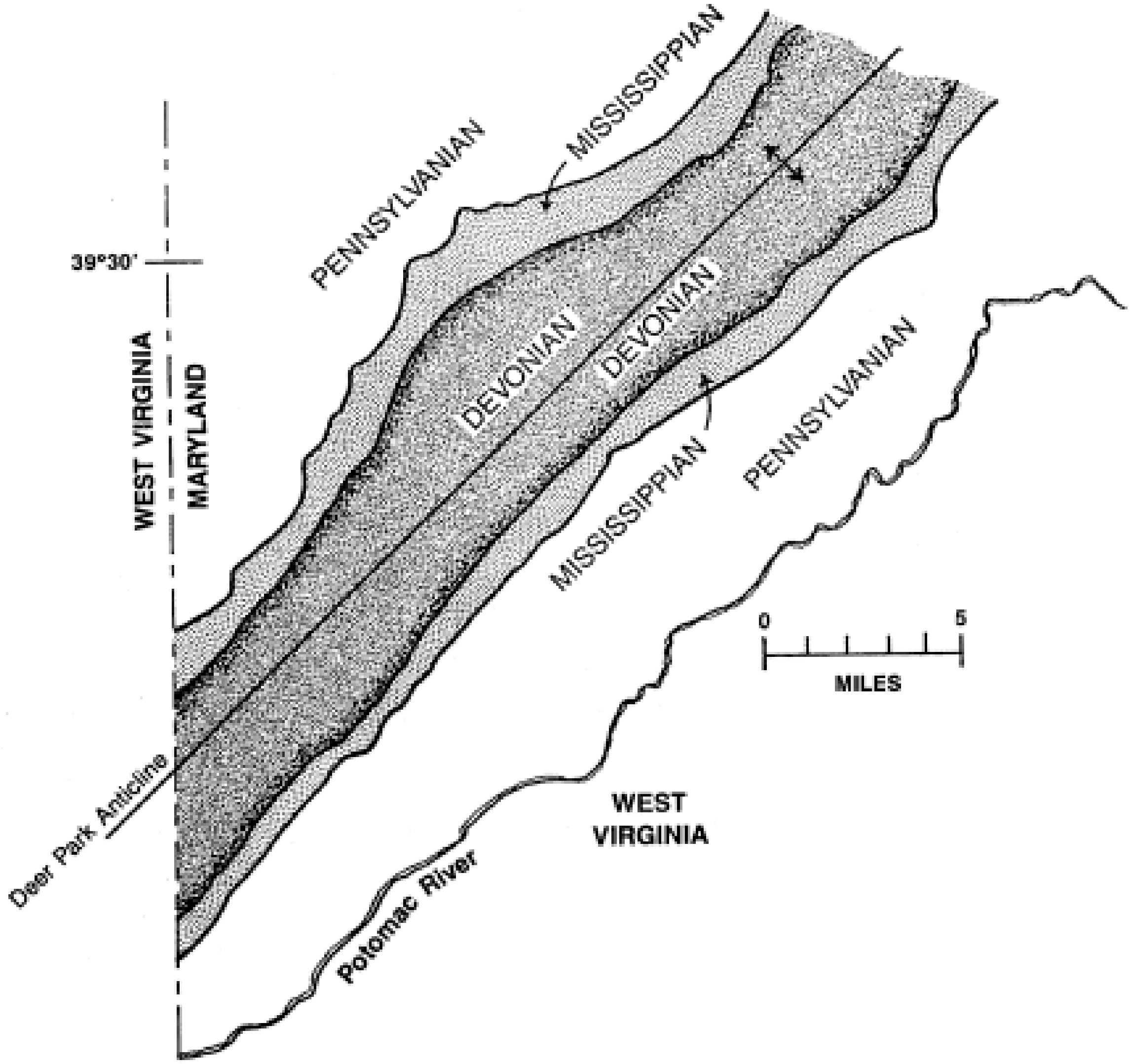

Daniel E. Wonderly

NEGLECT OF GEOLOGIC DATA: Sedimentary Strata Compared with Young-Earth Creationist Writings

NEGLECT OF GEOLOGIC DATA

Sedimentary Strata Compared with Young-Earth Creationist Writings

Daniel E. Wonderly

(For background of author, see last page)

To the reader: In keeping with the purpose of this book, it is necessary that the title be somewhat negative in character. However, you will find that most of the chapters contain large sections of *positive* information on various aspects of the earth's sedimentary cover.

Interdisciplinary Biblical Research Institute

Hatfield, Pennsylvania

NEGLECT OF GEOLOGIC DATA:
Sedimentary Strata Compared with Young-Earth Creationist Writings

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Cover: Geologic map of the westernmost county of Maryland, showing that a broad, very thick area of the Mississippian and Pennsylvanian (younger) rock systems has been worn off by extended erosion. For additional explanation, see pp. 57-60.
Cover design by James I. Newman.

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INTRODUCTION TO THE ELECTRONIC EDITION

In 1977, Daniel E. (Dan) Wonderly published *God's Time – Records in Ancient Sediment* through Crystal Press, Flint, Michigan. This was followed in 1987 by *Neglect of Geologic Data: Sedimentary Strata Compared with Young-Earth Creationist Writings*, published by Interdisciplinary Biblical Research Institute (IBRI), Hatfield, Pennsylvania. When IBRI reprinted Neglect in 1993 ("typeset, with stylistic changes"), Dan included this note:

> October 1997
>
> This new printing was slightly impaired as to its content by one of the IBRI editors who reworded about one-half of the sentences in most of the chapters, so as to make the book more readable for seminary students. Most of the essentials were retained in the new printing, but that printing cannot be regarded as having the same careful attention to all details which I used for the original.
>
> Because of the above mentioned changes of wording, and of the changes of format, the page numbers of this second printing are not the same as in the original.

The 1993 printing was used in making the files for this electronic version, primarily because IBRI graciously provided a CD copy, making it unnecessary to do an OCR conversion from the printed pages, so Dan's disclaimer should apply to it, as well. I must confess that I, too, have done some minor editing, although I did not make any significant changes and did not change anything enough to alter what Dan intended to say. Indeed, Dan's distinctive style is still there. The pagination likely does not match either of the printed editions.

Dan went to meet his Savior on December 3, 2004. I appreciate that I was able to work with him and get his permission to prepare this edition, but I regret that he did not live to see it.

Ted Smith deserves credit for converting the material to PDF format and Terry Gray for uploading it to the ASA website.

Kenneth J. Van Dellen
August 31, 2005

ACKNOWLEDGEMENTS

I want to express my appreciation particularly to Dr. George W. Andrews, an invertebrate paleontologist employed by the U.S. Geological Survey, and to Dr. Stephen O. Moshier, a carbonate sedimentologist who is an Assistant Professor of Geology in the University of Kentucky. George Andrews supplied helpful guidance and checked the parts related most closely to paleontology, and Stephen Moshier thoroughly checked practically the entire manuscript, making many specific suggestions which were appreciated and used.

Both Dr. Andrews and Dr. Moshier have been closely involved in the work of the Inter-Varsity Christian Fellowship, in addition to their professional work in the earth sciences. Before joining the faculty of the University of Kentucky, Dr. Moshier was extensively involved in the Applied Carbonate Research Program of Louisiana State University after having served as a petroleum geologist in the Mobil Oil Corporation for three years. He has now received his Ph. D. degree in geology from Louisiana State University. His dissertation was on one phase of carbonate petrology.

I also wish to express special appreciation to the following: Dr. Robert C. Newman of Biblical Theological Seminary for many useful suggestions; Dr. Edwin Myers for his willingness to allow extensive use of his thesis in the early pages of this work; my wife Edna for her constant interest in and help with this project; and SPCK/Triangle Books, of London, for their permission to quote the extended section from Alan Hayward's *Creation and Evolution: The Facts and the Fallacies*, 1985, used in the note 3 of chapter 2 of this book.

D. E. Wonderly

FOREWORD

For nearly two centuries now Christians have been debating the age of the earth. Is it merely some few thousand years old, as the Bible seems to tell us? Or is it some billions, as science seems to indicate?

Some have used this conflict to cast doubt on Scripture; others have come to view modern science with suspicion. Among evangelical and fundamental Christians in particular, the debate has been especially sharp. Charges of compromise with evolutionism or of obscurantism have frequently been flung back and forth by proponents of young and old earth, creating more heat than light, and raising emotions when careful consideration of methodology and evidence would have been more appropriate.

How are we to handle the biblical and scientific data? If we believe in the inerrancy of Scripture (as do the author and myself), does it follow that we must reject any scientific evidence that points to an old earth? We think not. And in this we are joined by many evangelical and fundamental leaders past and present who are old-earth creationists.

Are we just being concessive or compromising with evolution? No, we are recognizing that the Bible itself teaches that the world around us is a revelation from God (e.g., Ps. 19:1-4; Rom. 1:20). Therefore the evidence regarding origins which God's created world provides is to be used with Scripture in constructing a proper view of how God made all things.

In this endeavor, we wish to avoid two errors. The one is to take the simplest model which science proposes for origins and force the Bible to conform; the other is to take the simplest model which biblical interpreters propose and force the scientific data to conform. If indeed both God's word and God's world are his revelation to us, then both must be used together to construct an accurate model of origins. This is just the same as the procedure of harmonization used by Bible believers in reconciling Gospel passages which narrate the same event.

But is this not to deny the reformation principle of *sola scriptura*? No, it is not. Biblical scholars, including those who formulated the *sola scriptura* principle, regularly use extrabiblical information from grammar and history to help understand Scripture, and this sometimes leads them to propose a meaning for a passage which would not occur to someone unfamiliar with such outside sources. If we are correct that God's world is also his revelation to us, there is all the more reason to use such evidence in understanding what God has done in creation.

Of course, it does not follow from this that the majority view among scientists on some point is necessarily the truth; but neither does this follow for biblical interpreters.

The *data* of Bible and nature must be the foundation of our model-making on origins, not particular interpretations. For this reason it is all the more necessary that we know what the data are in both areas.

This is exactly what Dan Wonderly has provided for us in one specific area of origins, the scientific data relevant to the age of the earth. It is especially important that young-earth creationists be aware of this data in view of the tendency of many in the past to neglect it. It would be a serious tragedy if we were to keep people from coming to Christ because we convinced them that the Bible teaches a young earth while they remained convinced that the earth is actually quite old.

But doesn't the Bible expressly teach that the earth is only a few thousand years old? No, it doesn't. A foreword such as this is not the place for a detailed response. I have written on the subject in *Genesis One and the Origin of the Earth* (Inter-Varsity, 1977; reprinted IBRI, 1991) and in an article "The Evidence of Cosmology" in *Evidence for Faith* edited by John Warwick Montgomery (Probe/Word, 1991). Suffice it to note here that the Bible nowhere gives an explicit summation of the time from creation to some datable event like the time of Abraham, and that the Bible provides a number of hints pointing to an old earth. We believe in a relatively recent creation of man, and in a special creation of many types of plants and animals prior to the creation of Adam and Eve, but we cannot find definite statements in the Bible concerning when the earth was created.

But, if the earth really is old, why didn't God say more about it in the Bible? This situation is just like that which occurs frequently in Gospel harmonization. If there really were two demoniacs at Gadara (Matt. 8:28-34), why didn't God mention it in the parallel accounts in Mark and Luke? In both cases, I answer, "I don't know why God did what he did, but I don't explain away the evidence in either case." Why then should we object if only one of God's two parallel accounts of creation found in general and special revelation contains specific information pointing to great age?

There is a tendency abroad among Bible believers which we need to recognize lest it lead us into the sin of Job's comforters. These pious men, not being aware of certain data to which Job had access, took the easy way out and charged Job with fearsome sin in order to make it easier for them to defend God. But God himself was not pleased with them, and eventually shamed them by having Job intercede for them. In the same way, many Christians have said, "We will play it safe and use the simplest possible explanation of Genesis one." But since God has given us additional information concerning the creation, are we not being irresponsible (like Job's friends) if we formulate our own views without taking into account this other data God has made available to us? In all of our endeavors in this fallen world, we must seek the truth with all of our strength and continually recognize our need to depend on God for guidance in interpreting his revelation.

Dan Wonderly has provided us with important evidence in this book to help us do just that. May the Lord guide you as you read.

Dr. Robert C. Newman
Professor of New Testament,
Biblical Theological Seminary
Director, Interdisciplinary Biblical
Research Institute

LIST OF FIGURES

INTRODUCTION

An increasing number of capable evangelical scientists now find themselves in a difficult position because of the attractiveness of that popular creationist literature which espouses a young earth. For more than a decade this literature has been promoted by a large number of evangelical ministers and educators who are unaware that it represents a tragic neglect of careful and honest geologic research. While many young-earth creationist authors have presented important principles regarding the truth of special creation, at the same time they have displayed a very poor understanding of terrestrial geology. This book is intended to deal with this defect in the area of the earth's sedimentary cover.

A great many evangelicals now rely on the published works of prominent young-earth leaders who are aware of only minor amounts of data relating to some of the subjects with which they deal. This creates an embarrassing problem. On the one hand these leaders have provided us with some excellent and well-founded refutations of the theories of abiogenesis and macroevolution, but on the other hand their comments about the geologic nature of the earth are characterized by many deficiencies. The immense amount of non-radiometric data which indicates long periods of time prior to the creation of man is almost totally neglected by these creationist authors. They suppose that most geologic research reports contain attempts to support evolutionary theory, and thus avoid them. However, there are many, many geologic publications, both old and new, which show no detectable evolutionary purpose—as we shall see in most of the reports cited below. The creationist leaders also frequently say that those of us who recognize the evidences for long periods of time which are found in the earth's strata do so by relying on a stereotyped form of uniformitarianism left over from the 19th and early 20th centuries. This is not at all the case.

Instead of attributing great age to rock strata by applying uniformitarian theory, modern sedimentary geologists examine and evaluate the characteristics of the strata. We now have many reliable ways of determining the characteristics of rock layers and of the depositional activities which produced them. As a result we frequently find, in a given geologic formation, that some of the strata were deposited rapidly whereas other layers in the sequence were deposited very slowly. A high percentage of the methods which are used for such an analysis were unknown in the early 1960's when Whitcomb and Morris first published their ideas regarding "Flood geology." At that time many geologists did tend to rely too heavily on uniformitarian theory, but that picture has changed rapidly, beginning in the late 1950's.

Sedimentary geologists, such as those employed in the petroleum industry, now regularly look in the strata for evidences of early geological processes which indicate *either* rapid or slow deposition. For example, ancient debris flows (of sediments) are easily identifiable in the strata, and of course indicate rapid sedimentation. On the other hand, biologically cemented, fossiliferous, limestone mounds (bioherms) located in a sequence of strata indicate slow deposition. Many other processes which give definite indication of depositional rates in ancient sequences of strata are now known. Because of this the science of sedimentology has had spectacular success, especially in enhancing petroleum field research during the past two decades. This development of abilities to understand the ancient depositional processes by identifying characteristics of the strata was not for the purpose of promoting any particular theory of origins or age; so, we should feel free to use the results of sedimentological research. Thus throughout this book, the reader will find that we have not applied stereotyped uniformitarian assumptions of slow deposition, but have called attention to, and have documented examples of, geologic activities or processes of deposition, lithification, and erosion which can be definitely identified as requiring long periods of time. (For information on why it is proper to expect similarities between the ancient and the modern geologic processes, see the section, "Analogical Theory and Created Order," in Chapter 2.)

In this critique I am using some of the parts of young-earth creationist writings which are quoted in a recently written Master of Arts in Biblical Studies thesis, by Dr. Edwin Myers (1984)[1], plus additional quotations from those same works and authors, to illustrate the problem which is stated in the title of this book. At the same time, it is hoped that our dealing with these parts of extreme creationist teachings will point to some of the ways by which Christians can avoid or rise above the disadvantages which they encounter when essential data relating to geologic age is omitted.

In evaluating the problematic statements made by creationist leaders I have been careful not to use new, untested ideas or scattered bits of data. In almost every case we have cited well-established principles and sets of data which have been verified by several research scientists over a period of at least a few years.

The problem of evangelical men of science and of theology being confused as a result of a very widespread neglect of data by young-earth creationists is clearly illustrated by the above-mentioned thesis, which was written by a graduate student in Dallas Theological Seminary (Myers, 1984). His thesis is a very high quality work, with careful documentation, but it relies heavily on works by Morris and other young-earth creationists. Dr. Myers shows a wholesome interest in the subject of how the data of geology can be related to the Bible—especially to the first chapter of Genesis—and at the same time not impinge upon the doctrine of the full inspiration of the Holy Scriptures. His writing shows careful thought and an appreciation for the importance of being objective.

Myers has made a genuine attempt to "give a fair hearing to" some of the writings of conventional geologists as well as to young-earth authors. However, throughout the thesis he shows a preference for the latter. On p. 43 he begins to cite specific parts of

---

[1]Before taking his graduate work in theology Dr. Myers was employed in the fields of physics and geophysics with the Shell Oil Company for several years. He holds a Ph.D. in physics.

writings which give a “Flood geology” explanation of the origin of the earth’s sedimentary cover, and which deny that the sedimentary strata are filled with structures and inclusions which reveal slow, natural deposition. He then quotes from Henry Morris what he (Myers) feels is a fair summary of the “Flood geology” claim that most of the sedimentary cover of the earth “was deposited rapidly and quasicontinuously.” Myers gives the quotation as follows:

> 1. Each stratum must have been formed rapidly, since it represents a constant set of hydraulic factors which cannot remain constant very long.
>
> 2. Each succeeding stratum in a [rock] formation must have followed rapidly after its preceding stratum, since its surface irregularities have not been truncated by erosion.
>
> 3. Therefore the entire formation must have been formed continuously and rapidly. . . .
>
> 4. . . . if [the formation] is traced out laterally far enough, it will eventually grade imperceptibly into another formation, which therefore succeeds it continuously and rapidly without a time break at that point.
>
> 5. The same reasoning will show that the strata of the second formation were also formed rapidly and continuously, and so on to a third formation somewhere succeeding that one.
>
> 6. Thus, stratum-by-stratum and formation-by-formation, one may proceed through the entire geologic column, proving the whole column to have been formed rapidly and continuously. (Myers, 1984, p. 43-44; quoted from Morris, *Scientific Creationism* [General Edition], Creation-Life Publishers, 1974, p. 115-116).

CHAPTER 1

ANCIENT EROSION, FORMATIONS*[2], AND DEPOSITION OF STRATA

Christian authors have many times attempted to visualize and understand the nature of the earth's sedimentary cover. Just what do the rock layers (strata) which we see in road cuts and on the sides of mountains represent? How and when were they formed, and what changes have they undergone in the past? Have some of the layers been worn away and replaced by other rock layers at a later time? In the list of six statements concerning rock strata, quoted above from the book *Scientific Creationism*, Dr. Morris gives a hydraulic engineer's conception of what the answers to some of these questions might be. He recognizes the fact that water plays an important part in the deposition of some sediments, but neither his list nor the comments which follow it in the book take into account the many principles of deposition and rock formation which are now known as a result of careful geologic research. Many distinct *processes* of sediment production and accumulation, rock lithification, and erosion are now known to operate on the earth in forming new parts of the layered sedimentary cover. (It is incorrect to suppose that rock formation processes are no longer operative upon the earth.) A knowledge of these processes reveals to us, as we study their marks in the strata, an entirely different picture from that of a mere amassing of great thicknesses of sediments by flood waters. For example, some strata show that they were accumulated very slowly, with the activity of marine algae day-by-day playing an important part in the process.

The first two items of the list quoted above from Morris make the claim that "hydraulic factors," which he feels can be identified in the strata, eliminate the possibility of our finding the results of erosion between strata or on the top surface of any stratum. However, on-site examinations of the strata in the field show the unmistakable marks of erosion of the upper surfaces of a good number of the strata in the sedimentary cover of the earth's continents. We refer here not to recent erosion, with which everyone is familiar, but to the marks of ancient periods of erosion which can be seen where the deep strata have been exposed by uplifting, folding, and global changes in sea level.

In the list from Morris which we are considering, he undertakes to deal with the nature of the sedimentary formations of the earth's surface and with the relation of these formations to each other. A "formation" in geologic terminology is a lithologically distinct and mappable body of rock layers, representing an important depositional episode in the

[2]Words asterisked (*), as this one is, are defined in the "Glossary of Geological Terms" at the end of this book. Each word will normally be asterisked only the first time it occurs, or at the first place where its definition is especially needed.

history of the region in which it was deposited.[3] The formation was usually deposited without large time-gaps occurring during the depositional process; i.e., usually without time gaps of a few hundred thousand years. In most parts of the United States east of the Rocky Mountains the total local sedimentary cover contains at least a dozen formations in vertical sequence, and in many areas there are 40 or more—as in the Appalachians.

In item no. 2 Morris denies the existence of truncation* and the marks of erosion *within* sedimentary rock formations. It is true that we do not usually find evidence of *extensive* ancient erosion within a formation, but we do find a very significant amount, as in the case of the carbonate hardgrounds* described below. Even longer periods of erosion occurred *between* the deposition of *formations*. That is, we find within the rock record areas where there was extensive ancient erosion of the *upper* layers of various formations before the next formations above them were added. In some cases there was even a change of slope of the depositional basin floor before the next formation was added, leaving an "angular unconformity"* of the layers in the local geological column at that location. These facts are of great significance for understanding how the sedimentary cover of the earth was produced, and we will cite several examples in the pages below. Such examples are not merely surface or near-surface features which are all on or near the same level, but are often found in vertical succession and deep in the stratigraphic column. It should surely be obvious that such erosional surfaces represent long periods of time, not only for the erosion process, but also for the cementation* of the rock layers which were eroded. This cementation requires long periods of time, as will be explained in the sections which follow. The reality of these amounts of time for cementation and erosion eliminates any possibility of the strata and formations having been "formed rapidly and continuously," as Morris states. Yet such ignorance of the dynamics of sediment deposition, burial, and lithification is common in creationist literature. Reliable information on these processes is available in abundance in the literature of sedimentary geology, and should be used. The research reports include *many* descriptions of rock cementation and of erosional boundaries which could be understood and used by creationist leaders.

