitimate way to extrapolate from the sedimentation processes of the present to explain the sedimentary phenomena of the distant past. This is true not only in the case of geosynclines, It is equally difficult to show similarities between ancient deposits which are supposedly deltaic in origin and modern deltas. The same applies in general to the identification of most other possible depositional environments. In fact, many sedimentologists have taken the position that study of modern processes of sedimentation is of essentially *no help whatever* to their identification of sedimentary structures, preferring to use other methods![11]

In this Part I, it has been pointed out that the geologic postulate of uniformity is inadequate to explain the sedimentary rocks. These deposits are of course the most significant geologic phenomena as far as the theory of evolution is concerned, since it is in the sedimentary rocks that fossils are found, purportedly providing a documentary record of the development of all the various forms of living creatures which now inhabit the earth, And if uniformity is inadequate, it ought to be at least permissible to consider catastrophism as a possible frame of interpretation for the sediments.

This will be done in Part II (which will appear in a later Quarterly—Editors).

References

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[3]W. C. Ackermann: "Needed Research in Sedimentation," *Trans. American Geophysical Union*, Vol. 38, December 1957, p, 925.

[4]For a summary of modern research and methods in sedimentary processes, see Ch. 10, "Mechanics of Sedimentation," and Ch. 11, "Stream Channel Mechanics," in *Applied Hydraulics in Engineering*, by Henry M. Morris (New York, Ronald Press, 1963), pp. 321-401.

[5]Bruce W. Nelson: "Recent Sediment Studies in 1960, *Mineral Industries]ournal*, Virginia Polytechnic Institute, Vol. VII, December 1960, p. 4.

[6]Thomas H. Clark and Colin W. Steam: *The Geological Evolution of North America*, (New York, Ronald Press, 1960), p. 43.

[7]George C. Kennedy: "The Origin of Continents, Mountain Ranges, and Ocean Basins," in *Study of the Earth* (J. F. White, Ed., Prentice-Hall, Inc., 1962), p. 354.

[8]*lbid*, p. 355.

[9]*Ibid*, p. 356.

[10]J. I. Ewing, J. L. Worzel, and M. Ewing: "Sediments and Oceanic Structural History of the Gulf of Mexico," *Journal of Geophysical Research*, Vol. 67, June 1962, p. 25-26.

[11]E. Potter and F. J. Pettijohn: *Paleocurrents and Basin Analysis* (Academic Press, 1963). A reviewer of this book in a recent issue of *American Scientist* summaries the author's approach thus: "Potter and Pettijohn have focused attention on ancient rocks and present forcefully the point of view that most sedimentary structures are better understood by careful observation of ancient rather than of modern sediments. In this spirit they have emphasized the usefulness of structures for the determination of paleocurrents and have given relatively little consideration to fundamental fluid mechanics by which the structures are produced. In writing this book, then, they have had the approach of the historical geologist rather than that of the student of any particular set of sedimentary processes."