In items nos. 4 through 6 Morris says that formations "grade imperceptibly" into each other, and takes that as evidence that the deposition occurred "rapidly and continuously" throughout "the entire geologic column." It is true that many formations exhibit a gradual grading or transition into the next one above, over at least some of the total areal extent of the formation. On the other hand, in many cases the boundary surfaces are very distinct. Morris makes a serious and misleading error in saying, in his final, 7th, item of the list which the Myers thesis quotes, "The merging of one formation into the next is further indicated by the well-recognized fact that there is rarely ever a clear physical

---

[3]This definition of "formation" is based on the section "Geological Mapping" in the *McGraw-Hill Encyclopedia of the Geological Sciences*, 1978, p. 295. Definitions of the term vary considerably, but in all cases a formation is a subdivision within a stratigraphic "rock system."

boundary between formations." (Morris, 1974, p. 116.)[4] A few of the many examples of clear, distinct, physical boundaries between formations here in the Central Appalachians[5] where I live are given below. Each of these is a clear example of the failure of Morris and other young-earth creationists to familiarize themselves with the sharp* contacts which exist in the strata.

1. The Tuscarora Formation (Lower Silurian) is widespread in the Central Appalachians and crops out extensively in the Valley and Ridge Province (see Figures 1 and 2). Butts (1940, p. 230) says of it, "The lower boundary [lying on the Juniata Fm] is everywhere distinct. The upper boundary is clearly marked where the lower part of the Clinton [Group]* includes ferruginous sandstone, as in the middle portion of the [Appalachian] Valley in Virginia." However, in parts of the Central Appalachians the upper surface of the Tuscarora does have some "thin transitional beds" (Chen, 1977, p. 80). Chen and many other authors refer to the well-known "sharpness of contact" of the Tuscarora Formation in Pennsylvania, Maryland, West Virginia, and Virginia. (See Reger, 1924, p. 417.) The areal* extent of the Tuscarora in these states is more than 70,000 square miles, including the subsurface parts. Approximately one third of this consists of thick beds of almost pure quartz sandstone (or quartzite, depending on the amount of metamorphosis). The thickness of this quartz or quartzite is a few hundred feet in broad areas of Pennsylvania, Maryland, and West Virginia.

2. The Clinton Group, above the Tuscarora Fm, has approximately the same areal extent as the latter, and, in the many areas where it contains the ferruginous (red) sandstone formation, the boundaries of contact with both the underlying and overlying formations are nearly always sharp and clearly defined (Chen, 1977, pp. 86, 87, 90, 91; and Reger, 1924, p. 409-413). In some areas this red sandstone rests (with a sharp contact) upon the lower formation of the Clinton Group instead of on the Tuscarora, thus producing up to four sharp-contact boundaries in vertical sequence, all within the lower part of the Silurian age strata.

3. The lower contact surface of the Bloomsburg Formation (Upper Silurian) of Pennsylvania, Maryland, and West Virginia is frequently sharp and definite over wide

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[4]This book, *Scientific Creationism*, General Edition, by Henry Morris, was republished in a slightly revised form in 1985. However, practically no change was made in the chapters related to geology and the age of the earth's sedimentary cover. In fact, the page numbers and content are the same in both the 1974 and 1985 editions for all the sections cited in this book except page 130. We consider it appropriate to cite the material from the 1974 edition because it is the work which has had the most influence on evangelical creationists during the past decade. The 1974 edition is widely known since so many copies were sold that it was reprinted ten times between 1975 and 1984.

[5]The Appalachian Highlands Region is usually recognized as being divided into three parts with respect to north to south. The Central Appalachians include the parts located in Pennsylvania, Maryland, West Virginia, and some of Virginia and New York. This designation does not affect the usual division of the Region into "provinces," such as the "Valley and Ridge Province" and the "Appalachian Plateau Province."

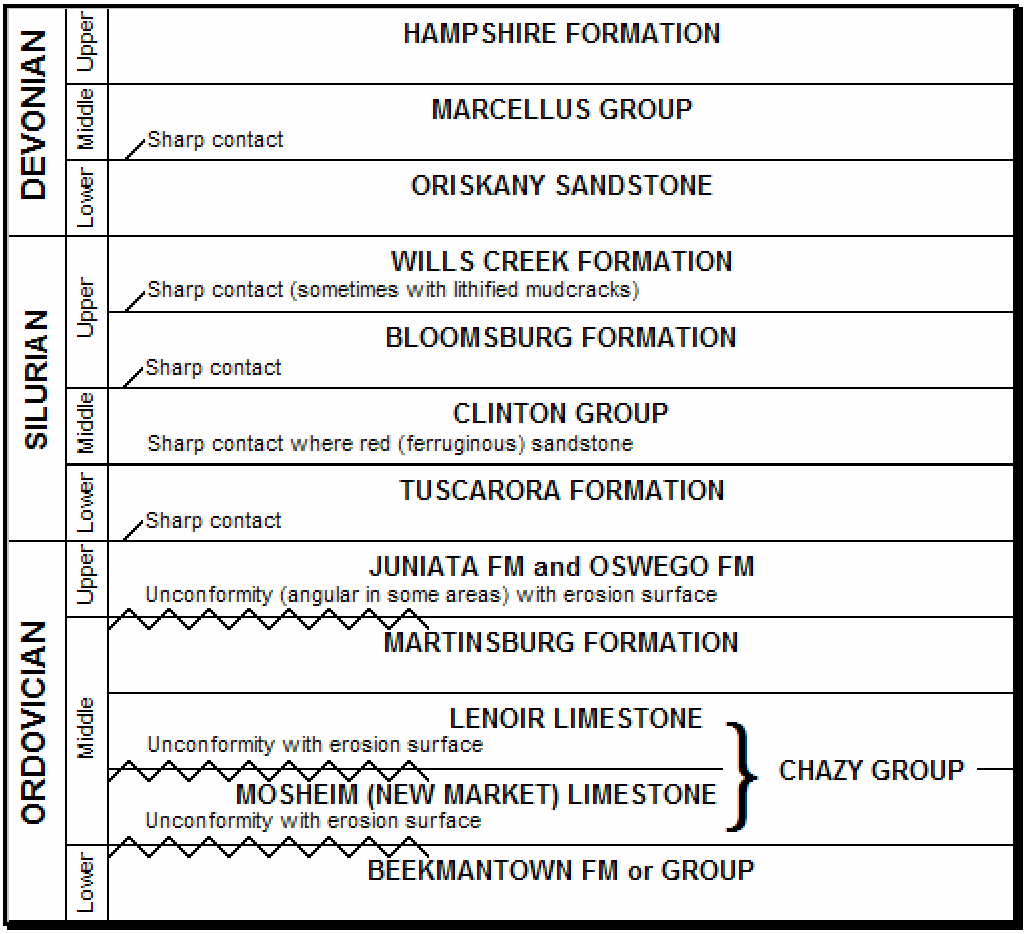


Figure 1. Some Well-Known Sharp-Contact Surfaces and Erosional Unconformities in the Central Appalachians. (These are discussed on pp. 19-20 and 31-38.) This figure shows only those formations, in each system, which are discussed in this book. Compare Figure 4, which shows parts of the Mississippian and Pennsylvanian rock systems which lie above the Devonian system.

areas (Chen, 1977, p. 92; Reger, 1924, pp. 389, 394; Hoskins, 1961, pp. 26ff). Also, the contact of the upper surface of the Bloomsburg with the Wills Creek Formation is sharp, at least in northeastern West Virginia. Not only this, but there was such a change of environment that desiccating conditions developed and persisted for a considerable time before the Wills Creek Formation could be added. This is evident from the "numerous mud-cracks" at this level. (Reger, 1924, p. 389)

4. The Oriskany Sandstone (formation, Lower Devonian), which covers a broad areal extent in West Virginia, Maryland, Pennsylvania, and New York, is well known for its sharp formational boundaries, described in oil and gas geology publications and elsewhere. The Oriskany Sandstone is deep in the subsurface of most of West Virginia, but in the eastern, uplifted mountainous sections it crops out in many places. The usual types of exposure are described by Reger:

> At its base the group herein classified under the general name Marcellus rests upon the coarse and massive Oriskany Sandstone, the change from black or gray shale to sandstone being abrupt without any interbedding or transitional sandy material. In addition to the change in lithology [rock type] there is a corresponding difference in fauna,* as shown by lists published in chapter XXI. Both of these factors indicate a considerable unconformity . . . (Reger, 1924, p. 317).

Examples of sharp contacts between formations, and also between "members"* of formations, are so abundant that the authors of works on stratigraphy usually do not even bother to mention them—so we will not cite any more here. However, in closing this section we would remind our readers that in at least most cases of sharp-contact surfaces, the lower formation of the two had to be significantly lithified before the next was added, in order for the boundary to be distinct. We must therefore conclude that the rock strata do not offer any support for the hypothesis of rapid and continuous deposition which is promoted in young-earth creationist literature. In each case mentioned above—and in at least most cases which are known—there is every indication that the lithification* was by the normal, slow cementation processes (which are described in the section "Neglect of Data Concerning Rock Lithification," later in this book).

It is also helpful to remember that there are a multitude of examples of surfaces *within* some kinds of formations which show that there were significant periods of exposure of the rock surface before further deposition took place. There are, of course, the erosion surfaces mentioned above, but there are also other time-indicating surface types buried in many local* sedimentary columns. Polygonal mud-crack surfaces are one such type. In these, the fine sediment of a mud flat along a seacoast dries out until the mud shrinks and is broken into polygonal blocks of from several centimeters to more than a meter in diameter. Later the entire area is buried by another layer of sediment (usually during a storm or tsunami*), and thus is preserved.

Very often, in both recent and ancient strata, such polygonal mud-crack surfaces contain the remains of thick mats of algal* growth. The algae help to bind the mud together, holding the shrunken blocks in their original shape until lithification processes can begin. This process of polygonal block formation has been observed on *many* seacoasts today, as described in such works as Ginsburg (1975). Bathurst (1975, pp. 202-204) gives a description of how such polygons form in some places on the shores of the Persian Gulf. Algal-mat, polygonal blocks, preserved along with fossilized remnants of the algal mats,* are found in ancient rock formations in various parts of the world. A vivid example of such preservation is shown in James (1979), figure 8. It is a photograph of an area of Upper Cambrian polygonal blocks from the East Arm Formation at the edge of Bonne Bay, Newfoundland, in the Northern Appalachians. In this formation the blocks were preserved with their edges noticeably curled up, "likely because the algal mats in the polygons shrivelled upon exposure and drying out" (caption of James' figure 8, p. 113).

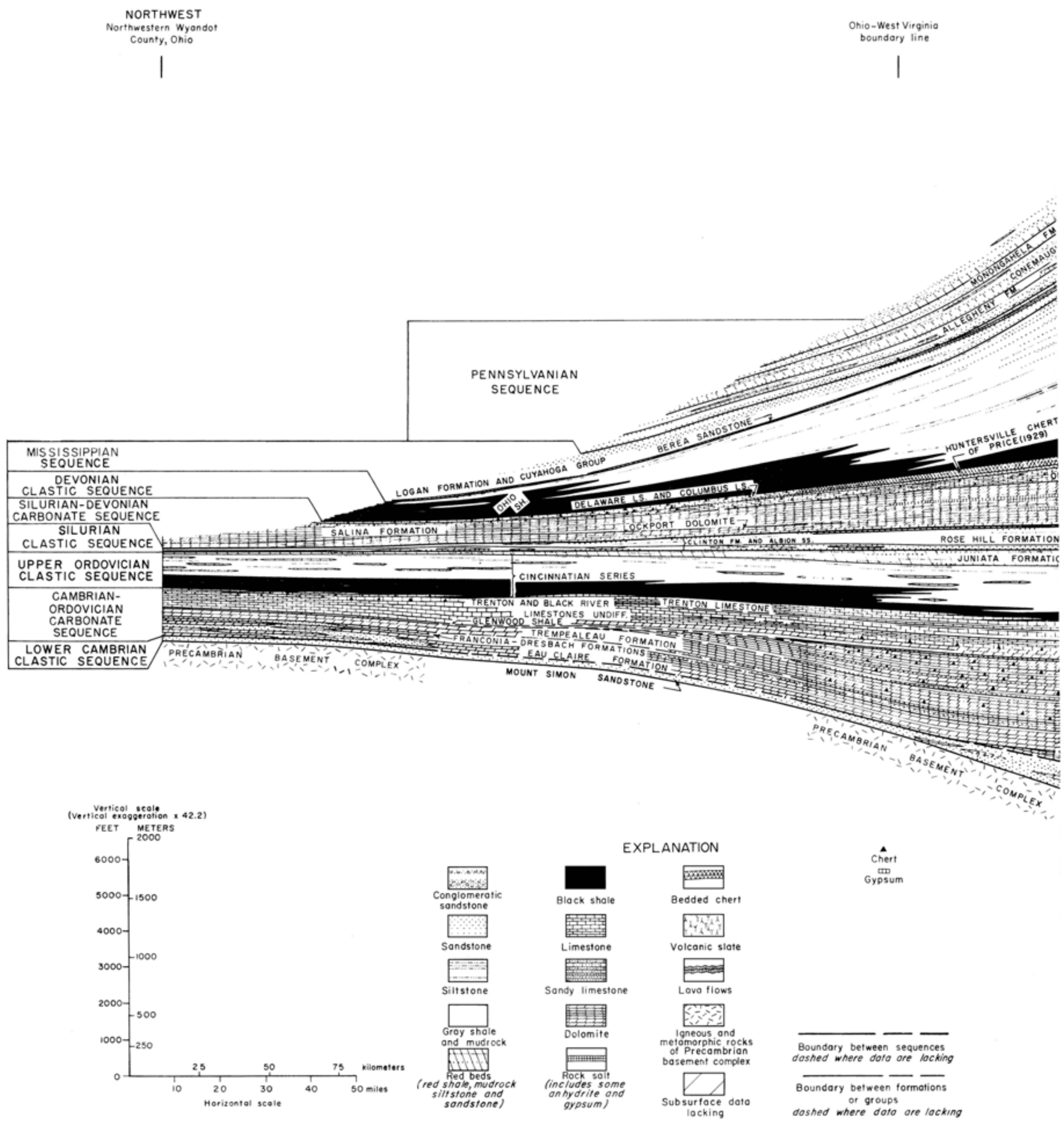
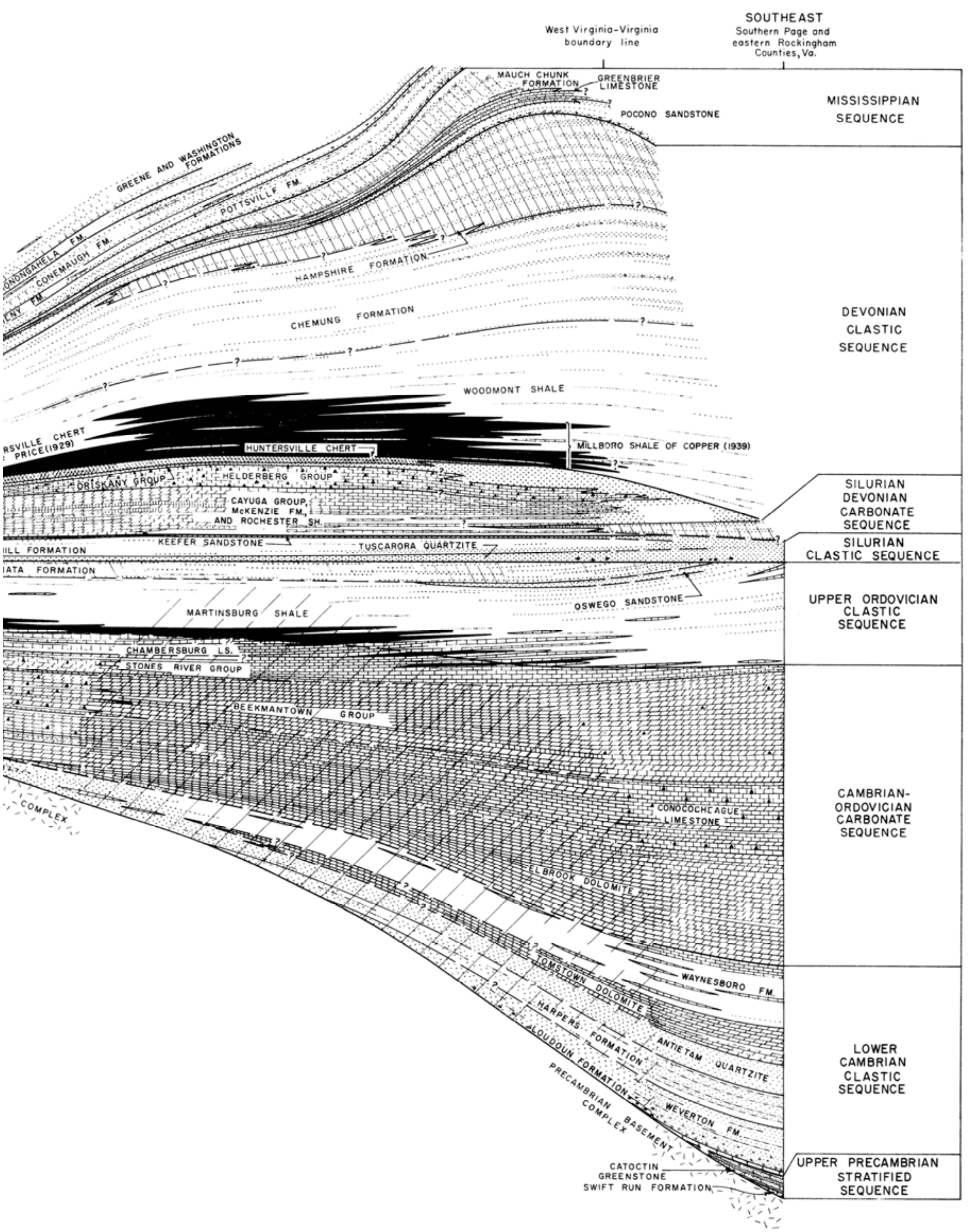


Figure 2. A Vertical-Section Diagram Through the Central Part of the Appalachian Highland Region. This diagram extends approximately west-to-east, beginning in Ohio and ending in western Virginia. In this “vertical map” we get a summary, perpendicular view of what the geological strata of this area would look like if one could view all of them at the same time, from the south looking northward. Note the thickness scale at the left of the diagram and the labeling of the geological Periods and Systems at each edge of the figure. All of the systems from Precambrian up through Pennsylvanian are present, and in the expected order, in most of West Virginia. These have been verified in this geographic area by drilling records from thousands of deep wells, and also by many detailed seismic surveys. Most of the labels within the diagram itself are the names of geologic formations which make up the various rock systems. From *Studies of Appalachian*



Geology: Central and Southern, by George W. Fisher, F. J. Pettijohn, J. C. Reed, Jr., and Kenneth N. Weaver, eds. This diagram is Figure 2 of the book, and is entitled “Stratigraphic relations of the basin fill.” Copyright 1970 by John Wiley and Sons, Inc., and reprinted by their permission.

Preserved, polygonal-block strata of this type are sometimes found in vertically repeating sequences, showing that there were climatic cycles which brought about a repetition of the desiccative conditions, with a considerable period of time in between.

Some Reasons for the Grading of Various Formations into Those Adjacent to Them

As we observe the edges of two adjoining formations which lie one above the other—as seen in the vertical walls of a canyon or road cut—we often find that the sediments of one grade into those of the other. (By this we mean that there is an intermingling of some of the sedimentary rock particles of one formation with those of the formation which lies either above or below it.) However, this does *not* mean that a given sediment layer above was necessarily always laid down soon after the one below it—as Morris asserts to have been the case. The following paragraphs cite some of the ways by which a grading of sediments into each other can occur without there being a rapid and continuous deposition of the layers one after the other, as Morris postulates.

There are several depositional conditions which make transitional contacts between strata possible. One of these is the common circumstance in which sediments are deposited, partially lithified, and then eroded in such a way that the sediment particles which are being removed from the first layer are incorporated into a second layer which begins to cover the area. Thus, the upper boundary of the first layer becomes blurred or indistinct as the sediment layer above it is added. This is often a part of the natural depositional process, because the depositing of silt, sand, and gravel is always accompanied by the expenditure of considerable amounts of energy by moving water or wind. Since firm cementation of rock particles usually requires at least several hundreds of years, the exposed surface of a given deposit is easily disturbed and partially broken up by wave action when a new depositional cycle begins. This process is frequently observed on arid seacoasts today, where components of an earlier deposit become incorporated into a new layer. In this way a gradational or transitional effect is produced.

In any depositional basin where there has been a return of the sea and a resumption of normal deposition, mixing actions such as this are more vigorous and extensive at the edges of the basin than in the parts where the water is deeper. This factor is sometimes sufficient to account for the more extensive grading of a given formation at its edges, into the overlying formation, which Morris mentioned in item no. 4. It is only normal that the wave and water-current actions should scour the bottom more vigorously at the edges of the basin (where the waves break) than out where the water is deep.

Of course in many cases sediment deposition was not resumed until the upper surface of the deposit had become firmly cemented. For example, a formation may have been deposited as a carbonate* beach sequence which prograded out onto the shelf of the basin, moving the shoreline several miles seaward, much like a delta builds out at a river's mouth. If deposition was followed by a temporary drop in sea level, such as during an ice age, the deposit would be "left high and dry." When the sea level rises again, the deposit might get covered by subsequent beach deposits. This is what we see in cyclic carbonate deposits like the Conococheague Formation of western Maryland. In such situations we will find either (1) a sharply defined contrast or "contact" between the two formations, or (2) the marks of erosion on the hard rock surface at the top of the first formation accompanied by a small amount of mixing of the old components with the new. This principle is evident in the examples of erosion which we will cite in the succeeding pages.

A very helpful, and seemingly valid, model* which is invoked by most sedimentary geologists for explaining the grading of sequences of strata into each other in many parts of the world is given in the Appendix of this book. This model not only offers an explanation for the grading of many formations into each other, but also includes a very reasonable solution for the problem of why stratigraphic time boundaries often cut across formational boundaries. (The latter is a phenomenon which Morris has misunderstood—as in Morris and Parker, 1982, pp. 203-205.)

Some Examples of Ancient Erosion in the Sedimentary Cover of the Earth

The results of erosion found between the sedimentary strata at various levels in many local* sedimentary columns in the United States, Canada, Europe, and Australia are so well known and thoroughly described in the literature of geologic research that it seems almost unnecessary to cite examples. But since large numbers of creationists seem to be unaware of them, we want to give several examples. Each of these is an undeniable indication of the passage of at least many years of time for the erosion of a layer of rock before the next layer above it was added. We will concentrate on parts of the sedimentary cover which are generally thought of by young-earth leaders as having been formed during the Biblical Flood and which are in locations where they obviously could not have been gradually deposited and eroded in post-Flood times.[6]

1. Carbonate Hardground Surfaces

In many of the carbonate (limestone or dolostone*) rock layers of the world we find "hardground surfaces." In such cases the layers of rock have visible characteristics on their upper surfaces which show that each such surface was exposed to at least some scouring, dissolution, or other alteration after it was lithified and *before* the succeeding layer of limestone was added above it.

Since these hardground layers are marine* in origin, many of them have an abundance of marine fossil shells embedded in the limestone. Commonly, in such a layer,

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[6]Let me make it clear here that I am not attempting to support all the time that is usually suggested for the composite geologic column. But we do need to recognize the amounts of time which actually were required for producing the types and numbers of layers and structures which we find in the sedimentary formations observed on the earth.

the shells which are at the upper surface are extensively eroded (truncated) so that only one half or less of the shell remains—solidly embedded in the hard limestone. Since this rock layer was lying in water while the erosion was going on, encrusting-type, lime-secreting, marine animals (such as oysters) are frequently found on the eroded surfaces. Also many of the eroded surfaces have been "bored" by sponges and other types of marine animals which bore holes in the rock by a process in which they secrete acid which dissolves the carbonate rock. The inner surfaces of these "bored" holes frequently contain the truncated remainder of *component grains** of the rock which were cleanly cut off by the animal as it advanced deeper into the rock (Bathurst, 1975, pp. 373 and 395-397; Wilkinson, et al, 1985, pp. 171-173). (See Figure 3.)

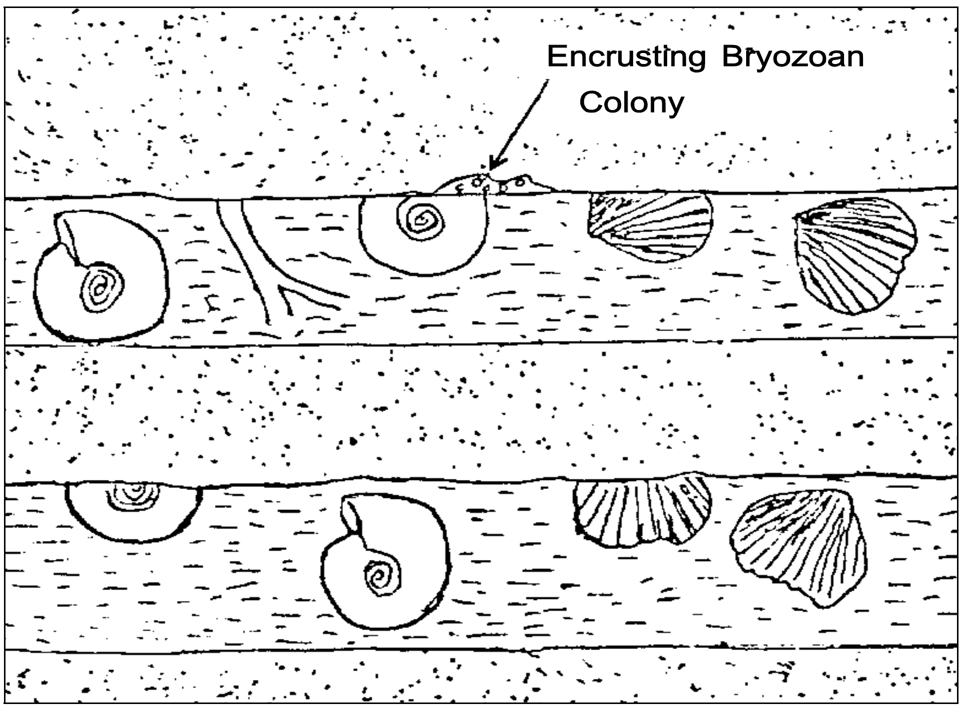

Figure 3. Diagram of a Vertical Section of Two Carbonate Hardground Layers and the Sediments Between Them. Note the shells which were cemented into the limestone surface on the sea floor and then eroded off before the next layer of sediment was added. On the upper hardground surface a colony of bryozoans is building a calcium carbonate deposit over the remainder of a shell which was earlier subjected to erosion. This is typical of the incrustation found on ancient carbonate hardground surfaces in many parts of the world.

It is very evident that all of these processes of change in the upper surface of the layer required several years of time. And one must not forget that an extended period of time was required for cementation of the carbonate grains into the form of a hard layer *before* these processes of erosion, encrusting, and boring could begin. In the rock record where vertically repeating, successive layers of such hardgrounds are found, it is obvious that a change in the environment on the sea floor eventually brought in sediments fast enough to bury and preserve the organisms which had encrusted the limestone layer. Then, after from a few centimeters to more than a meter of these loose sediments were brought in, more carbonate sediments were produced and cemented into a second hardground layer. In this way repeating successions of the alternating hardgrounds and softer intercalating sediments were built up over relatively broad areas outward from the seacoast.

Hardgrounds can be observed in limestone formations in the Appalachians and in other parts of the United States and Canada. Also, the process of hardground formation which is actually going on today has been observed and described in various parts of the world. For a long time the development of hardgrounds in modern carbonate environments of the world went unnoticed because it is a rather slow process. But now there are better methods of observation, and so the rates of growth, boring and erosion have been measured in a good number of shallow-water marine areas (Bathurst, 1975, pp. 371, 374-375, 381-382; 1983, pp. 355-359).

Some of the best examples of older carbonate hardgrounds which have been formed in ancient rock systems on the continents are the following. (1) A formation of Jurassic limestones of Lorraine in France containing 30 to 40 hardgrounds, with many encrusting and boring organisms represented (Jaanusson, 1961, p. 228; compare Bathurst, 1975, p. 396, Fürsich, 1979, p. 27, and Purser, 1969). Fürsich (1979, pp. 3-9) lists over 30 locations in Europe where Jurassic hardgrounds are located, and gives references for the descriptions of them. (2) A Devonian formation in Russia in which hardgrounds with “a rich epifauna* ... occur at many different levels” (Jaanusson, 1961, p. 227). (3) An Ordovician formation in Sweden, slightly over 6 meters thick, containing a succession of fossiliferous hardgrounds, with the beds being from 2 to 20 cm thick, with marl or shale between them (Bathurst, 1975, pp. 397-399). (4) Hardgrounds of Middle Ordovician limestone sequences in southwest Virginia (Read and Grover, 1977, pp. 961-963). These exhibit encrustation by bottom-dwelling marine organisms such as bryozoans. Also most of the hardground surfaces are impregnated by brown-to-black opaque minerals which obviously accumulated on them by precipitation *before* they were covered over by the next succeeding layer. In this Ordovician limestone the hardgrounds “are commonly multiple, several occurring within one meter [of thickness]” (Read and Grover, 1977, p. 962). (5) An excellent example of a Jurassic carbonate hardground sequence here in the United States which has been carefully described and studied in detail is that found in the Sundance Formation of southeastern Wyoming. The main description of the stratigraphy, lateral distribution, and general petrology of this hardground sequence is by Andersson (1979). A thorough study of the petrology, inferred depositional environments, and cement types of this formation has recently been made by Wilkinson, Smith, and Lohmann (1985). This latter study carefully investigated the cement crystals which were formed during early lithification (i.e., before erosion and burial) of at least nine of the hardgrounds in the vertical sequence found in this part of Wyoming. One particular layer of these hardgrounds was identified at several widely separated sites covering an area of approximately three thousand square miles.

These hardgrounds in Wyoming are composed mainly of identifiable biogenic* particles and are an unusually good example of how such layers were bored and encrusted after having been well lithified by the "early cement." Many of the borings made clean-cut truncations, not only of the well-formed grains of this early carbonate cement, but also of the ooids* and fragments of fossils which had been cemented into the layer. During this time when borings and encrustations were being made, erosional processes in varying degrees affected the surface of the hardground. And in the case of some units in this sequence, the hardground layer itself was broken up and the pieces moved around on the Jurassic sea floor before burial by additional sediments. (Wilkinson et al, 1985, pp. 170-171). The hardgrounds which were not broken up show just the usual amounts of alteration of the encrusted surfaces which occurred before burial. After burial, pore-filling carbonate cement filled in most of the holes and other cavities which had been made by boring endolithic* fauna and also formed "late cement" layers over many of the shells of animals which had encrusted the hardground layers. Finally, the entire formation was buried so deeply that the results of compaction are now evident in the distortion of some of the microlayers of cement crystals in the hardgrounds. (Wilkinson et al, p. 178). Wilkinson and his colleagues summarize these events as follows:

> Macroscopic features demonstrate that sandstone and limestone units [layers or sets of layers] were repeatedly lithified during deposition of the Sundance Formation. Boring by endolithic[*] mollusks as well as encrustation by oysters and serpulid worms requires the formation of well-lithified substrates prior to the deposition of overlying units. Rounding of sandstone and limestone clasts[*] further attests to the repeated development of well-indurated[*] units during deposition. (p. 179).

Thus, in many parts of the earth the carbonate hardgrounds testify to long periods of time. These are either unknown or unrecognized by recent-creationist authors.

2. Some Ancient Erosional Features of the Grand Canyon of Arizona

One of the areas in which the eroded upper surfaces of ancient buried strata can be readily observed is in the Grand Canyon. On the upper surface of the well-known Redwall Limestone Formation of this canyon there are extensive, ancient erosional features left from the period of time (end of the Mississippian) when this great area of limestone was exposed to weathering. Since this is limestone[7] it was prone to the development of caves, caverns, and sinkholes during the time it was exposed, before the rock formations above it were deposited. These erosional features are characteristic of *karst* topography* which is even now in the process of development in parts of the world where limestone formations are at or very near the surface. Such areas of karst development are common in parts of Kentucky and Virginia.

[7]The word "limestone" is here used in the *general* sense, which includes both true limestone and dolostone, a magnesium limestone.

Before describing the karst development of the upper part of the Redwall Limestone we should mention that there are definite erosion surfaces both at the base of this formation and farther up, about one-half way to the top. The definite unconformity at the base of this formation, where it rests on the Devonian Temple Butte Limestone, was noted as early as 1880 by Walcott. Since that time a good number of geologists have studied this contact and have identified various kinds of erosional features there. McKee and Gutschick carried out very extensive and careful research of the nature and depositional conditions of the entire Redwall Limestone formation. They describe the erosional basal contact of the formation which we have just mentioned, and also include eight to-scale diagrams of some of these very distinct types of erosional structures which they observed (McKee and Gutschick, 1969, pp. 15-17, 24, 614-619, 625-628). Their study also revealed similar, distinct features of erosion at a higher level in the formation between the Thunder Springs Member* and the Moony Falls Member which rests upon it. McKee and Gutschick (1969, pp. 49-52) describe this erosional unconformity and give seven to-scale diagrams of the ancient erosional structures at this level in the Redwall Limestone which have been uncovered in Kanab Canyon, Marble Canyon, Havasu Canyon, and other sites. (The reader should understand that the *uncovering* of the ancient erosional features has been accomplished by modern erosional processes.)

The extensive eroded surface at the top of the Redwall Formation is even more spectacular than those which we have just been discussing, and was more extensively studied and described by McKee and Gutschick as well as other geologists. The karst-topography cavities and channels of this eroded surface, which we mentioned above, extend far back away from the canyon itself. Just as with other erosion surfaces at the lower levels, more cavities become exposed as the canyon is progressively worn further back into its banks. (The Redwall Formation extends for over 175 miles north to south and more than 275 miles east to west, being known from many drilling records and seismic surveys.*)

It is evident that the original period of erosion on the top of the Redwall Formation was at least several thousand years in length, as some of the solution cavities which formed in the already well-cemented limestone are large and complex. Another clear evidence of this is the abrupt blocky knolls which were left standing on the ancient limestone landscape and later buried by the addition of the Supai Formation. These knolls (or small mesas) are periodically exposed as the canyon wall widens. They range up to 40 feet in height and are composed of limestone which, at the time of the ancient erosion, was more resistant to weathering than that which was around it, thus withstanding the erosion process.

After the erosion of the ancient landscape had progressed to the karst-blocky-knoll stage, conditions for sediment deposition (rather than erosion) were restored, and the remaining 2,000+ feet of rock layers were added. During the early stages of this later deposition, the solution cavities of the Redwall Formation were filled in with non-marine,* clastic sediments of the Supai Formation which was being deposited above the Redwall, and the blocky knolls were buried by the same. There is a good description of these cavities and knolls in McKee and Gutschick (1969, pp. 74-85, 563-564). They have included several to-scale diagrams of the ancient erosional features which have been found uncovered at various locations at the top of the Redwall Limestone (pp. 78-81). Also included are photographs of some of these, taken in the field (pp. 94-95). There is a simplified but fairly inclusive summary of their findings on the Redwall Limestone in Wonderly (1977, pp. 140-145). The young-earth creationists' omission of information concerning the erosion surfaces of this well-known formation has misled large numbers of people into thinking that all of the Grand Canyon strata could have been formed rapidly.

We would be guilty of extreme negligence at this point if we were to fail to mention the significance of the *main body* of the Redwall Limestone formation. Here is an enormous expanse of unusually pure limestone (most of it over 98% $CaCO_3$ and $CaMg(CO_3)_2$) which has a thickness of 500 to 700 feet. It is abundantly supplied with marine* fossils—in stark contrast to the formations which lie directly above it, only two of which possess any marine fossils. Furthermore, there are many layered, *in situ** growth mats of fossilized, lime-secreting algae embedded in the rock in the normal position in which the mats grew (McKee and Gutschick, 1969, pp. 104, 554, and plate 15). No amount of speculation can produce a rational, one-year-Flood explanation for such a geologic formation. To suppose that it was precipitated* rapidly out of the ocean water is utterly unreasonable for the following reasons: (1) supersaturated* ocean water cannot contain or release so much $CaCO_3$; (2) the *fossils* obviously were not precipitated; and (3) the Flood was (according to "Flood geology") a convulsive event, not able to permit the settling of 500 feet of pure $CaCO_3$ and $CaMg(CO_3)_2$. It is also utterly unreasonable to postulate that the components of this great body of limestone were concentrated and washed into place by the Flood, because: (1) any hydraulic cataclysm which could bring about such a massive transport as this (in the short time allowed) would mix the carbonate shell materials and other grains with many foreign kinds of rock components; (2) there is no way in which *in situ* algal growth mats could develop during such a high degree of agitation; and (3) if they were somehow to develop, they and the many other delicate fossils of the formation would have been crushed by the immediate adding of the huge weight of one-half mile of sediments dumped on top of them before there was time for even the beginning of the rock cementation process.

Most creationists seem to be unaware of these and other enormous problems which make the "Flood geology" explanation of the earth's sedimentary cover completely incompatible with the large amounts of carefully collected data now available. As Christians we should all feel a solemn obligation to collect and use the available data before formulating a hard-and-fast opinion as to how the earth's crust was formed. There is an abundance of carefully collected, published data readily available for studying the

Redwall Limestone, and creationists who discuss the Grand Canyon have an obligation to use it.[8]

Those who believe that superficial, non-microscopic studies can sufficiently reveal the nature of the Redwall and other similar rock formations are like the person who might concentrate on the gross anatomy of the human skeleton while denying the validity of microscopic anatomy. It is possible to make an elaborate and high-quality study of the various bones of the human body, only describing the mechanical structure, strength, and function of each. Such a study, however, can never reveal the nature of the solid bone substance or how it was formed. Without microanatomy the student will invariably assume that bones are homogeneous, solid material, and will know nothing of the living cells (osteoblasts) which have been responsible for the production of the bone; and that all of these cells are constantly supplied with food, oxygen, and minerals by a complex microscopic network of blood vessels which permeate each cubic centimeter of bone.

Thus no amount of high-quality study of gross skeletal anatomy, or of the chemical nature of bone, can enable the student to learn how the bone was formed. If he wants to know this, he must become willing to use the information provided by microanatomy. Similarly, no amount of study of gross stratigraphy or the chemical nature of limestone layers can reveal the means by which those layers were formed. For that, one must make microscopic petrological studies to find the marks and structures left by organic growth and by the cementation processes.

3. Examples of Ancient Erosion Which Are Observable in the Appalachians

In the Central Appalachians there are from 3 to 5 miles of *thickness* of Cambrian to Pennsylvanian sedimentary layers. This is from three to five times the thickness of the Grand Canyon strata. A summary of these strata systems in the West Virginia-Maryland area is given in Figure 2. Because of the great amount of folding during mountain building, followed by extensive faulting and erosion processes, most of the formations of this great array of sedimentary systems are now exposed at various places, clear down through the Ordovician, and they can be studied where they crop out along the mountain ridges and elsewhere. The contacts of many of these formations are very often sharp and distinct, and in some places the marks of ancient erosion of the upper surface of a formation can be clearly observed when the formation above it is removed, as in a rock quarry. The observation of erosional features in this manner is possible in many parts of the world, and reference is made to them in the literature of stratigraphy and sedimentology. Yet Morris and his colleagues have neglected such features and leave their readers to suppose either that they do not exist, or that they are unimportant.

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[8]For some readily available, very helpful sources on the geology of the Grand Canyon, see the Bibliography, pp. 57-59, in *The Record of Geologic Time: A Vicarious Trip*, by Dale Nations (McGraw-Hill Concepts in Introductory Geology Series, 1975).

(a) The oldest well-known erosional level which is widespread in the Central Appalachians is that found at the top of the Beekmantown Formation or Group (Lower Ordovician, Fig. 1). This formation is composed mainly of limestone and dolostone, and extends throughout most of West Virginia, western Maryland, central and western Pennsylvania, western Virginia, and eastern Tennessee. Most of a NE-SW band of it, 100 miles wide along its eastern extent, is at least 1,500 feet in thickness, and much of it is 2,500 feet or more.[9] In much of this area the Beekmantown has been observed to have extensive erosion features on its upper surface where the overlying formations contact it. Butts (1940, pp. 119-120, 135-136, 139, and 168) refers to this great erosional unconformity as he has observed it in various counties of Virginia. Any unconformity* of this type and extent represents the passage of many years of time—probably hundreds of thousands of years—before the next layer above it was added.

The magnitude of carbonate dissolution and erosion of the previously cemented rock layers of this unconformity at the top of the Beekmantown Formation is dealt with in detail by Mussman and Read (1986). They point out that the erosional relief (vertical variation due to erosion) of this unconformity is as much as 140 meters in southwest Virginia (where it is called the "Knox Unconformity"). The erosional relief gradually decreases northward (parallel to the Appalachian mountains) to only a few meters in the northern part of Virginia (Mussman and Read, 1986, pp. 283-284). In Middle Ordovician times dissolution and erosion modified the basal strata of the unconformity—which strata are composed of limestone and dolostone—leaving various karst features, including knolls, stream channels, sinkholes, and caves. Concerning the length of time required for this, Mussman and Read state: "Given that rates of carbonate dissolution in karst terranes range from 10 to 100 mm / 1000 yr (Sweeting, 1972), from 1 to 10 m[illion] y[ears] would be necessary to form the observed unconformity relief." (1986, p. 283). There are several sedimentological and petrographic* indications that most of this dissolution occurred during periods when the previously-cemented limestone was exposed above sea level—probably during the Taconic Orogeny. For example, the preserved, ancient sinkholes and caves closely resemble many of the same found in present-day karst terrane in Florida, Tennessee, and Kentucky, and most of the Ordovician ones studied by Mussman and Read were filled with nonmarine, nonfossiliferous sediments. The authors state:

> Most Knox sinkhole fills are nonmarine. Detritus was shed from walls and roofs of cavities or was washed in from the unconformity during heavy rains. Some blocks were incipiently brecciated after collapse, possibly by impact or weathering, or by later deep burial compaction. (1986, pp. 285-286).

This is in contrast to the *marine* sinkhole fills observed in the northern part of this unconformity (northern Virginia) where the filling sediments were apparently brought in

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[9] This is shown on maps and diagrams in Chen, 1977, pp. 46-49 and 54-55.

during a Middle Ordovician marine transgression* and contain an abundance of distinctively marine fossils (Mussman and Read, 1986, p. 286).

As for the ancient caves observed in the unconformity by Mussman and Read, all of them were filled with nonmarine, nonfossilferous sediments. It is very significant that, in both the sinkholes and caves, the contact between the cavity walls and the body of sediments which had been brought in later was everywhere found to be sharp or distinct (1986, pp. 285-286 and Figs. 10 and 11). This demonstrates the fact that the limestone in which the cavities were formed had been thoroughly cemented into hard rock long before the main filling process was begun.

If one wonders how these and the other ancient karst features of the Beekmantown unconformity can be observed in the field, and why they have not all disappeared by weathering and erosion, here is the main reason: The Middle Ordovician rocks in which these features were found were buried by additional formations of rock which were added after the erosional period had ended, and so have been protected from further weathering. Because of uplifting and faulting, especially during the later orogenies, certain parts of the unconformity were exposed (and worn away) while other parts remained in positions of burial such that they are only now being exposed and worn away. These latter exposures are now observed by field studies, with their ancient, filled-in caves and sinkholes seen in various stages of exposure. Thus we have a situation very similar to that described above for the upper part of the Redwall Limestone of the Grand Canyon. In both cases, modern erosion is exposing the ancient karst features and infillings which were deeply buried by the addition of later formations added above them.

Not only is there the erosional unconformity precisely at the upper surface of the Beekmantown Formation, but on up in the next group which covers it (the Chazy or Stones River Group), another is found. Thus, Butts (1940, p. 136) says, "The quarry at Marion, Smyth County, shows a pronounced erosional unconformity [at the upper surface of the Mosheim Limestone, which lies directly on the Beekmantown]." The Mosheim Limestone is usually from 30 to 100 feet thick in Virginia, and is covered by the Lenoir Limestone (Fig. 1). In the caption of a photographic plate showing the eroded surface of the Mosheim Limestone, with the Lenoir naturally resting on it, Butts states, "Irregular contact of the Mosheim limestone (below) and the nodular Lenoir limestone. This kind of contact of the two formations has been observed at several places in the Valley [Appalachian Valley of Virginia] through a distance of several hundred miles." (Butts, 1940, p. 168). On p. 139 he says concerning this, "... the irregular contact surface of the Mosheim, caused by pre-Lenoir erosion [of the Mosheim Limestone], which resulted from pre-Lenoir emergence, indicates a considerable hiatus in some areas." (Butts, 1940). The ancient erosion marks of this and similar contact surfaces, which are observed when they are uncovered, could have been made *only* in rock that has been at least moderately well cemented. Read and Grover (1977, pp. 957-961) describe this erosional unconformity at the top of the Mosheim Limestone (now called the New Market Limestone) in more detail and name other places in Virginia where they have observed it.

(b) In the Middle Ordovician there is another well-known erosion surface at the top of the Martinsburg Formation (Fig. 1). This is described as follows in *Guidebook: 47th Annual Field Conference of Pennsylvania Geologists* (1982, p. 26):

> Above the Martinsburg [Formation] is a distinct erosion surface of Taconic age that cuts through every autochthonous unit as well as the Hamburg klippe. The Juniata and Tuscarora Formations (Stop #4) contain unmistakable terrestrial and beach deposits (Cotter, 1982), marking the return of the sea over this unconformity. This unconformity indicates uplift and erosion between late Middle ordovician and Silurian time in Pennsylvania from the Maryland state line to the Delaware Water Gap.

Regional uplift of Middle Ordovician strata caused the Martinsburg Formation to be tilted over a rather wide area, making the unconformity an angular one, before the Juniata and Tuscarora Formations were added (Guidebook, 1982, p. 30).

This angular unconformity, as it exists in the Valley and Ridge Province of eastern West Virginia, is described by Reger (1924, pp. 424, 427):

> At its base the Gray Medina [the old name for the Oswego Formation] rests upon a dark, shaly sandstone [the Martinsburg Formation] containing fossils of Ordovician age, there being a slight but clearly perceptible angular unconformity at this division-plane. In passing from this lower group up into the Gray Medina, the end of a long period of uninterrupted marine sedimentation and the beginning of another epoch of lacustrine,* estuarian,* or possibly in part continental deposition began, there being both a lithologic* and faunal unconformity...

On pp. 427-428 he adds, “the most marked feature [of this unconformity] is the utter absence of marine fossils in the Gray Medina as compared to their abundance in the Martinsburg.” Here in the Appalachians many of the formations, over very wide areal extents, show this contrast of fossilized fauna, where one formation—or even a whole, consecutive group of formations in the particular strata system—is of nonmarine origin. This is a contrast which cannot be explained in terms of the Biblical Flood. Even Henry Morris admits that in his flood model “the land sediments and waters would commingle with those of the ocean” (Morris, 1974, p. 118). But he apparently was not aware that most physiographic provinces which have sedimentary series, on all major continents, have extensive areas where we find the same sort of marine-nonmarine distinctions, involving whole formations, as we have just noted for the Appalachians. These are voluminously described in practically all sedimentary geology research journals and in encyclopedic works on regional geology, such as the U. S. Geological Survey’s Professional Paper no. 1110, *The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States* (U. S. Government Printing Office, 1979).

(c) When we go on up to the Mississippian strata System in the Central Appalachians (see Figs. 1 & 2) we find at least two definite levels of erosion surfaces. The lower one of these is at the base of the Lower Mississippian Pocono Group. Reger (1924, p. 282) observed that the Pocono in eastern West Virginia "rests unconformably on the oxidized red shales of the Catskill Series of the Devonian Period, a long lapse of time and wide exposure to aerial and erosive action being apparent." (See Fig. 4).

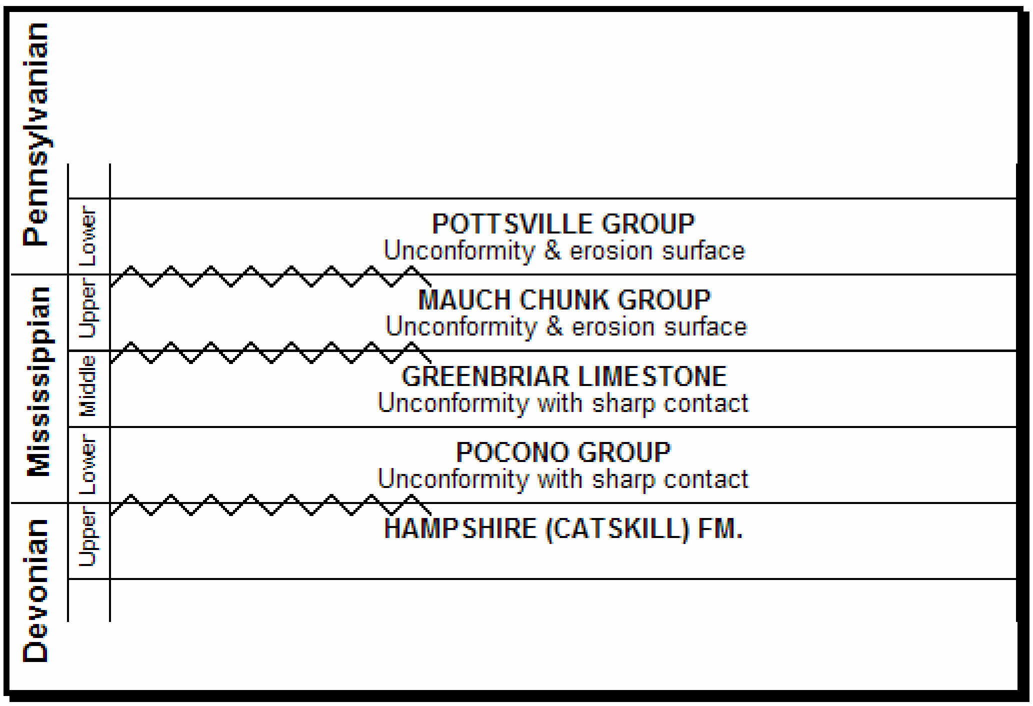

Figure 4. A Sequence of Unconformities and Ancient, Buried, Erosion Surfaces in the Mississippian and Lower Pennsylvanian Rock Systems of West Virginia.

(d) In the Middle Mississippian is a rather thick deposit of highly fossiliferous, definitely-marine limestone. It is called the Greenbrier Limestone (Fig. 4) and underlies approximately 75% of the state of West Virginia, and parts of Pennsylvania, Maryland, Virginia, Kentucky, and Ohio (Flowers, 1956, p. 3). In the southernmost counties of West Virginia this formation is from 500 to 1200 feet in thickness, but farther north and west it tapers to between 100 and 200 feet, and occasionally less (Flowers, 1956, pp. 14-15). A considerable percentage of the thickness in the southern counties is made up of shales and sandstones—though most of the shales are calcareous*.

It has been known since 1956, when Flowers published his report on the Greenbrier Limestone, that a major part of this formation exhibits pronounced erosional features at its deeply buried upper surface. In fact, in a few areas of northwestern West Virginia, the entire thickness of the Greenbrier was eroded off in an irregular manner, leaving only a few isolated knolls of the formation. By means of well drilling records and seismic surveys, personnel of the West Virginia Geological and Economic Survey have been able to trace the course of one major river and several tributaries which cut deeply to form abrupt channels in this limestone formation. The channels are now filled in with non-carbonate sediments of the Pottsville Group (Lower Pennsylvanian) and lie at a depths of 1,500 to 2,000 feet below the surface. The buried channels are described in Flowers (1956). J. K. Filer of the Survey has now completed a more thorough study of these and other erosion features in three counties where this erosion is known to exist (Filer, 1985). Since the time Flowers published his work on the Greenbrier Limestone, this formation has been penetrated by thousands of additional wells. Between 1979 and the end of 1983 the number of new wells drilled through the erosion surface and into the Devonian below in just the three counties mentioned above, was 1,110 (Filer, 1984, p. 39). Also many more detailed seismic* surveys, which are very effective for determining underground contours and thicknesses, have been made.

The West Virginia Geologic Survey's knowledge of this erosion surface is now much more complete than it was when Flowers made his study (Filer, personal communication, 1985). The evidence is decisive that the period of erosion was at least hundreds of thousands of years in length. This evidence includes the fact that parts of the Greenbrier Limestone have Mauch Chunk (Upper Mississippian, Fig. 4) non-marine, sedimentary rock layers immediately overlying them, but that the latter were worn thin or (in the western edge of the state) entirely removed by the erosion process (Flowers, 1956, p. 14). Therefore we know that, before the great period of erosion began, there had to be a period of deposition of the Mauch Chunk sediments, and *at least* several thousand years beyond that for the minimum amount of cementation necessary before the Mauch Chunk strata could be eroded off to the present tapered ("stair-step") form which has been identified by the above-mentioned petroleum explorations. There is just no conceivable way that this type of erosion, and the subsequent cutting of steep canyon walls in the Greenbrier Limestone itself, could have been accomplished while the sediments were still soft and uncemented.

An observation of Reger in the eastern edge of the state further reinforces the conclusion that the upper Mauch Chunk strata lay exposed for a long period of time before the Pottsville Group sediments were added. He describes the contact between the Mauch Chunk and Pottsville strata, in areas where they are exposed in Mineral and Grant Counties, as follows:

> At the base of the [Pottsville Group] where it lies upon the Mauch Chunk Red Shales, there is a wide-spread and striking unconformity. Here the coarse, gray, and massive rocks of the Pottsville, with their attendant coal beds and bituminous shales, rest upon red shales with included thin strata of fine-grained, micaceous, and flaggy sandstones, there being an almost total absence of coal. The inference drawn by many observers is that the sediments forming the Mauch Chunk Series may have been exposed to oxidizing agents for a long period prior to deposition and that they were

> deposited in comparatively shallow water which receded and left them bare and subject to erosion for another long time before Pottsville deposition began. (Reger, 1924, p. 254).

Thus, it is seen that even in the eastern part of West Virginia there is strong evidence for the long period of erosion which, on the western side of the state removed much of the Mauch Chunk and some of the Greenbrier.

(e) Discussion

Concerning the significance of all these examples for young-earth creationism, Morris admits that angular unconformities "may conceivably indicate a long period of erosion," but then immediately adds:

> One might at first suppose that major unconformities could be used to note a time-break—perhaps the end of one geological epoch and the beginning of another. The problem with this, however, is that there is no world-wide unconformity! A time break in one region may not be noted in another region at all (Morris, 1974, p. 113).

This assertion that erosional unconformities could not have real significance with regard to time unless they were worldwide in extent should be immediately recognized as false logic. *Even one* of the many geographic areas which possess a local stratigraphic column with erosional time gaps and other stratigraphic features which demand some millions of years for their deposition and subsequent modifications is enough to show us that at least *that* part of the earth is millions of years old. And since there are actually many such local columns, both in the Appalachians and elsewhere, Morris' claim that the earth's sedimentary strata were practically all laid down "rapidly and continuously" without time breaks is a rejection of these local* columns as they actually exist. Morris tries to justify this rejection by quoting from two geological articles on the subject of geochronology, but the quotations only recommend that unconformities not be used as definitive *markers* in geological time systems (Morris, 1974, p. 114). The quotations do not imply that the unconformities fail to represent long periods of time in the history of the local stratigraphic columns in which they are found. The authors are merely recognizing that the changes of elevation on the land of the various continents were very naturally limited in their areal extent, and not time-synchronized. It is very well known that the rising and falling of the land areas with respect to sea level was not such that all land areas rose and sank at the same time. Such movements are governed by local conditions of the earth's crust, not by linkage to a worldwide control system.

However, it is appropriate to state here that within a very few years after the publication of Morris' 1974 work, oceanographers, petroleum geologists, and other earth scientists were realizing that recently-made observations in many parts of the world indicate the presence of several interregional unconformities which involve most of the continents. These are largely due to marine regressions during the (now well-catalogued) major global sea-level fluctuations which have occurred since Late Paleozoic* times. Data which strongly indicate the locations of several interregional unconformities are described in Schlee (1984), Ross and Ross (1985), and Saunders and Ramsbottom (1986). Sea level fluctuations often reflect regular climatic changes affecting the volume of ice accumulated at the poles, or changes in the volume of the ocean basins due to movement of the continents. So Morris' claim that there are no worldwide unconformities appears to be unjustified and invalid.

Morris makes a further attack on the significance of unconformities in the book *What is Creation Science?* (Morris and Parker, 1982, pp. 203-206). Here he attempts to show that, because unconformities in the various strata systems do not always correspond to the chronostratigraphic (time) boundaries which are recognized by geologists, they cannot actually represent appreciable *amounts* of time. For example, his Fig. 47 has the caption "Inadequacy of Unconformities to Determine Age." The figure is a diagram showing that "unconformity surfaces" are independent of time boundaries which have been established for the earth's sedimentary cover. Morris tries to convince his readers that because unconformity surfaces are not useful for determining *the* age or geologic time period of the stratigraphic units in which they appear, they do not represent the passage of any significant amount of time. This is very misleading, and evades the real issue, namely the passage of time during the cementation, erosion, and other processes which occurred before the next deposit above the unconformity was added.

In this book we have cited numerous examples of erosional unconformities covering large geographic areas, which show that in each case the area was eroded very visibly after it had acquired at least a moderate degree of cementation. These examples demonstrate clearly that these unconformities *do* represent very appreciable amounts of time—both for the prior cementation and for the erosion, as well as for the subsequent reestablishment of conditions for sediment deposition. Such a sequence of events and processes could not be achieved in a mere few decades, over a broad area, without a major alteration of *several* fundamental physical laws, and we have no scriptural grounds for believing that such an alteration of these laws occurred at any time after life was placed upon the earth. So, Morris is completely illogical in asking us to suppose that erosional unconformities do not represent long periods of time which elapsed during the formation of the local stratigraphic sequences in which they occur.

Furthermore, in order to have an accurate picture of what the strata systems of the earth's sedimentary cover are like, we must recognize that a considerable percentage of the extensive erosional unconformities actually are located at geological time boundaries. This is the case with the unconformity at the top of the Redwall Limestone of the Grand Canyon which we described above, and also with most of the unconformities in the Central Appalachians which we described as well.

CHAPTER 2

SIGNIFICANCE OF THE GREAT THICKNESSES OF SEDIMENTARY ROCKS IN THE APPALACHIAN REGION[10] AND OTHER AREAS

One important feature of the Appalachian Region of North America which we should consider here is that of the actual amount and number of limestone deposits which are found alternating with strata of quartz sandstones, siltstones, and shales. (We will here use the term "limestone" in the broad sense which includes dolostone.) These thicknesses and the enormous number of alternations of sediment type are practically ignored by the recent-creationist writers. When these characteristics *are* recognized by them, they are regarded as having little significance with regard to time because the writers do not understand sediment types or rock formation processes.

1. Quantities of Lithified Sediments

A partial idea of the thicknesses of lithified sediments in the Appalachians can be obtained by examining Fig. 2, but only the most major changes from limestone to other types of rock strata can be shown in a small diagram of this type. When we examine isopach* (thickness) maps and measured sections[11] of the various types of rock strata in eastern and central West Virginia, western Maryland, west-central Pennsylvania, and the western part of Virginia (the areas represented by Fig. 2), we find the following approximate thicknesses of limestone, beginning at the top of the Precambrian and proceeding upward:

Cambrian — an average of 7,000 ft thickness over most of the area named above. Parts of several counties have over 11,000 ft of Cambrian limestones.

Ordovician — an average of 2,500 ft thickness over most of the area named above. Parts of several counties have more than 6,000 ft of Ordovician limestones.

Silurian, Devonian, and Mississippian (combined) — an average of 1,000 ft thickness of limestones over most of the area named above. These strata

[10]The term "Region" is used of the entire Appalachian area. The Region is divided up into Provinces.

[11]A "measured section" is a sequence of formations or parts of formations, with their various types of rock layers which have been measured and recorded in detail, with the thickness of each type of rock given. Such section measurements are usually made at road cuts, river canyons, rock quarries, or mountainside cliffs.

> systems are easily distinguished from each other in the local columns of the large area here being considered, but are lumped together because of the fact that much the largest part of these three rock systems consists of non-carbonate strata, with only approximately 500 ft of limestone thickness in the Silurian and 500 ft in the Devonian and Mississippian combined. In some areas, for example, the combined thickness of the Devonian limestone units may be 300 ft and that of the Mississippian 200 ft, while in other areas there may be only 200 ft of Devonian and 300 ft of Mississippian.

The above thicknesses have been taken mainly from Chen (1977), Reger (1924), and the vertical column parts of the large *Geologic Map of West Virginia* (West Virginia Geological and Economic Survey, 1968). In each case I have used the most conservative figures and have avoided exaggeration. A very detailed listing of thicknesses and rock types at several hundreds of deep-well and measured-section sites is given for the four-state area in the second volume of Chen (1981). Most of these were used in the production of his 1977 volume. Several other detailed sources of the thicknesses are available in addition to these. It should also be kept in mind that in most areas of the Appalachians the thickness of non-carbonate (clastic*) sedimentary rocks is greater than that of the limestone, making a total thickness of from 20,000 to 35,000 ft in the eastern part of West Virginia and the western edge of Virginia (Butts, 1940; Chen, 1977; Patchen, 1982). In some areas of the Appalachians the non-carbonate part of the local stratigraphic column contains thousands of thin siltstone, quartz sandstone, or graywacke sandstone layers alternating with layers of shale or mudstone, forming very significant vertical sequences in the local column (McBride, 1962, pp. 39-40, 43-44, 47-49; Thompson and Sevon, 1982, pp. 19, 23-31, 124, 127-133). We say "significant" because of the *contrast* between the conditions for deposition necessary for sandstone, graywacke, and siltstone on the one hand, and for shales and mudstones on the other. Rapidly moving water is required to transport the particles of coarser sediments, but the clay-rich sediments which make up shale and mudstone layers are deposited in deeper, low-energy waters.

2. Discussion

The rates of deposition of sediments of the types found in the above-mentioned 20,000 to 35,000 ft of strata in the Appalachians vary greatly. Careful studies have shown carbonate deposition in a semitropical, shelf environment to be sometimes as high as 30 cm (about 1 foot) per 1,000 years (Goodell and Garman, 1969, pp. 527-528). Coral reef deposition has been found to range up to 8 meters per 1,000 years on the fastest-growing parts of tropical reefs. Non-carbonate deposition on continental shelves usually averages 15 to 40 cm per 1,000 years, though it was greater during parts of glacial periods in the past (Gross, 1982, p. 105). All of the rates just given are for environments where deposition is rapid. The rates for both carbonate and non-carbonate deposition are *much* slower on the deep ocean floors, but not many of the sedimentary strata of the Appalachians were deposited in a deep-sea environment. Most of the shale and mudstone strata were deposited in fairly deep waters in inland seas, and their rate of deposition was probably no more rapid than the *slower* rates we have cited for continental shelves.

Even when a body of water is tranquil, at least many hours are required for the settling out of a single clay particle to become part of a shale or mudstone deposit. Even if the suspended clay particles have undergone flocculation (clumping), the water has to be essentially tranquil as the small clumps of flocculated clay are not nearly so dense as grains of sand. We have referred to these alternating sandstone and shale series as a reminder that the conditions for their deposition over this and other broad areas could not have existed in a one-year flood of the sort visualized by Morris and Whitcomb (see Morris, 1974, pp. 117-118). One year just does not allow enough time for anything like the number of relatively quiet settling periods needed for the existing clay and mudstone layers.[12] And we

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[12]Dr. Alan Hayward, an old-earth creationist, has written an unusually vivid, yet essentially correct, portrayal of this problem:

> We will take the average thickness of strata as 3 inches, which is really an overestimate. Consider a place where the sedimentary layer is only 20,000 feet thick (there are some places where it is twice that thickness). Combining these figures gives a total of 80,000 strata in a typical column of sedimentary rock.
>
> The Flood lasted about a year, but during the first part of it the flood waters were building up, so only a portion of the year would have been available for the deposition of sediments. Let's allow 9 months, which is probably over-generous. 80,000 strata [for a 20,000 foot column] in 9 months works out at 5 minutes each.
>
> In each 5 minutes, then, the Flood had to bring in a particular kind of sediment, distribute it fairly uniformly over a wide area—often over many tens of square miles—and deposit it on top of the previous layer. The two layers might sometimes be similar in composition, but would often be quite different. The Flood would have had to deposit the upper layer so gently that the layer deposited in the previous 5 minutes was not disturbed, so that no mixing of the two layers could occur. And it would have had to be so firmly in place at the end of the 5 minutes that the next layer could then safely descend upon it—and so on, *every 5 minutes for 9 months*.
>
> Then there is the observation of geologists that the upper surfaces of strata often have fossil limpets or barnacles on them. This shows that those layers had time to harden into rock and attract rock-clinging shellfish before the next stratum was laid down; this is hardly likely to happen in 5 minutes!
>
> In some areas, the problem would have been even more severe than I have portrayed it. The Haymond rock formation in the USA is only a portion of the sedimentary column, with other rock formations above it and below it. Yet the Haymond formation, less than a mile thick but extending over a large area, contains more than 30,000 alternating layers of shale and sandstone—two entirely different types of rock.
>
> Shale is made of compacted clay. As most readers will have noticed, clay consists of exceedingly fine particles which take a long time to settle in water. Turbulence keeps them in suspension, and consequently clay will only settle in quite calm water.
>
> The "Flood geologist" looking at the Haymond formation has a problem. How did the Flood bring in a thin layer of sand and deposit it over a large area, then bring in a thin layer of clay and all this to settle quietly—all in a matter of minutes? And then repeat the whole performance *fifteen thousand times*?
>
> It seems rather obvious that there is only one way in which such a series of events could possibly occur. God would have had to direct and control the whole process miraculously to achieve this

have to account also for the many thousands of feet of carbonate rocks and non-cyclic mudstones and sandstones which are present in the same local columns with the sandstone and shale series. Two well-known areas in the western half of the United States where many thousands of couplets of sandstone or siltstone with shale occur in vertical sequence over broad areal extents are in the Marathon region of western Texas (in Pennsylvanian strata) and in the Ouachita basin* of eastern Oklahoma (in Mississippian strata).

Since we are describing orderly sequences of strata in the Appalachian Region it is necessary here to mention the bold claim which Morris has made, saying that the stratigraphic system and formations of the Appalachian Region have no orderly arrangement are only a disorganized "jumble of rock." In the book *What is Creation Science?* (Morris and Parker, 1982, pp. 198-200) he devotes a few paragraphs to this claim, taking as his authority an article which appeared in a 1979 issue of *Science News*. It is obvious, from his description of the article, and from the part of it that he quoted, that its author was not at all denying the existence of the orderly formations and systems here in the Central Appalachians. The author was referring to certain *parts* of the sedimentary cover in the Appalachians which were subjected to extreme lateral pressure during one or more of the orogenies,* and as a result were folded and crumpled. For example, in the Valley and Ridge Province, well drillers encounter multiple thicknesses of the same set of formations where they were folded. *But these are no mystery* and are not difficult to identify. In fact, these folds and short overthrusts have been identified and mapped very carefully from seismic surveys[13] and earlier drilling records, so that modern drillers usually know ahead of time which of the sedimentary formations they will encounter and which ones may be found a second or third time because of folding or faulting as they proceed down through the rock system. Then there are large areas of *non-folded* stratigraphic sequences of the Appalachian Plateau Province which have been mapped for the use of drillers and other interested persons. These maps (and also drilling logs*) are available from the West Virginia Geological and Economic Survey, and from the Pennsylvania Topographic and Geologic Survey.

Dr. Morris' idea of the Appalachian strata being a disorganized jumble stems from his lack of knowledge of it. He took the popular-level language of the *Science News* article to mean that all or nearly all of the Appalachian Region is unintelligible and mixed up. Such an idea can be nothing but absurd to the many petroleum geologists who work daily with the orderly geologic formations of West Virginia, Pennsylvania, and western New

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result. But what of our agreed rules, that God would not use his powers to produce an effect which would mislead scientists, and that the Flood operated by Whitcomb's "purely natural processes"? (Hayward, 1985, pp. 123-125).

[13]Seismic surveys are very effective for distinguishing carbonate vs. non-carbonate, and shale vs. sandstone, as well as the thicknesses of the various units. See Glossary, "seismic survey."

York. If Morris had checked with one of them before writing he could have avoided introducing another erroneous and confusing idea into the book.

Even if he had read the short article, "The 'Eastern Overthrust Belt': An Explanation of Oil and Gas Activities in Central and Eastern Pennsylvania," by J. A. Harper and C. D. Laughrey, in the October 1982 issue of *Pennsylvania Geology*, Morris could have understood that the horizontal thrusting which is evident on the east side of the Appalachians is not something that turned the whole area into a confused chaos. But he made the mistake of focusing on some of the more drastically affected parts—such as those of the mountains in the Southern Appalachians—and concluded that this is typical of the entire area. He was apparently entirely ignorant of the many thousands of square miles of the Appalachians which contain the orderly preservation of all of the rock strata systems from the Cambrian up through the Pennsylvanian.[14] And east of the most intensely folded province (the Valley and Ridge) there are hundreds of linear miles of easily identifiable, continuous sequences of ancient, shallow-water, shelf carbonate sediments, preserved as they were formed and deposited. Some good references on these are: Spelman (1966, pp. 1-11, 54-76), Reinhardt (1974), Reinhardt and Hardie (1976, pp. 15-25, 42-49), Laporte (1975), Markello, et al. (1979), Pfeil and Read (1980), Read (1980), Kendall and Schlager (1981, pp. 196-205, and Table II-E), Ruppel and Walker (1984).

We will now come back to the great thicknesses of limestone in the Appalachians which we listed at the beginning of this chapter. These and other broad and thick sequences of limestone strata in different parts of the world are of great significance because of the fact that the limestone layers nearly always *contain special features* which give us some idea of the length of time required for their formation, as in the case of the Redwall Limestone of the Grand Canyon described in chapter one.

3. Unsupportable Hypotheses of Limestone Deposition

Some creationist authors, not being familiar with the special features of limestones, have supposed that most of the limestone deposits of the earth could have been formed rapidly by chemical precipitation* from seawater during the Flood. This assumption ignores the fact that very major deposits of the earth's limestone are composed almost entirely of biogenic materials. It also fails to realize that the waters of the ocean—no matter how supersaturated with $CaCO_3$—could not have precipitated the vast quantity of limestone formations of the earth in the short time provided by "Flood geology." Consider the fact that there are large areas in the U. S. and other parts of the world where the thickness of *limestone deposit* is as great as the depth which the *water itself* likely was over any part of the continents during the Flood! The problem of the inadequacy of precipitation is further compounded by the fact that the Flood is alleged to have been a convulsive event, with turbulent waters dominating it and not leaving the necessary periods of time for

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[14]Concerning the absence of some *formations* of these systems, see pages 56-60 of this book.

the settling out of precipitated minerals in quiet waters. If one counters this by responding that there was a long period of tranquil waters at the *end* of the Flood, this does not help either because there are often whole formations of sandstones, conglomerates, siltstones,* and shales intercalated* between the limestone formations—or overlying them—even in a single local stratigraphic column. In fact, the thickest limestone deposits of the Appalachians are usually in the lower parts of the column, sometimes covered by several miles of non-carbonates (Fig. 2).

When Morris (1974, p. 104) says that "Nothing less than massive precipitation from solution in chemical-rich waters ... seems adequate to account for [the great limestone deposits in the geologic column]" it is obvious he is unaware of: (a) the actual extent and nature of the limestone deposits of the earth; (b) the conditions necessary for extensive deposition by mineral precipitation; (c) the fact that known carbonate sediment production characteristics and rates on the Bahama banks and in several other parts of the earth *are* adequate to account for the earth's limestone deposits; and (d) the fact that biogenic components are dominant in most of the great number of limestone formations which have been studied. M. E. Tucker gives a helpful summary of the careful studies of these limestones, and of limestone formation processes, which have been made during the last three decades, saying:

> Biological and biochemical processes are dominant in the formation of carbonate sediments; with few notable exceptions inorganic precipitation of $CaCO_3$ from seawater can rarely be demonstrated (Tucker, 1981, p. 96; see also Wilson, 1975, pp. 4-10).

If, on the other hand, one tries to explain the limestone formations as having been formed from seashell material which was *washed in* from the oceans during the Flood, other problems are encountered which make such an explanation impossible. There is first the problem of quantity. Here in the Central Appalachians the total thickness of limestone usually exceeds 5,000 feet, and the *average* thickness over the continental United States east of the Rocky Mountains is approximately 900 feet. (Sources summarized in Wonderly, 1977, pp. 127-128; see also Cook and Bally, 1975, for isopach maps and "cross sections.") Several states in the interior of the U. S. have 900 or more feet of limestone covering *almost all* of the state. To suppose that enough seashell materials were stored in readiness around the North American continent, so as to be swept in by the Flood and deposited in neat layers, to this thickness, is completely out of the question. Second, there is the problem of how the flood waters could transport all the shell material—even if it had been stored in readiness—and distribute it so evenly over broad areas of the continent from 500 to 1,000 miles away from the "storage depot."

Also, there is no possible way that the surging flood waters could transport the shell material inland without mixing it with terrigenous* materials on the way. And how would the flood waters bring in layers of pure clay, silt or sand a few minutes later, to deposit the shale, siltstone or sandstone layers over great areas of shell material? Non-carbonate layers of these types often appear within a limestone layer sequence, and sometimes regularly alternate with limestone layers in the local column.

We must face the facts of physical laws which control sediment suspension and transport, and realize that fine sediments cannot settle out of surging flood waters to form neat, smooth and uniform layers—also that seashells of all sizes do not float like masses of seaweed and then suddenly sink down in a uniform layer. To suppose that deposition of sediments occurred in a manner which violates the physical laws which God created certainly appears to dishonor God. And even if shell materials could have been transported inland in pure and more-or-less uniformly thick slurry* sheets 50 miles or so broad, think how many such sheets would be needed in order to make up a limestone formation even 200 feet thick in what are now the states of Illinois, Indiana, and Ohio! Isopach maps such as those in the Indiana Geological Survey bulletin, *Cambrian and Ordovician Stratigraphy and Oil and Gas Possibilities in Indiana* (Gutstadt, 1958), show that such a 200-foot formation would amount to only about 10% of the average total limestone thickness throughout Indiana. The average thicknesses of limestone for Illinois and Ohio are even slightly greater than for Indiana, and in large areas of the Appalachian Highland Region the thickness is 2 to 5 times as great (Cook and Bally, 1975, pp. 8, 14, 15, 26, 28-35). Thus no method is known to mankind by which even a minute fraction of the existing limestone strata could have been deposited by either precipitation or rapid transport of shell materials.

4. *In Situ* Growth Structures Ignored by Young-Earth Creationists

Another insuperable problem for any and all proposals of rapid formation of the limestone deposits which we have been discussing is the *in situ* biological growth structures which they contain. These include stromatolites* and algal mats* (both formed by marine algae which either collect or secrete calcium carbonate), small bioherms,* large organic banks, and coral-algal reefs. Obviously, any limestone formation which contains such structures could not have been formed by rapid precipitation or by transport of calcareous shell material from elsewhere during the Flood. All of these kinds of growth structures are found in Europe as well as North American, and have been carefully identified many times and in many places. The technical literature describing them is truly abundant. For example, in M. R. Walter's work on stromatolites (Walter, 1976), the bibliography contains 2,034 entries (with no repetitions) relating to stromatolites and carbonate algal mats. The bibliographies for ancient bioherms and reefs (including fossilized true-coral reefs) are at least as large; see Wilson (1975, pp. 96-280) for a summary treatment and references on ancient reefs and bioherms.

Unfortunately most creationist authors do not know that the lime-secreting organisms responsible for building the *in situ* stromatoids,*[15] algal mats, bioherms and

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[15]A "stromatoid" is an individual, many-layered unit of a stromatolite—a "stromatolite" being the rock layer which contains stromatoids. Stromatoids are thus small mounds which are built up as a result of the

reefs have been accurately identified in abundance and from many ancient limestone formations. Neither do they know that these growth structures *really are* found in their natural growth positions, relatively undisturbed, in many places. Because of this lack of information these authors—including Morris and Nevins/Austin—usually dismiss the idea of such growth structures as imaginary. It is true that the identification of the algae which produced the ancient stromatolites and the fossilized algal mats was difficult at first, but with the advent of the scanning electron microscope and improved usage of standard electron microscopes it has become possible to see and identify the cells and filaments of the fossilized algae in the stromatoids (Walter, 1976, pp. 251-259; Flügel, 1977, pp. 57-60; Schopf, 1977). Furthermore, the process of formation of calcareous* algal structures of types very similar to these ancient ones, by present-day species of marine algae, has been observed in many places, such as the Bahamas, Bermuda, the Persian Gulf, the Red Sea, and the western coast of Australia (Friedman, et al., 1973; Ginsburg, 1975, pp. 198-232; Kendall, 1968; Walter, 1976, pp. 193-203).

Anyone who is interested in observing the *in situ* growth structures of limestone formations can do so by visiting ancient limestone exposures which crop out in many places in the Valley and Ridge Province of the Appalachians, and in many ancient limestone exposures in Canada and in southern Europe. Another way to study them is to go to the state Geologic Survey offices and examine the well cores from deep wells which have penetrated the limestone formations. The personnel at such offices are usually very helpful to persons requesting the use of their resources. There is thus no reason to continue supposing that the great limestone formations could have been produced by a rapid deposition of carbonate materials by flood action.

5. Analogical Theory and Created Order

Sometimes it is said by young-earth creationists that the recognition of ancient environments, tidal flats, carbonate shelves,* algal growths, coral atolls, etc., which are buried in the sedimentary strata is a mere application of analogical theory. Such critics assert that we have no grounds for thinking that ancient life, growth, and sedimentation were similar to that which we observe today, and that the finding of modern analogs which appear to have a valid similarity to ancient structures or deposited layers is only worthless speculation. Such an accusation is improper and unreasonable. We, as rational beings recognizing God as an *orderly* Creator, are *not* at liberty to assume that such specific structures in the ancient strata were built by processes which are inconsistent with the marine life and growth processes which exist today. Making such an assumption amounts to a denial of the orderliness of God and of his works. For example, some extremists refuse to recognize fossilized clam shells or sea urchin skeletons as the real remains of living organisms. We believe God's creation was and is consistent and rational. We know that

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growth of marine algae in the same way that thinner algal mats are formed. A stromatoid is therefore a rather complex algal mat which has many algal-built laminations in its thickened, central part.

ancient clam shells, with their scars from muscle attachment, and sea urchin skeletons, with their many mouth parts for food handling, are not of some origin different from the shells and urchin skeletons in today's oceans.

CHAPTER 3

NEGLECT OF DATA CONCERNING ROCK LITHIFICATION

As we contemplate the inescapable significance of the many complex and thick sequences of sedimentary rock layers on the earth, we must take special note of one fundamental problem in all “Flood geology” explanations of the strata. Those who have set forth such attempted explanations have, without exception, failed to take into consideration the processes which are absolutely necessary in the conversion of sediments into hard, indurated* rock.

1. Misconceptions of Far-reaching Proportions

To the best of my knowledge, all such authors assume either (a) that the lithification of sediments is a simple process similar to the baking of brick or the hardening of concrete, or (b) that, if the process is more elaborate than that, some unknown provisions must have existed by which the steps in lithification could have been accomplished during the short time since the flood. The latter group invariably fails to face the problem of how soft sediments could remain amassed together in vertical sequences even several miles thick without either amalgamating the many thin layers or crushing the fossils—and without literally flowing off the high elevations into the low ones. Everyone who stands looking at even a road bank of hundreds of repeating alternations of shale and sandstone, or of shale and limestone, should contemplate the significance of the fact that these remained distinct after their deposition. Then they should go to a State Geological Survey Office and examine deep-well cores of similar sets of layers which are also distinct, even though they are from 2 to 5 miles deep in the subsurface. Obviously, these had to be strongly cemented* before the enormous weight of the overburden was added, and before the tectonic adjustments of position occurred.

2. Rock Cementation Processes

We must face not only the fact that the lower parts of the sedimentary cover had to be lithified before the upper were deposited, but also that the lithification of practically all kinds of sedimentary rock is of necessity a slow change—slow because of the very nature of the several processes involved. None of the proposals that the sedimentary rock strata of the earth could have been formed rapidly are based upon scientific observations. On the contrary, these proposals ignore the whole field of sedimentary rock petrology and the thousands of careful scientific observations which it has recorded. Some of the creationist leaders have made a few scientific observations of how sediments can be moved and re-deposited by water in local floods. But observing the moving of sediments is a far cry from making scientific observations on how the many types of rock layers are deposited and have actually lithified.

In the case of igneous* rocks the crystalline structure which binds the particles together is formed as molten rock material cools and solidifies. But in the formation of most sedimentary rock types, already-solidified particles are the basic raw material, and these must be cemented together by the precipitation of layers of minute crystals around the solid particles. The substances for forming these delicate microlayers of crystals have to be carried by circulating water, in ionic form, to the surfaces of the sediment grains. The most common cementing substances which are thus carried and precipitated are calcium carbonate, silicon dioxide, and various types of iron oxide. It is possible for extremely fine-grained sediments such as clay to be indurated to a considerable extent without much cementation as a result of the establishing of attractive forces between the closely fitting particles when compaction takes place (Blatt, et al., 1972, p. 353). This has often resulted in the formation of layers of shale. But unless the shales are either heated hot enough to become slate or cemented at some later time, they remain soft enough to be broken between one's fingers—as is true of at least most of the vast bodies of shale which we find in the Devonian through Pennsylvanian strata systems in the Appalachian Region. (Thick sequences of shales similar to these are found in most of the great geosynclinal areas of the earth.) In formations which have layers of sandstone alternating with the layers of shale, the sandstone became strongly cemented because water could circulate horizontally through it. But since only small amounts of water could pass between the particles of the shale, only a weak cementation could develop in it.

To come back a moment to the popular idea that if bricks and concrete can become hard in a short time, then perhaps layers of naturally-deposited sediments could have lithified rapidly, we point out the following. First, the binding materials which hold the particles of a brick or a block of concrete together are *entirely* different in arrangement from those which hold limestones, quartz sandstones and siltstones together. If we make a standard thin-section* of a brick or piece of concrete for microscopic observation, we find *nothing* similar to the rows upon rows of calcite crystals that are in a thin-section of limestone, or of silicon dioxide crystals in sandstone or siltstone. The section of limestone will usually show a few to several known *types* of crystals, according to the physical conditions under which the crystals were formed—a great contrast to the monotonous, hastily-formed binding substance of concrete. (For photomicrographs of several types of cementing crystals actually in place in the limestone where they were formed, see Scholle, 1978, pp. 160-167.)

We also need to contrast the splendid durability and almost indestructible nature of many sedimentary rocks with lack of durability of bricks and concrete. Some bricks and carefully made concrete may last for 50 years before crumbling. But slabs of hard, quartz sandstone used by man for monument stones have stood in the weather for hundreds of years without appreciable wear or damage. Sandstone of this quality is very abundant in the sedimentary cover of the earth, and exposed strata of it are used extensively in most countries of the world.

Some persons might be tempted to say that the sedimentary petrologists only know about cementation from looking at thin-sections, and not from observing actual cementation processes. This is not at all the case, however. In many parts of the world, sedimentologists are now observing and taking samples of rock in *various stages* of lithification. These samples come from shallow sea floors, coral reefs, lake bottoms, caves, and other places where stationary sediments are being permeated by water flowing through the pores of the sediment mass. Also we have access to many different bodies of sediment, e.g., Pleistocene carbonate sand accumulations, which show varying degrees of cementation, depending on how well they have been supplied with the necessary mineral ions for forming the cement crystals. Thus the production of rock from sediments has been observed to be a dynamic, ongoing, and orderly process which involves many sequential steps.

3. Methods and Rates of Rock Cementation

Mention has already been made of the precipitation of cement crystals between the particles or grains of sediment in sedimentary rocks. This precipitation is dependent upon the transport of the necessary ions of the precipitating mineral by water percolating through the sediment mass. In order for the process of cement formation to proceed, the pore water passing through the sediments must not only contain the right kinds of ions, but the concentration of those ions must be sufficiently high for precipitation of the cementing mineral (usually calcium carbonate or silicon dioxide) to occur. This precipitation of cement crystals must occur in an orderly manner *on* the surfaces of the mineral grains—a process which does require substantial amounts of time. This is especially true for hard limestone and dolostone, where frequently 50% of the composition is the cement crystals themselves (Friedman and Sanders, 1978, pp. 147-148). Thus the enormous amount of mineral which has to be carried *in solution* in order to complete the cementation process demands considerable periods of time, and favorable conditions for cement precipitation have to continue throughout these time periods. The concentrations of several kinds of ions, as well as other factors such as temperature and pressure, must remain at the proper levels, or precipitation of the cement crystals will not take place.

Many detailed studies of both present-day and ancient cementation have been made. It has long been known that carbonate sands lying at the surface on tropical beaches can sometimes be cemented into hard rock within a mere few years. However, the resulting “beachrock” is readily identifiable microscopically because of the distinctive types of fibrous and micritic* cement within in. Only a small percentage of ancient limestones show these types and arrangement of cement or other distinctive characteristics of beachrock, so we know that the formation of beachrock was very limited. The formation and occurrence of beachrock on many coasts has been known for over a century, though the precise conditions for its production are only now being learned. The formation of this type of rock is almost entirely restricted to the warm climatic belts of the earth, and occurs *only at very shallow depths* on the beach. Friedman (1975, p. 389) states,

> The only required conditions appear to be: (1) the sediment must remain stable [not disturbed by waves]; (2) water that is supersaturated with respect to calcium carbonate must be maintained in the pores of the sediment; and (3) the beach composed of sand or gravel must be steep and well drained and well ventilated. Cement is precipitated from hypersaline* seawater held in the pores by capillary action between tides. (Compare Friedman and Sanders, 1978, pp. 154-155.)

The exact means by which this water is brought to the necessary supersaturated state, and precipitation of the beachrock cement induced, have not yet been discovered with certainty. Friedman (1975, p. 389) states that the precipitation is likely due to supersaturation caused by periodic evaporation of water near the surface of the accumulated sediments. J. S. Hanor (1978) made a detailed study of beachrock formation in the Virgin Islands and concluded that the precipitation of beachrock cement is induced mainly by the loss of dissolved carbon dioxide gas from the water present in the pores of the carbonate sediment. The solubility of $CaCO_3$ in the pore water is governed in part by the amount of dissolved CO_2 gas. The periodic loss of CO_2 gas decreases the $CaCO_3$ solubility, and the precipitation of calcium carbonate cement ensues.

The main point for us to note regarding these events is that *in any case* the precipitation of beachrock cement is dependent upon chemical processes which are maintained only at or very near the surface of the shore sediments. Thus we must not expect to find *rapid* formation of cement taking place after sediments become deeply buried. For this reason no "Flood geology" proposal, that great thicknesses of sediments were deposited during the Flood and then rapidly cemented, can find support in the process of beachrock formation.

Carbonate sediments which have been buried to an appreciable depth are lithified by a set of controlling factors different from those which cement beachrock. Bathurst and others have determined the approximate rate of normal cementation of thick masses of buried carbonate sediments found beneath beaches in semi-tropical latitudes. From these known cementation rates they have calculated that 80,000 to 90,000 years are necessary for normal filling in of the spaces between the sediment grains in a deposit of carbonate sediment 10 meters thick if the deposit is receiving a *constant* flow of ion-bearing water from top to bottom of the mass (Bathurst, 1975, pp. 439-441; 1983, pp. 355, 367-369). That means that 80,000 years are required, under *very good* cementation conditions, to convert a 10-meter deposit of sediment into hard limestone. Notice here that this is a thickness of sediment through which a continuous flow of water can conceivably be maintained, without its being subjected to an early sealing off from percolating seawater by clay-sized sediment. Thus, while the upper 10 meters of sediment are receiving a good flow of water between the grains, the sediment which is deeper down below that particular deposit will likely receive an inadequate flow most of the time.

4. Postulating an Unnatural "Plumbing System"

An understanding of some of the principles of cementation such as the above will cause us to realize that young-earth creationists have been completely unrealistic in proposing that the great thicknesses of sedimentary cover of the earth were formed rapidly, only a few thousand years ago. Even if one could surmount the problem of how rapidly-amassed sediment layers could have been maintained as distinct, without amalgamating into one another and without crushing the fossils and various ephemeral sedimentary structures, the great problem of cementation would remain. How could the vast expanses of thousands of square miles of sedimentary layers, often piled 3 to 5 miles deep, *receive the proper flow* of pore water for cementation—*especially* if the cementation were to be accomplished in a minute fraction of the normal time? We are not asking how all of that sediment could be rapidly cemented into *one solid mass*—though even that would require a supply of pore water too elaborate to contemplate. Instead we are faced with the fact that practically any area of sedimentary cover with a thickness such as this—as in the Appalachian Region—contains an orderly sequence of many distinct *types* of cemented rock layers. When one considers the entire vertical column at any point, such as in West Virginia or central Pennsylvania, he finds hundreds of changes in rock type per mile of thickness. Each of these rock units usually extends for some miles horizontally in all directions, and samples of these layers are readily correlated from different deep wells drilled within a large radius.

This means that each type of rock layer—whether it be sandstone, siltstone, graywacke, or one of the different types of limestone—during the time it was being cemented, had to be receiving its own *proper* kind of ion-bearing pore water. And this supply of special pore water had to be furnished to the sediment layer *over a wide areal extent*. This is possible so long as there is a large body of water nearby and the burial depth of the sediments being supplied with pore water is not great. Then there is the fact that quartz sandstones are nearly always cemented by pore water rich in silica (rather than calcium carbonate), resulting in the formation of silicon dioxide cement crystals, whereas limestones are practically always cemented with crystals of calcium carbonate or dolomite. This is no problem so long as the cementation is occurring in a near-surface location, with water passing over or near the sediment mass. But how can one logically postulate some sort of unimaginably elaborate "plumbing system" which would have supplied *each* of the deeply-buried layers, over all those thousands of square miles, with the *types and amounts* of pore water needed for rapidly cementing them into distinct types of rock?

One cannot solve this problem by saying that the water was circulating vertically up or down through all the sediment beds (even if such were possible through 3 to 5 miles of sediment) and that the quartz sand and silt layers were cemented with silica* ions from their own grains, and the carbonate layers with calcium, magnesium and carbonate ions from theirs. The fact is that we regularly find such distinctly different layers in *direct contact* with each other, each with its own kind of cement. If the flow of water had been passing from one type of layer into the next above or below, there would have been an intermingling of cement-types throughout the column. Also, it is necessary to face the fact that the physical conditions for silica cementation are very different from those for carbonate cementation. There seems to be no way the two sets of physical conditions could have been maintained adjacent to one another in alternating, repeating, and *often thin* layers. The only really logical conclusion concerning the formation of such strata is that the limestone layers achieved their original primary cementation while they were within reach of the type of pore water they needed, and that the sandstones and siltstones were cemented at a time when a non-carbonate-producing environment was prevailing in the area.

Postulating rapid cementation due to a supply of mineral-laden water from hydrothermal springs or volcanoes, as some creationists have done, is also futile. Such localized sources could not provide a horizontally-moving, uniform supply of the needed kinds of ions (or even of pure water) to produce the distribution of cement we find in these 3 to 5 mile columns of layers. Young-earth creationists hypothesize that all of that cementation has occurred in the short time since the Flood, but both the necessarily-slow character of the process and the insuperable problem of distribution of the proper kinds of ionic solutions makes this impossible. The difficulty of fluids from hydrothermal springs providing a uniform and rapid supply of ion-bearing water to far-away sediments is further complicated by the presence of many hundreds of layers of tightly compacted clay (now shale and claystone). These, being distributed throughout much of the 3 to 5 mile-thick mass of sediments, would have almost completely blocked vertical movement of water to strata above or below.

In thinking about the origin of the thousands of orderly strata in such a sedimentary column, we need to realize that there is a pronounced lateral uniformity of layers over broad areas. This uniformity is of course not always a uniformity of *thickness* from one mile to the next, but it usually is an impressive uniformity of cement type, grain type, and chemical composition. And most cement types are those of natural marine or fresh water cementation, rather than types produced under the influence of volcanic brines.

Catastrophist creationists who learn of these problems are invariably thrown into a confused set of speculations in attempting to explain them, advocating hypotheses for which they have no relevant observed data. For example, they cannot cite even one cubic kilometer of limestone and sandstone sequences which have been cemented by circulation from hydrothermal springs or other rapid means. Furthermore, such explanations will never work, since fluids from hydrothermal springs and volcanoes could not produce cementation of the marine and fresh-water types, even if there were some way for them to be evenly distributed to the sediment layers. We should remember that God has never asked us to defend his truth with irrational explanations, or by postulating processes which contradict or violate the natural laws He has created.

CHAPTER 4

CATASTROPHISM AND "ABSENT" STRATA

1. "Flood Geology" and Scientific Models

Since the "Flood geology" view has been offered as a "scientific model," evangelical Christians have supposed that it is somehow a workable explanation of the origin of the earth's sedimentary cover. They do this even though it runs counter to the most fundamental facts concerning the components of, and formation of, rock strata. But in science, when it is discovered that a given model has failed to take a fundamental set of principles or data into account it is immediately discarded. And the catastrophic "model" of the formation of the earth's sedimentary cover must not be "granted immunity" to this practice of scrutiny in the scientific community. Perhaps it would be nice to have the benefit of a young-earth-creation type of doctrine in our opposing of evolutionism; but, since the proposed model violates so many of the natural laws which God established in the earth, we dare not cherish and cling to it.

Morris's well-known descriptions of how he visualizes the laying down of the strata of the earth's sedimentary cover during the Flood are based almost entirely on hypotheses of what the physical conditions might have been like during the Flood. But these hypotheses can never be substantiated, because they take as their basis the belief that the sedimentary strata were formed mainly as a result of a set of "once-in-earth's-history" physical processes or events which have not been (and will not be) repeated. With no possibility of making scientific observations for verification of these supposed, unique events, there is no way to use this "Flood geology" concept as a scientific model. And, even on a more local level, the "Flood geology" explanation of how the thick sequences of rock layers were supposedly formed has no scientific basis. It is not at all based on observations of how rocks are being formed in various parts of the world, or of the real processes by which they are deposited and lithified.

2. The Rumored Revival of Catastrophism

A perplexing, recent development in the promotion of "Flood geology" hypotheses is the claim, now being frequently made, that within the past decade "there has taken place an amazing revival of catastrophism among evolutionary geologists" (Morris, 1985, p. 130). Similar statements are made in Morris and Parker (1982) and in other recent creationist publications. To uphold this claim they quote brief excerpts from paleontologist David Raup, and geologist Derek Ager, both of whom thoroughly and clearly recognize the presence of deposits and processes in the earth's sedimentary cover which require long periods of time. These men, and the others who young-earth creationists are saying are "returning to catastrophism" are not at all denying the rock-lithification processes or suggesting that there is evidence that the earth's sedimentary cover contains only rapidly-formed components. They are merely calling attention to certain definite, rapidly-formed deposits such as those laid down by volcanic action, ocean storms, and the debris flows dealt with in Chapter 6 of this book.

Ask any of these geologists and paleontologists about the origin of the Great Bahama Bank, the coral atolls, buried coral reefs, multiple coal deposits, cyclic evaporite deposits, and great limestone formations which contain *in situ* algal structures, and they will give essentially the same answer that their colleagues in paleontology and geology give. The reason that the young-earth leaders mistakenly think that these scientists no longer recognize the many geologic and petrologic evidences for long periods of time seems to be only that (a) the young-earth leaders are themselves unaware of the vast amount of data demanding long periods, and (b) they are so out of touch with the geologic profession that they do not know the nature of the research reports which are regularly being submitted to the various geologic symposia. By attending or reading such symposia it is very easy to find out why the geologists are recognizing certain rapid events which appear at intervals in the strata. The reason that they refer to these events more often now than formerly is that they now have much more adequate methods of detecting and recognizing the characteristics of deposits formed by them. On the other hand, there has been a great increase in the writing of research reports recognizing the abundance of deposits which *require long periods* of time for their formation, such as those named in the first sentence of this paragraph. New methods of sedimentary and petrologic observation which have been developed during the past two decades have *greatly* enhanced our ability to identify *both* the rapidly-formed and slowly-formed parts of each local sedimentary column.

So, the increased recognition of catastrophic processes is a much different situation from the recent recognition by some evolutionary biologists that they have not been able to find much real evidence for abiogenesis and macroevolution. Most of the data which inform us of the passing of long periods of time are readily observable, definite and concrete—as has been pointed out at various places in this book.

3. Why We Do Not Find All of the Rock Strata Systems* Everywhere on Earth

A question is often brought up concerning why certain formations and systems* which are present in one area are absent in another area. For example, some of the formations which are found in the Appalachian Valley of Virginia are not present in Pennsylvania. This condition leads many young-earth creationists to say that the practice of classifying rock systems and their formations, and of recognizing that some are older than others, is only an imaginary exercise carried out by geologists.

(a) Principles

The absence of certain formations is not really disturbing when one considers the characteristics of the depositional processes which formed the Appalachian provinces. At least three orogenies* (the Taconic, the Acadian, and the Appalachian) were changing the elevation of various parts of the land and thus were alternately forming and draining inland seas in the region. It is also easy to realize that, during any period of time when a given area of land is above sea level, it is not as likely to have sediments deposited on it as when it was covered by water. Parts of the land which are above sea level are subjected to erosion, whereas adjacent parts receive the sediments which are eroded off the former. (Sometimes these adjacent parts which received sediments were still above sea level, though lower in altitude than the areas which were supplying the sediments—as was frequently the case in Pennsylvanian times.)

It is significant, however, that *all* of the major rock *systems* (formed during the geologic *periods**) up through the Mississippian are present almost everywhere in the Central Appalachian zone which we are considering. So, interruptions of deposition were not so long as to cause an entire strata system of formations to be omitted. Of course, after the *last* major orogeny (the Appalachian or Alleghenian), the land was left too high to receive further layers of marine sediments. Thus we should not expect to find such systems as the Jurassic, Cretaceous, and Tertiary present in the Appalachians.

Historical geologists have for many years recognized evidence which shows that at least the Permian System was formerly present over much of the Appalachian Region, but that it was worn off by erosion after the time of the Appalachian Orogeny—just as considerable areas of the Pennsylvanian and Mississippian were worn off in certain other parts of the Appalachians. For example, an examination of a color geologic map of northern West Virginia and western Maryland shows that there is a long valley of Devonian farmland and forest extending from a point somewhat south of Elkins, West Virginia, to slightly beyond the northern boundary of Garrett County, Maryland. Further examination of the map reveals that on either side of this NE-SW Devonian, linear exposure the various formations of the Mississippian and Pennsylvanian systems are present, appearing as linear bands of different colors (Fig. 5). (The set of bands to the west of the Devonian valley forms an approximate mirror-image of the eastern set.) This arrangement, coupled with the fact that the area of Devonian exposure lies on the surface of a well-known NE-SW anticline,* gives us unmistakable evidence that at least the entire Pennsylvania, Mississippian, and the first one or two formations of the Devonian were worn off by long-term erosion.

This is such a clear example of the removal of at least two entire rock systems, long after coal had been formed and the area then uplifted, that we will briefly describe the local conditions. In this Devonian valley the local business men and farmers have long been aware that there were no layers of coal or limestone in the valley, but that they could obtain both by going a few miles west or east to the bands of Mississippian and Pennsylvanian rock and soil exposures. They also knew that near the center of this Devonian valley was an apex of the bedrock, so that all rocks on the west side of the apex which had never been

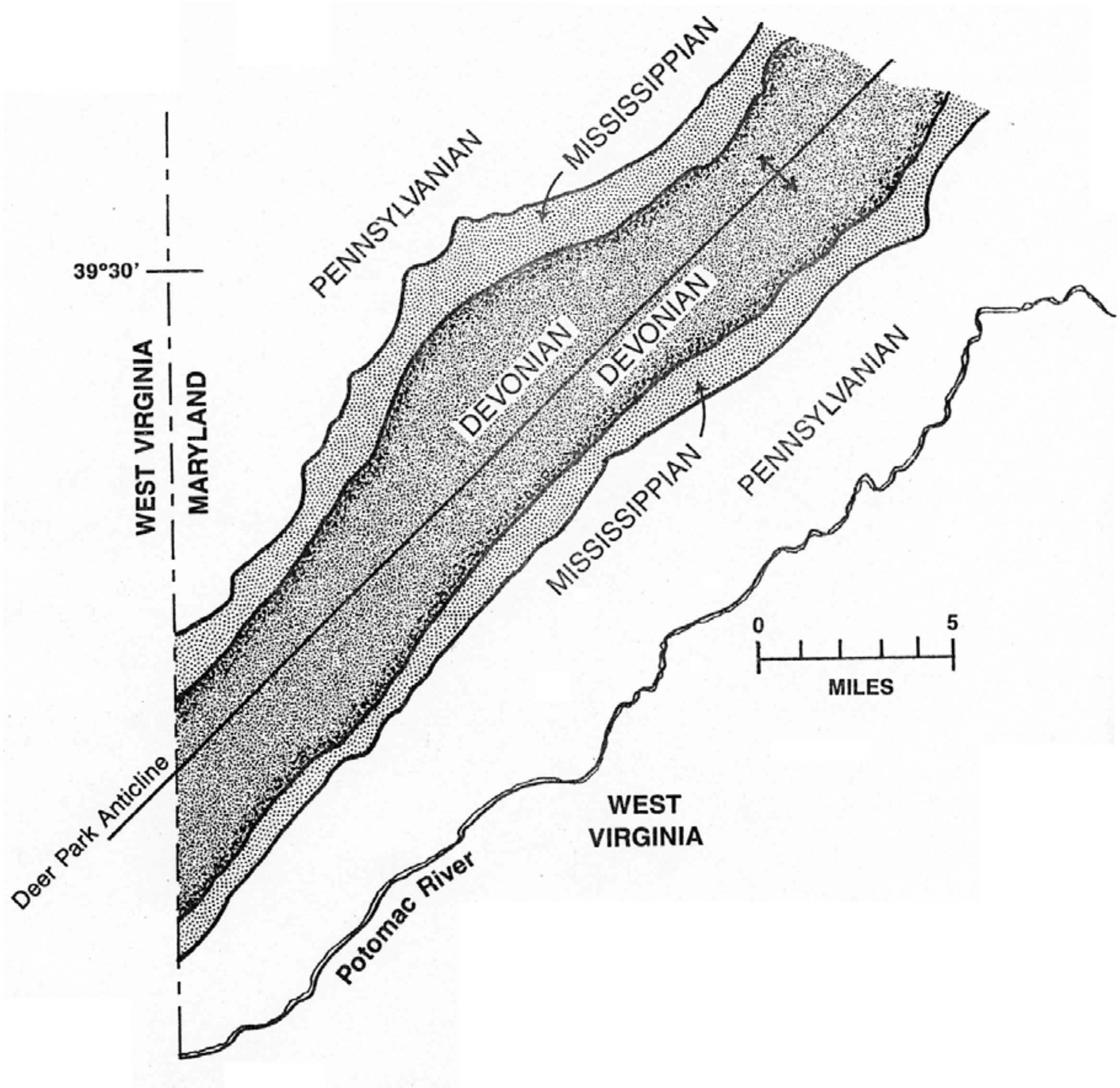

Figure 5. Geologic Map Showing an Example of the Removal of Two Entire Geologic Rock Systems by Ancient Erosion, Along the Axis of an Anticline. (Redrawn from *Geologic Map of Maryland*, Scale 1:250,000, Maryland Geological Survey, 1968.) The removal of these rock systems is discussed in this chapter. There is no sizable river or stream running through the Devonian valley. It is drained by small streams which flow northward, and eventually into the Ohio River.

moved sloped downward toward the west, and that those on the east side of the apex dipped downward toward the east (because the apex which the people observed as they excavated for buildings, etc., was the axis of the above mentioned anticline—called the "Deer Park Anticline"). Because of these facts a good number of even the manual laborers realized that a great mass of rock layers had been worn off in early times. This was a vivid fact to them, because many of them wished that they could find the Mississippian Greenbrier Limestone and the Pennsylvanian coal seams which the more fortunate people who owned land along these bands (and extending to the west and to the east from the bands) were able to find and use for economic gain.

Another important observation in this geographic area is that the bands of Mississippian and Pennsylvanian exposure along the sides of the Devonian valley are abrupt, and sometimes even cliff-like. This shows that the erosion which removed the center of the NE-SW area occurred after the rock layers had been well cemented into hard rock and the coal had been hardened to maturity. Thus it would be completely illogical to suggest that the upper strata systems were removed as soft sediments after the Flood.

(b) Young-earth Misconceptions

Many young-earth creationist books, and even the article "Ten Misconceptions about the Geologic Column" by Steven A. Austin (1984), contain a section which promotes the mistaken belief that since all the earth's land surface is not covered by all of the geologic strata systems, we should regard most of the teachings of sedimentary geologists concerned the origins of the earth's sedimentary cover to be erroneous. In his section dealing with this subject, Austin says that the geologic strata systems are "poorly represented on a global scale," and even indicates that all of them should be found on the ocean floors (even though nearly all of the present ocean floors were formed from new magma long after the Cambrian, Ordovician, Silurian, and Devonian systems had already been deposited!). He then accusingly states, "Even where the ten [strata] systems may be present, geologists recognize individual systems to be incomplete [i.e., to lack some of the formations]," (p. ii). Thus Austin, Morris, and other writers have neglected much essential data concerning the strata systems and the early conditions of the earth's crust, causing confusion even among Christian men and women of science. These authors, and those who put confidence in them, have totally failed to understand that it was perfectly normal for parts of the earth's surface to be above sea level at various times and thus not to receive continuous sedimentary deposition.

It is very detrimental that there is such a widespread misunderstanding about the absence of some of the strata systems from parts of the earth. Morris shows himself to be a victim of this misunderstanding when he says, "Rocks of any 'age' may rest vertically on top of those of any other 'age.' The very 'oldest' rocks may occur directly beneath those of any subsequent 'age.' " (Morris, 1974, p. 132) (The word "vertically" in this quotation and elsewhere in that section of the book seems to mean *sequentially* instead of vertically.) He is here referring to the absence of the strata systems in certain geographic areas, but has failed to understand the reasons for this.

The principles which we have pointed out in the above several paragraphs, plus the fact of overturned folds and short-distance overthrusts—which are so common and well mapped in the Valley and Ridge Province of the Appalachians—are entirely adequate to account for the variations in stratigraphic order to which Morris refers. He regards such variations as inconsistencies in the work of regional geologists and stratigraphers. But practically all such "inconsistencies" are cleared up by careful and logical field studies of the regions involved. Those few for which there seems no good explanation may have to be explained in terms of earlier wrong identification of the "out-of-order" formations. But the amazingly complete seismic mapping of the past two decades, together with drilling records in areas of intense folding, force us to recognize that the formations with which we are so familiar to the east and west of the Valley and Ridge Province really were folded, overturned in a few places, and sometimes faulted and pushed up on one another.

Thus, the idea held by most young-earth creationists that the absence of certain geologic formations in a given region, and the superposition of formations in some places, is an indication that the work of geologists is invalid, is simply due to their failure to familiarize themselves with what the sedimentary cover of the earth is really like. We need to study the available data (which are very abundant) and not to rebel against it. Since the rock strata testify that there *really were* orogenies and other tectonic* processes and events which produced major changes in the altitude and slopes of the land, we should be willing to recognize that the order and existence of the rock systems and formations is consistent with these processes and events. Christians are really placed at a disadvantage when they read creationist works which encourage a disregard for the data. Even if such works are written by one of the very few young-earth creationists who have graduate degrees in geology, this is not an indication that such an author has to be correct in what he is teaching. Two reasons for this are: (1) earth science is such an extensive and broad science that no one person can be competent in more than a small percentage of it, and (2) every profession has a few iconoclasts who attempt to challenge even well-established and demonstrated principles. These iconoclasts sometimes do some good, but they usually end up losing the argument, and we hear little more of them; but they invariably gain a satisfying prestige within a limited circle of friends.

CHAPTER 5

MAJOR FACTORS WHICH HAVE CONTRIBUTED TO THE NEGLECT OF GEOLOGIC DATA BY CREATIONIST LEADERS

The preceding pages of examples of sedimentary characteristics which demand long periods of time raise an essential question. Why do the young-earth leaders not recognize the significance of these structures and characteristics? These leaders are maintaining a method of thought and practice which is really foreign to what most evangelical scientists know as responsible scientific research. Yet, perhaps because evidences for long periods of time have so often been taught within a context of objectionable evolutionary theories, some evangelical scientists seem to be willing at this point not to investigate or question the scientific accuracy of the creationist leaders' writings. As to why Morris and his colleagues handle Bible-science questions in the way they do, we can give no full answer; but there are some obvious factors which contribute to their method.

1. Early Influences and Assumptions

Perhaps the *most basic* reason that they are willing to be so uninformed as to the actual conditions in, and nature of, the earth's strata is that they, very early, adopted an unusually narrow system of Bible interpretation. When Morris and Whitcomb were laying the foundation for the current young-earth creationist movement they forsook the pattern of biblical exegesis which had been used by the main fundamentalist leaders of the first half of this century, to the extent of declaring that the Bible does not at all allow for long periods of time. (Also, the strong Seventh-Day Adventist influence on these and other recent-creationist authors can easily be noted by checking through the books, articles and bibliographies produced by such creationists from 1960 to the mid 1970's.) Thus Morris, Whitcomb, and their colleagues, going on an independent track, have worked all these years on the supposed principle that, since there "cannot be" long periods of time represented in the strata of the earth, there is no use to look for them—or even to study the strata very much. So, when the young-earth leaders have gone out to examine rock strata it usually has been for the purpose of looking for features which they felt might confirm their view of the earth's youth. This type of field activity does not qualify as scientific research, and does not yield reliable information, because it is an attempt to "take a short cut" instead of to follow consistent research methods.

Another false assumption which has been a major source of error among young-earth creationists almost from the beginning is as follows: if one part of a local stratigraphic column is of a type which conceivably could have been deposited rapidly by moving water, then it is assumed that the entire column was deposited by the Flood. Thus, if an ancient, ocean-storm deposit of sand and silt, or a debris-flow deposit, is found in a particular location, it is assumed that the entire column of stratigraphic formations beneath that site was produced rapidly—by the Flood—regardless of the rock types or of how many thousands of feet thickness are present.

2. Influence from Current Philosophy of Science

There has been an increasing tendency during the present century for some philosophers, educators, and even some practicing scientists, to abandon the idea that man has the ability and privilege of discovering truth. Philosophers of science have focused mainly on the more theoretical sciences such as physics, and have forgotten that such sciences as genetics, physiology, biochemistry, oceanography, and geology are regularly using the scientific method of research to successfully learn the true nature of many aspects of the world around us. The influence of these philosophers has affected creationists to the extent that many of them now assert that science cannot dependably and accurately observe or identify reality. By accepting these erroneous opinions, many extreme creationist leaders have promoted the opinion that little or none of the geologic research carried out during the past decades is reliable.

Let us briefly examine some of the reasons why such a view of scientific research is unacceptable. We have at least two types of evidence that man can carry out reliable observations of the natural world, and thus can collect accurate data and draw correct conclusions.

The first of these evidences comes from the teachings of Jesus Christ. When He was on earth He acknowledged the reality of man's ability to correctly observe and understand at least the more common conditions and processes of nature. This fact is in agreement with the teaching of Scripture concerning man's having been made "in the image of" the God who created the natural world. Some of the statements of Christ declaring that man can correctly observe and be sure of conditions in nature are the following: (a) the distinction between old cloth and new cloth, and between old wine and new wine (Matthew 9:16-17); (b) time distinctions (John 11:9); compare John 4:53 for an inspired assertion of a particular man's ability to make time distinctions; and (c) the recognition of clouds as precursors of rain (Luke 12:54-56). (See Wonderly, 1981, for a discussion of these passages and of their relation to the reliability of scientific truth.) Thus the idea that man cannot reliably discover truth by observing nature is not a Christian concept.

The second strong reason we have for recognizing that many scientific research projects have resulted in conclusions which are in agreement with God's created world is that such research has achieved reliable results. Thousands of highly successful research projects are completed each year in the United States, Canada, and Europe. Nearly all of these are carried out with honesty and integrity on the part of the scientists—because there are usually at least several scientists checking on each other.

The general human population, and also some of the creationist leaders, have no conception of how much successful scientific research had to be carried out before we could have such things as antibiotic medicines, the many wonderful synthetic medicines which we now use, and insecticides which are deadly poison to insects but harmless to man (such as the modern fly sprays). Each of these was developed by a long chain of *successful* scientific observations and scientific research projects, one building upon another until the truly correct chemical was finally produced. Until man finally succeeded in designing consistent inductive scientific research, the human race had to get along without such medicines and other beneficial chemicals—and as a result was ravaged by disease, parasites, and early death. It is truly absurd to find philosophers who daily enjoy the benefits of high-quality scientific research, yet tell us that such research cannot accurately reveal truth concerning the natural world. It is very difficult to accept such an assertion, or the commonly heard claim that all scientific conclusions are tentative, while watching wasps and flies fall helplessly to the ground only seconds after being sprayed with a complex *synthetic* substance. The research projects which developed such substances were successful because they resulted in the discovery of relationships of different kinds of chemicals which God created. God knew what those relationships were from the time they were first formed, but man is just now deciphering them.

We need to keep in mind also that the discovery of real scientific truth has not at all been confined to the field of medicine and pest control. The only reason that we can now have the vast transportation system that we do, and the convenience of gas and oil heat in most of our homes, is that many systematic, geologic, and petrologic research projects were carried out for locating the world's oil and gas reserves on which we now depend. It has been necessary for these research projects to identify the basic nature, relationships, *and origins* of most of the kinds of rock formations in which petroleum is found. Of special importance is the determining of the particular, ancient environments in which the sedimentary layers of each oil-producing area were originally laid down. The old idea of just guessing at where to drill for petroleum could never have provided more than a small percentage of the present flow of oil and gas. The modern petroleum industry is absolutely dependent upon the excellent understanding of the sedimentary layers of the earth's crust which has been worked out by many hundreds of systematic research projects. If correct human observations were not really possible, then these projects would not result in a knowledge of where the oil-bearing layers of rock are to be found.

During the time that the petroleum geology personnel are carrying out these research projects, they realized that it is urgent that they be as objective as possible. This includes being aware of the fact that any introduction of their own personal preferences and opinions into the research process will jeopardize the success of the project. The research personnel know that they must try to learn the *real* nature and arrangement of the rock layers in order to predict the locations for drilling. Thus they make every effort to screen out their own prejudices and personal opinions as they collect data and relate it to what is already known.

This is in direct contrast to a considerable amount of the teachings of present-day philosophers of science. Many such philosophers, including some Christian ones, assert that all of the conclusions of scientific research are heavily colored by the cultural background and personal interests of the research personnel. But this assertion is applicable primarily to the more theoretical fields of research such as theoretical physics, anthropology, and human evolution.

Thus the belief that scientific research cannot reliably reveal truth about the natural world is wholly incorrect. Yet many creationist leaders, being unfamiliar with inductive scientific research methods and projects, promote this mistaken idea.

3. Lack of Acquaintance with the Various Branches of Geology

A third very important factor contributing to the young-earth creationists leaders' failure to take the geologic data seriously is that, almost without exception, they have had little training in geologic research, and no training in actual sedimentology or sedimentary petrology. Because of this they have no way to notice or to identify the many evidences for age which are in the rocks, even when they do go out to look at them. Because Morris himself finished what training in geology he had, before sedimentology and sedimentary petrology had become developed disciplines, he missed out on gaining a knowledge of these. And besides, his main interest and practice have been in civil engineering (with special emphasis on applied hydraulics), which has very little resemblance to these branches of geology. Hydraulic engineering has little or no connection with the study of the *actual* nature of mature, cemented rock layers or of the dynamics of sediment deposition, burial, cementation, and deformation.

So, Morris, Whitcomb, and their colleagues have spent more than twenty years of writing and public speaking on the subject of "Flood geology" without ever making a serious study of the rock layers of even their own United States. And practically all other young-earth authors have followed their example.

To illustrate the tragedy of this we can use the example of limestones. Limestones in particular possess a structure (or "fabric"*) and components which readily reveal the depositional history of the rock. Thus the origin of limestone strata, whether they be near the surface or deep in the oil fields, can be fairly well understood by a study of (1) the petrology of carbonate rocks (limestones and dolostones), (2) the invertebrate and plant fossils in limestones, (3) carbonate sediment production and deposition processes, as observed in tropical marine environments today, and (4) rock cementation processes (diagenesis*). During the 1950's petroleum geologists began in earnest to put these principles to work in understanding the carbonate (limestone and dolostone) bodies of rock which frequently serve as source rocks for the recovery of petroleum. Because so much petroleum is obtained from carbonate rock, the petroleum industry realized that an understanding of the subsurface distribution of these strata, and of the rock itself, would greatly enhance their ability to predict the locations of oil deposits. (It should be noted by creationists that this concentration on limestone formations had nothing to do with any attempt to demonstrate or fortify evolutionary theory, and that hardly any of the hundreds of research papers in carbonate studies which are given at professional meetings each year make any attempt to defend or promote the teaching of evolution.)

By 1959 a detailed and useful system of classification of the different types of limestones had been worked out by petroleum geologists. This system, which soon came into general use, recognized approximately 10 basic textures of limestones (biomicrite*, oomicrite, oosparite, etc.), depending on the microscopically identifiable components present, and upon the types of cementation with which the particles were united together. Most of these basic types exhibit specific biogenic structures such as *in situ* algal microlayers within the rock layer. (Microscopic particles, cement crystals, and algal growth layers are seen and identified by grinding sections of rock thin enough for light to pass through.) But Morris and his colleagues have perpetually neglected to use such studies of carbonate rock in their attempts to explain the origin of the sedimentary cover of the earth. This is a great loss and hindrance to evangelical Christians who are interested in studying origins, because, as stated above, limestone is the only common kind of rock which possesses a fabric and components which readily reveal the depositional history of the rock. Even though the book, *The Genesis Flood*, by Morris and Whitcomb, has an unusually complete index, it has no entries for "limestone," "dolostone," "carbonates," "calcite," "dolomite," or "petrology." Yet the book purports to give definitive explanations for the origin of practically all the sedimentary strata of the earth, and it has continued to serve as the main pattern of "Flood geology" doctrine. Virtually all young-earth creationists' books published since *The Genesis Flood* ignore carbonate sedimentology and petrology to a similar extent.

Thus the young-earth creationist leaders have continuously failed to use the primary "tools" (sedimentary information and data) which could help them the most in finding out what the strata are actually like. One should remember that in most parts of the world any deep drilling into the sedimentary cover will encounter several to many intervals of carbonate rocks or sediments—on the average about 20% of the total column or drill hole. Since a multitude of high quality cores from such drillings give convincing evidence that nearly all of this carbonate rock was laid down in marine environments with lime-secreting animals and plants playing a large part in the deposition process, the carbonate layers are the primary key to understanding the depositional history of the sedimentary cover at any particular location.

Furthermore, there is an abundance of research reports which carefully describe various kinds of cyclic, marine, sedimentary strata that contain characteristics which show that their deposition had to take place over a period of many years, with time for cementation and other diagenetic processes to proceed before other strata were added above them. The many known geologic formations which contain these types of cyclic sequences thus rule out any "Flood geology" explanation of their origin. The reading of papers such as those found in the published symposium *Cyclic and Event Stratification*

(Einsele, 1982) could effectively inform creationist leaders concerning this type of deposition. Several of the chapters of this book give details of cyclic sequences of strata in Europe and other parts of the world and describe their petrographic* characteristics. Many of these characteristics give abundant evidence that the strata studied were formed over long periods of time, in developmental stages determined by the local environments existing at that time. Most of these environments can be identified as similar to those found in various marine settings known today.

In spite of their lack of knowledge of such principles as these, the young-earth authors who write on subjects dealing with the origin of the earth's sedimentary cover appear to show great confidence. Because of this image of confidence, evangelical scientists and Bible scholars who are unfamiliar with sedimentology and petrology assume that the authors know these disciplines. (Scientific studies today are too vast and too specialized for a physicist, chemist, biologist, engineer, vertebrate paleontologist, or a Bible scholar to be expected to know what information, methods, and data have to be used for understanding rock formation processes.)

4. Isolation from the Earth-Science Professions

A fourth factor which has greatly hindered the leaders of young-earth creationism is their usually intense suspicion of earth-science research. They nearly always feel that a person who believes in macroevolution and abiogenesis cannot be honest, or at least cannot use good scientific methods when investigating the nature of the earth. This is an illogical opinion, and simply does not correspond with the facts. The high quality and honesty exhibited in hundreds of research projects in sedimentology during the past 20 years have to be recognized by anyone who is familiar with them. Most of these projects have little or nothing to do with evolution, and were designed to enhance our understanding of the underground strata so as to promote success in the oil and gas industry. Furthermore, there are so many researchers working on the same or similar projects, and all publishing a high percentage of their work, that they serve as a very effective check on each other's honesty and accuracy.

Because of their unwarranted suspicion of sedimentary geologists, the recent-creationist leaders have missed out entirely on the help which they could be receiving from these scientists. They could be going on field trips with them to learn the nature of the sedimentary formations and should be attending professional meetings at which the research reports of sedimentary geology and stratigraphy are given, but the ubiquitous suspicions seem always to prevent their doing so. Sometimes recent-creationist groups even go down into the Grand Canyon, but they seem never to be concerned to have a sedimentologist go along to show them the rock features which reveal a great deal of the history of the Canyon's formation. As a result, misinformation about the Canyon is perpetuated among creationist teachers, ministers, and laymen.

Another cause of misunderstanding about the reliability of geologic data among young-earth creationists is their frequent reference to the fact that there are disagreements between geologists, expressed in the literature of geologic research. The creationist leaders seem not to examine the literature enough to notice that disagreements concerning the earth's sedimentary cover are nearly always regarding minor features—not the basic structure or nature of the strata. For example, in sedimentology symposia of professional geologic meetings we sometimes hear heated debate concerning minor aspects of the environments in which a particular marine sequence of evaporite and carbonate strata were deposited; but all are in agreement that these are natural deposits punctuated by periods when the seas locally became hypersaline and precipitated the evaporites.

5. Using Only Small Packets of Data

A fifth factor which appears to contribute heavily to the creationist leaders' usual inability to understand the nature of the earth's crust is their habit of wanting to consider only small "packets" of data which relate to geologic time. They usually seem to feel that it they have a small amount of data concerning a particular geologic formation, or type of rock, they can build an explanation of origins on that small amount of data. But science just doesn't work that way, and trying to *make* it work in that manner results only in confusion. Down through the years these leaders have, for example, used merely small segments of information concerning deposits of evaporites, the Grand Canyon, the great geosynclinal area of North America, fossil reefs, and the nature of the earth's coal deposits, but have almost completely avoided the thorough, often exhaustive, field and laboratory studies which have been made and published concerning all of these. They apparently do not realize that the scientific method of research requires the collecting of a large amount of data on which to base one's interpretation and conclusion. If a good amount and wide range of data are not available, then one cannot arrive at any valid scientific conclusion on the question involved. Because of the creationist leaders' lack of understanding of this principle, and because of their failure to take the great amount of data which *is* available into consideration, they have made large numbers of claims which are unsupported by scientific research. Many of the ideas which they have taught and published concerning sedimentary geologic structures have been so illogical and contradictory of the enormous amounts of carefully collected data published concerning them, that creationists have now been almost universally branded as pseudoscientists and charlatans by the educational and scientific communities.

For example, Morris's habit of considering only small packets or segments of data led him to make his now widely publicized claim that "there is no type of geologic feature which cannot be explained in terms of rapid formation" (Morris, 1974, p. 94, and restated in slightly different words in Morris and Parker, 1982, p. 213). Thus he has shown himself to be ignorant of the ancient erosion surfaces such as we have described above, and the great biogenic growth structures in the strata, as well as of many other types of sediment deposition which required long periods of time. As a result of these great omissions in the creationist leaders' thinking, anyone who is familiar with what the earth's sedimentary is actually like usually considers them to be either dishonest, grossly ignorant, or irresponsible. Of course the saddest part of it all is that these creationist leaders are in possession of much truth which the world needs, concerning at least the *fact* of creation by our Wonderful and Holy God; but they have ruined their opportunity to help scientists, educators, and many others who have now found out about extreme creationism's obscurantist stance.

CHAPTER 6

RAPID BURIAL OF ORGANISMS AND SEDIMENTARY STRUCTURES TO BE FOSSILIZED

1. Introduction

A surprising number of evangelical scientists and theologians tend to accept the much-publicized assertions of Morris and Whitcomb that rapid burial (such as in a flood) is absolutely necessary for the production of fossils, and that practically all fossils found in the earth's strata are the result of the Biblical Flood (Myers, 1984, pp. 44-45, 55; compare Morris, 1974, p. 100). Most geologists agree that rapid burial usually enhances fossilization, and that the formation of some kinds of fossils is dependent upon it. But we need to realize that, (a) there are many places on earth where large numbers of fossils are now being formed gradually, and that (b) we now know of many geologic events which occurred in the past, *rapidly* covering relatively large areas of the sea floor with sediments.

First, we will consider item (a), places where fossils are now being formed gradually. During the past 25 years many research projects carried out on coral reefs in various parts of the world's oceans have shown that gradual fossilization takes place both within the hard parts of the reef and in the accumulations of sediment around the base of the growing masses of coral. A piece of coral rock broken off the outer part of an actively growing reef has skeletons of living corals and calcareous algae on its surface. But sawing the piece in two reveals that, even at a few centimeters below the surface, fossilization processes are well under way. See Friedman and Sanders (1978, pp. 155-56) for a description and photomicrographs of some of the progressive stages of this fossilization. The reef rock is often found to be in a completely cemented condition, with the skeletal fragments fully fossilized, at 60 centimeters below the surface of the living layer of reef growth. In a detailed study of fossilization in Bermuda patch reefs, Scoffin (1972, p. 1281) found that, in the accumulations of loose sediment around the bases of the living clumps of coral, fossilization processes frequently begin at a depth of about 30 centimeters. In such a sediment mass the cementation process contributes to the fossilization, and also binds the shells of many small marine organisms present in the sediment, thus forming a kind of rock which shows a high percentage of small skeletal units throughout. Whether or not this cementation will progress to the point of eventually forming hard rock depends on the amount of water currents forcing water through the pores of the sediment mass.

A great number of studies of drilling cores taken from ancient, buried coral reefs in the oil fields of the world have shown that an appreciable number of the reef organisms were fossilized in growth position, having then been covered over by additional layers of growth of corals, algae, and other carbonate-secreting organisms (Langton and Chin, 1968, pp. 1925, 1927, 1930-42). So here are great bodies of highly fossiliferous rock, sometimes extending over several square miles and to a thickness of hundreds of feet, which contain immense numbers of fossils which were formed gradually as the reefs increased in size and thickness. This should also serve to remind us that the ancient, carbonate hardground layers discussed in a previous section of this book contain an abundance of fossils which were formed on the sea floor and eroded extensively before additional layers were added.

Now we will examine the second item, (b), mentioned in the first paragraph of this chapter. This has to do with known processes of rapid burial which have been going on throughout much of geologic history (at least from the Cambrian to the present).

Twenty-five years ago, when Morris and Whitcomb set out to revive the old "Flood geology" view, geologists and paleontologists did not have very much evidence for ways by which the animal and plant fossils (except microfossils) could have been buried rapidly. But with the great—really enormous—increase in sea-floor and continental-shelf research since that time, several means of rapid burial have been discovered, and a large number of cases of it have been identified in both recent and ancient strata by sedimentary geologists. Unfortunately Morris and his associates have not been in touch with the geologic profession enough to know that these discoveries were being made. So they have continued to assert that the only way that the animals and plants could have been buried was by a worldwide major flood.

2. Principles Having to Do with Burials

In order to understand why it is incorrect to say that practically all burials had to be accomplished by a single flood, we must first recognize that *nearly all* of the animals which were fossilized lived in marine habitats, and that most of those were shell-producing invertebrates. The depositional events which can effectively bury such animals occur mainly in underwater environments. Such events can occur very easily and on very gentle slopes of sea floors, because of the buoyancy of the water. The water is much more dense than air, so it has a strong supporting effect upon the loose sediments and organisms which normally lie on the floors of bodies of water. Various kinds of sediments flows,* such as mud flows and debris flows,* often occur on sea floors, both on the continental shelves and farther out to sea.[16] There is also much evidence that such movements of sediment

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[16]Debris flows and mud flows are types of sediment movement classified under the general heading "sediment gravity flows'' (called merely "sediment flows'' in this book). In debris and mud flows the density of the mixture of slurry is greatly increased because of the suspended particles. Another common type of sediment gravity flow is the "turbidity current flow,'' in which the sediment particles are supported mainly by the turbulent water, without major dependence on increased density of the fluid. Turbidity current flows usually produce sediment beds which are graded ("graded bedding''), whereas debris flow deposits are usually not well sorted. Sediment flows are not to be confused with simple, submarine slides—though debris flows often develop within and simultaneous with a submarine slide (Embly and Jacobi, 1978, pp. 205-11). See Tucker (1981, pp. 72-74) for a brief but good treatment of sediment flow types.

Since a high percentage of marine fossil beds contain many sizes and shapes of shells and other skeletal parts, this appears to indicate that most of the rapidly-buried fossil deposits were buried by debris flows, occurred on the shallow bottoms of the ancient inland seas in North America and other continents. This activity apparently provided a means by which bottom-dwelling organisms were buried rapidly from time to time when earthquakes or heavy storms triggered the start of sediment slides and sediment flows.

Sediments slides and flows have also been observed to occur on land. These flows are often continuations of landslides which have begun on steeper slopes during heavy rains. In this kind of situation the rains supply enough water that parts of the slide will become a debris flow, with the particles supported by water and the additional density contributed by mud particles in the water. In such a case the debris flow may continue for a relatively long distance on down to where the slope is very gentle, and vertebrates as well as invertebrates are usually trapped and buried in it.

3. Some Examples of Known, Large Sediment Flows

In submarine environments sediment flows occur easily, and on slopes as gentle as one degree (Cook, 1977, p. 372; Molnia, et al., 1977; and Cook and Mullins, 1983). Once the movement begins, the fine particles which become suspended effectively increase the density and viscosity of the water mixture, so that coarser materials can be suspended and moved also (Friedman and Sanders, 1978, p. 205). Such a flow frequently gains a rapid momentum and continues for several miles out to sea, covering great numbers of marine organisms. The fact that earthquakes were frequent and often intense in earlier times, especially during the orogenies,* makes it almost certain that such burial events were more frequent than now. Cook (1977, p. 372) states that some modern sediment flows off the coasts of the U.S., Alaska, Chile, and elsewhere have “occurred after earthquake shocks of magnitudes ranging from 6.7 to 8.5,” and that the amount of sediment moved in each of the flows has ranged from 300,000 cubic meters up to 70 x 10^9 cubic meters. (A cubic mile of sediment contains 4 x 10^9 cubic meters.) The formation of sediment-flow deposits frequently occurs both in carbonate sediment environments and in areas where the slopes are covered by terrigenous sediments (Cook and Mullins, 1983). A detailed study of very recent carbonate debris flow and turbidity flow deposits in the Bahamas was made by Crevello and Schlager (1980). They found that approximately 25% of the upper 7 meters of sediment lying on the lower slope of Exuma Sound was made up of these types of deposits (1980, p. 109).

Thus, there is no doubt about the ability of sediment flows to bury large numbers of marine animals and accumulated shells for their later fossilization. Lists and descriptions of a large number of known, submarine sediment slides and flows can be found in the following works: Embly and Jacobi (1978), Kelts and Arthur (1981), Saxov and Nieuwenhuis (1982) and Cook and Mullins (1983). The article by Embly and Jacobi

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submarine slides, and storm-produced currents, rather than by turbidity flows. If they had been buried by turbidity current flows, the fossils would have been sorted according to size and density.

describes mainly slides and flows which occurred on slopes of 3 degrees or less, and in water depths of greater than 200 meters (p. 207).

In areas inland, on the continents, where there are great, thick sequences of sedimentary strata—as in most of the United States—stratigraphers and sedimentologists have observed the remains (deposits) of many ancient sediment flows which occurred while the areas were under water. These flow areas can be identified by the shape of the sediment mass, a sharply defined base, and the thinning out of the mass at its extremities. The gradation of particle size in various parts of the body of sediment, due to difference in the velocity of movement and differences in density in different areas of the flow, also aid in identification. So, we do have a good record of sediment-flow burial events in the sedimentary strata inland, on the continents.

Also, in the inland areas, the sedimentary formations contain many small bodies of silt, sand, and sometimes gravel. (Some of them are known as "lenses" of sediment, due to their lens-like shape.) Some of these bodies of sediment show definite evidence of having been accumulated rapidly by the direct action of storms on the seacoasts and often resemble sediment masses which are piled up by present-day hurricanes. Many such storm deposits are found in ancient sedimentary strata, and are described in the research reports of sedimentary geology—including large numbers of fossils which are found in the storm sediments (Kreisa, 1981).

The failure of creationist authors to recognize and disseminate the data concerning these methods by which rapid burial takes place has given most creationists the erroneous idea that natural processes could not have formed the fossil deposits (see Myers, 1984, pp. 54-55). The belief that the majority of these deposits were formed by the Biblical Flood, which we recognize as being relatively recent, is especially untenable when we consider the mature state of most of the fossils found on the continents. Nearly all of these show not only the evidences for having been completely fossilized and encased in cemented sediment, but also the marks of having been further altered chemically and physically over long periods of time. In many formations we even find fossils which have been "reworked." That is, they are fragments which were eroded out of older strata and then incorporated into new rock layers.

Within the past few years some young-earth creationist authors have learned that certain sediment flows have been observed in the earth's strata, and have hypothesized that they took place during the Biblical Flood. It *is* likely that sediment slides and flows occurred during the Biblical Flood, and it is possible that some of these may have been preserved in near-surface formations on land. But there is no conceivable way that such masses of soft sediments could have retained their *form and identity* if they were rapidly covered by the weight of thousands of feet of sedimentary deposit and subjected to the tectonic movements which are thought to have accompanied the Flood. We must realize that these sediment-flow deposits are often found at more than one level in a given sedimentary column, the lower ones having been buried very deeply. This is illustrated in the strata of the Devonian, Catskill clastic wedge deposits of Pennsylvania and New York (Thompson and Sevon, 1982, pp. 23-31, 102-04, 115-16).

As we pointed out in the section on significances of the great thicknesses of sedimentary sequences found in the Appalachians, uncemented layers of mud and other sediments amalgamate into a confused mass if they are subjected to great weight, and to disturbing tectonic events. Yet we find the neatly-preserved remains of ancient debris flows* deep in the Appalachian and other strata (Cook and Mullins, 1983, pp. 562-64), still showing a striking resemblance to the flows which have occurred in recent times and have been found on or near the surface of the sea floor—though much more mature and cemented than the latter flows. (Compare Cook and Mullins, 1983, pp. 567-69.)

4. Sediment Flows as Agents of Terrestrial Burial

Concerning the burial of terrestrial animals such as amphibians, reptiles, and mammals, one has only to recall the fact that sediment flows have been observed to occur on land during local floods, and that some of these have left rather thick and extensive deposits which contain many kinds of objects and animal and plant bodies. From this it is evident that most of the terrestrial-type fossils found in the earth's strata could have been buried by this same means. (The remains of very severe local floods in ancient strata have been recognized in several parts of North America and other continents for most of this century.) On the other hand, we do not deny the possibility that some near-surface "fossil-graveyards" may have been formed by the Biblical Flood. The frozen mammoths of Siberia are an example of this possibility.

But it is false logic to conclude that because *some* terrestrial-type fossils may be the result of burials which occurred during the Flood, then most or all terrestrial fossils originated in that manner. Neglect of the well-known principles of rock lithification which we gave in Chapter 3 has caused many creationists to go astray in this respect. They as well as the present writer agree that the Biblical Flood occurred less than one hundred thousand years ago; so we have to realize that fossils which are found embedded in hard, fully-cemented sedimentary rock were entombed in that rock long before the Flood—unless the rock is the one distinctive type of limestone which can become cemented rapidly, namely beachrock.

5. Fossils Which Were Buried in the Diatomaceous-Earth Deposits at Lompoc, California

The well-known diatomaceous sediment deposits at Lompoc have been found to contain many macrofossils, such as marine fishes and even a whale. (Such fossils are frequently uncovered there by mining operations, since the "diatomaceous earth" has several commercial uses.) From the positions in which the animals were trapped in the diatomaceous sediment and from the excellent state of their preservation, we conclude that these fossils are the result of a rapid burial event. Before the discovery of rapid, submarine sediment flows the circumstances under which these animals were buried was very much a mystery. Followers of "Flood Geology" sometimes made the claim that the Biblical Flood was the only event that ever occurred on earth that could have caused these burials. However, this was always a very unsatisfactory hypothesis, because the questions of where this great, thick mass of diatom shells came from still remained.

Diatoms are microscopic-size plants which live either a floating (planktonic) existence near the surface of the oceans and of other bodies of water, or live on the bottom if the water is not so deep as to reduce the light too much for their photosynthesis. Diatoms are actually one group of the algae, and have the distinctive ability to secrete a thin, very durable, silicon dioxide shell ("frustule") in which to live. When they die, the protoplasm disintegrates and the shell sinks to the bottom of the ocean. In areas where diatoms grow in abundance, a few centimeters of diatom-shell sediment can accumulate on the sea floor in one thousand years. There is obviously no way that the waters of a great flood could *select* large quantities of diatom shells from the ocean surface, or from the diatom deposits on the ocean floors, and safely transport them in relatively pure form to the California area, to produce diatom beds which are several hundreds of feet thick. And we are not at liberty to postulate that God assembled all those multiplied trillions of microshells to the California coast by a special miracle, and caused them to suddenly drop out of the surging waters in a way that would confuse, smother, and bury the animals before they could escape. (Remember that most of these diatoms are so small that at least 400 diameters magnification is required for seeing them under the microscope.) So it surely seems far better to recognize the natural world of microorganisms, and their growth and deposition, for what they are—a part of God's wonderful, orderly creation.

Because of the long periods of time which diatoms have existed in the oceans, the shells have been able to accumulate to great thicknesses on some parts of the ocean floors. Drillings made by the Deep Sea Drilling Project crews have located beds of diatom sediment hundreds of feet thick in several areas of the world. For example, at 53° 32′ south latitude, south of western Australia, the drillings of Cruise no. 28 recovered approximately 260 feet of diatom sediment cores from the hole drilled at Site 265. Nearly all of this sediment contained 80% to 90% diatom shells (Hayes, Frakes, et al., 1975, pp. 60-65). Since the drilling crew recovered cores of only about 25% of the total thickness of diatomaceous sediments they drilled, the thickness of diatom sediments there is much more than 260 feet. The cores which were recovered were from fairly regular intervals from the surface of the sea floor down to a depth of 370 meters. Drilling samples were taken continuously from the intervals which were not cored, and it was found that diatom shells make up a high percentage of almost all of the entire sediment column drilled (Hayes, Frakes, et al., 1975, pp. 51-52, 60-65). Then at Site 266, three degrees further south, they drilled through 148 meters of practically continuous diatom ooze of similar diatom content to that of Site 265, and approximately 50% of the 148 meters were recovered as cores (Hayes, Frakes, et al., 1975, pp 82-84, 92-97).

Some other drilling sites where the Deep Sea Drilling Project discovered thick deposits of sediments containing high percentages of diatoms are as follows:

- Site 329, at 50° 39′ south latitude, east of the southern tip of South America. The total depth drilled was 464 meters, with almost 50% of the sediment column being recovered as cores. Nearly all of the sediments from the surface of the sea floor down to 246 meters had a diatom content of at least 40%. (Barker, Dalziel, et al., 1976, pp. 143, 160-70, 329.)

- Site 173, at 39° 57′ north latitude, off the coast of northern California (125° 27′ west longitude). Diatomaceous sediments were encountered at 130 meters below the sea floor, and the next 71 meters were diatom ooze and diatomite (very rich in diatoms). The arrangement and purity of the sediments indicate that these 71 meters represent "a continuous record of high diatomaceous productivity" during the Miocene Epoch. (Kulm, von Huene, et al., 1973, pp. 31, 55-62, 674-75.)

- Site 184, at 53° 42′ north latitude, south of the Aleutian Islands (170° 55′ west longitude). This site was drilled to a depth of 603 meters, and almost all of this entire sediment column was very rich in diatoms, most of it being classified as "diatom ooze." (Creager, Scholl, et al., 1973, pp. 93, 102-43, 807.)

- Site 185, at 54° 25′ north latitude and 169° 14′ west longitude. The total depth drilled beneath the sea floor here was 728 meters, with the upper 600 meters being mostly diatom ooze (very similar to that of Site 184). (Creager, Scholl, et al., 1973, pp. 169, 176-204.)

- Site 188, at 53° 45′ north latitude and 178° 39′ east longitude (in the western Aleutian Islands). The total depth drilled was 638 meters, with 580 meters of it consisting mainly of diatom ooze. (Creager, Scholl, et al., 1973, pp. 291, 298-320.)

- Site 192, at 53° north latitude and 164° 42′ east longitude. The total depth drilled here was 942 meters, with the upper 550 meters being mostly diatom ooze—except for some interruption by volcanic ash beds in the upper 125 meters of it. (Creager, Scholl, et al., 1973, pp. 478-526.)

For all of these sites listed, the sources (*Initial Reports of the Deep Sea Drilling Project*, by the authors I have cited) have a detailed listing of the sediment content, meter-by-meter, and include photographs of the cores. These thoroughly documented examples, together with the results reported in other volumes of the *Initial Reports* series, from various parts of the world's oceans, show that there are vast, very thick expanses of diatom sediments which have accumulated by natural sedimentation. In any place where such an accumulation is lying on a gentle slope of the sea floor, it is possible for a sediment flow of diatomaceous sediments to occur.

Because of these facts it is logical to conclude that the Lompoc diatom beds were deposited naturally on the ocean floor, and that sometime before the period of tectonic activity which finally raised them to an elevation above sea level, the earthquakes in that area triggered at least one large sediment slide and flow which overwhelmed and buried the animals that were down-slope from where the slide began. As pointed out in the early parts of this section on rapid burial, we now know of large sediment flows in various parts of the world which apparently had all of the characteristics necessary for overwhelming and burying both swift and large marine animals. Henry Morris's statements concerning the fossilization of so many fish in the diatomaceous sediments near Lompoc, California, shows how desperately he needs to acquire a knowledge of natural burial events (Morris, 1974, pp. 97-98).

6. The Burial of Non-living, Ephemeral Sedimentary Structures

Before ending this section we should refer to the burial and preservation of sedimentary structures, such as ripple marks, cross bedding, sole marks, and desiccation cracks. Myers (1984, p. 43) emphasizes the claim, made by Morris and others, that such ephemeral structures could not have been preserved in the sedimentary strata except by a worldwide flood. This belief is of course due to a lack of knowledge of the many and frequent burial events during geologic history to which we have been referring. The evidence of these events is seen at *many* levels in the strata of the rock systems which are present in local stratigraphic columns.

Sediment slides and flows, and storms on the coasts, are very capable of burying ripple marks and other sedimentary structures intact. Why then should anyone think that a great flood would be necessary for burying the results of wave and current actions on the sea floor at various levels in a sedimentary column? It is much more likely that normal burial events such as mud flows or storm deposits could effectively bury them than could a great convulsive flood such as Morris visualizes. The latter would surely be far more likely to destroy such ephemeral structures than to cover and preserve them.

CHAPTER 7

FOSSIL DISTRIBUTION AND THE "ECOLOGICAL ZONING" HYPOTHESIS

A problem which young-earth creationists have always had to face is that there are many very common kinds of fossils which are found in the deeper layers of the sedimentary cover of the earth, but not in the upper or younger layers. If practically all of the earth's sedimentary layers were formed by the surging waters of the Biblical Flood, as they maintain, then how could a specific kind of animal which was very abundant on the earth escape being mixed into practically all levels of strata?

Dr. Gary Parker, formerly of the Institute for Creation Research, is quoted by Myers as admitting that this problem exists. Parker's statement, as quoted by Myers, is:

> Scientifically, the major challenge facing Flood geologists is the regularity of the fossil record. If the Flood and its aftermath were responsible for deposition of the fossil record, would not plants and animals be all jumbled together?
>
> Sometimes fossils *are* jumbled together. . . . Still, the majority of fossils are associated consistently with identifiable systems such as the Cambrian, Ordovician, etc. (Myers, 1984, p. 46; quoted from *The Fossil Record in Christian Perspective*, by Parker, 1978, p. 77.)

Even though he admits that fossil distribution is a serious problem for young-earth creationists, Parker later attempts to assure his readers that the "ecological zoning" hypothesis which was set forth by some of his colleagues is adequate to solve it (Morris & Parker, 1982, pp. 129-31).

Morris uses the ecological zoning hypothesis extensively, too, but in his *Scientific Creationism* concentrates mainly on trying to minimize the problem of fossil distribution. He says:

> In the preceding chapter, we pointed out much evidence that the plants and animals in the fossils were much the same as in the present world. The same classification system applies, with the same categories and the same gaps between the categories. Most modern plants and animals can be found in the fossils, and a great many fossil animals and plants are still living today, especially when we allow for variations within the kinds to adjust to changing environments.

> All of which indicates that many organisms of the fossils, in all "ages," were indeed contemporaneous, since they have in fact survived into the present era. (Morris, 1974, p. 116.)

This may sound reassuring to a layman, but any paleontologist—and many biologists—will immediately recognize how incorrect such a claim is. Notice that Morris says that the classification system of the modern and ancient animal worlds has "the same categories and the same gaps between the categories." This is such an obvious, important, and misleading error that we will now examine several of the outstanding examples of exactly the opposite which are found within the sedimentary rock strata of the earth.

1. Examples of Great Differences Between Ancient and Modern Forms of Animals

It is true that most of the 20-odd *phyla** of modern animals have some representatives in the early strata systems. But *within* individual phyla there are great differences. For example, it has long been recognized that nearly one-half of all species of Phylum Mollusca are found only as extinct fossils, and that only about 260 of the known 30,000 species of Phylum Brachiopoda are living today. Within these phyla—and also in Phylum Bryozoa, Phylum Cnidaria (Coelenterata) and Phylum Echinodermata—it is not just *species* that are extinct, but there are many families, orders, and even subclasses, which are known only as ancient fossils. (The five phyla named above make up practically all of the *volume* of macrofossils* we find in the rock strata.) The trilobites (members of Phylum Arthropoda), which became extinct before the end of the Paleozoic* Era, make up a very small percentage of the fossil assemblages which we find in the rocks. But all eight orders of the trilobites, with all their suborders, families, genera,* and species, are extinct and confined to the Paleozoic rock systems.

Morris, not knowing that the trilobites had a relatively light (non-dense) chitinous skeleton, similar to that of crabs, has long said that they were so dense that they all sank to the lower layers during the Flood. Actually they were much less dense than the clam-type mollusks which are found in great abundance in the rock systems of the Mesozoic* and Cenozoic* eras; and both animals types lived in the same marine ecological zone (subtidal* sea floor).

Let us consider some of the large extinct groups within the five phyla we have just named. All of these phyla—Mollusca, Brachiopoda, Bryozoa, Cnidaria, and Echinodermata—have contributed very extensively to the immense volume of macrofossils which are found in the Paleozoic rock systems (especially in limestone deposits). And all five of these phyla have major groups (families, orders, and sometimes even whole classes) which are extinct, as documented in any good paleontology textbook.

In the case of Phylum Echinodermata (which contains the starfishes and sand dollars), the members of Class Crinoidea (the "sea lilies" and "feather stars") contributed greatly to the masses of fossils we find in Paleozoic strata. There are now only 650 known, living species of these "crinoids," but 5,000 extinct species have been classified. Many of the extinct species are very abundant in the Paleozoic rock systems of the Appalachians and in other parts of the world. These animals have a long, segmented, calcified stalk by which they are loosely attached to the sea floor. When the animal dies the segments easily become disjointed and buried in the sediments as separate "crinoid rings" (columnals) or as sections of stalks, each with several columnals still attached to each other.

In the *Treatise on Invertebrate Paleontology*, Class Crinoidea ("crinoids" or "sea lilies") is divided into five large subclasses, four of which are found only in the Paleozoic systems of the earth (Cambrian through Permian, except for a few Triassic ones). There were slightly over 160 taxonomic families among these four extinct subclasses, representing a wide variety of crinoid physical forms not living today. Most of the families, all of which are listed in the *Treatise on Invertebrate Paleontology*, included several genera—and of course many more species (Ubaghs, Moore, et al., 1978, pp. 372-93). A few of these ancient crinoids were truly giants, possessing a stalk up to 20 meters long and 10 cm in diameter; many of them possessed structural features which contrast greatly with the species which are living today (Ubaghs, Moore, et al., 1978, pp. 63-64, 113-30).

Another taxonomic* class of Phylum Echinodermata, similar to the crinoids, is Class Blastoidea. This class is entirely extinct, found only in Paleozoic strata (Silurian through Permian). They are not nearly so abundant as the crinoids, but have been found on all the continents except Antarctica. In some places, such as southern Indiana, they are rather abundant. The blastoids are thus considered important enough that the *Treatise on Invertebrate Paleontology* series includes one entire volume of 650 pages describing them (Beaver, Fay, et al., 1967). Seventy-eight genera, grouped as 12 families of blastoids, are described in this volume. No living animals like them have ever been found.

Within the Phylum Cnidaria (Coelenterata) are three *orders** of corals which have been major producers of limestone formations. (Many miles of our nation's roads are paved with the fossilized skeletons of these creatures, because the ancient coral reefs frequently became very thick and massive, and thus are good sites for locating rock quarries.) Two of the most common and productive of these orders, Rugosa and Tabulata, are entirely extinct and are found only in Paleozoic rock systems (except for a few species in the Lower Triassic). The order Rugosa included many species of solitary corals, which grew individually rather than as part of a colony. These solitary species are very commonly found in limestone formations even where there are no reefs. Yet they are *not* found in the limestone deposits of the many geographic areas which are covered by Jurassic through Quaternary rock systems.[17]

[17]The stratigraphic ranges (age ranges) of these and of all other animal fossil groups which we are discussing in this book can easily be found in textbooks of paleontology such as the following: *Principles of Invertebrate Paleontology*, by R. R. Shrock and W. H. Twenhofel: McGraw-Hill Book Co., 1953, 816 pp.;

2. A Great Fossil Group Which Did Not Sink During the Flood

No specimens of the *other* of the three major orders of corals—Order Scleractinia—are found in any of the vast areas and thicknesses of Paleozoic rock systems on the earth. These corals, often called "scleractinians" or "hexacorals," have built (together with the help of algae) all of the many great reefs which are found in the oceans today, and also many that are found in limestone deposits of the Triassic System up through the Quaternary. This order of corals includes many solitary, as well as colonial, species. Of great significance for our consideration of fossil distribution is the fact that the scleractinian corals all have very fundamental and obvious morphologic differences which distinguish them from both of the great extinct orders we have just discussed. So there is no possibility of confusing them with Order Rugosa (the "tetracorals") or with Order Tabulata (the "tabulate corals") when they are found in the field—or as one examines museum specimens. Large numbers of specimens of all three orders are available in any of the larger museums, and all of them are well described in most paleontology textbooks. The distinct difference between these three orders can be observed and understood even by people who have no training in paleontology. Thus, Morris's claim that the ancient animal groups "were much the same as in the present world," without important contrasts (1974, p. 116), is easily refuted by examining the fossil specimens of these, as well as of several other animal phyla.

Since the scleractinian corals are found in abundance almost worldwide, and since more actual *volume* of their fossils is present on the earth than of any other group of Cenozoic, animal megafossils, it is inconceivable that they would not have become mixed into the lower strata—in fact, all strata—of the earth's sedimentary cover, if the "Flood geology" hypothesis were correct. By reading any of Henry Morris's descriptions of the convulsive activities which he visualizes as having occurred during the Flood (such as that quoted just below from Morris, 1974, pp. 117-18), one can see how completely illogical it is to assert that the Paleozoic strata were formed by the Flood, with these dense, calcified animals somehow being held up and not allowed to sink into the lower layers of sediment. They are *as dense* as the corals of the two great ancient orders, because composed of $CaCO_3$, the same as those orders were.

Morris's description of the Biblical Flood, in which these corals were excluded from the lower two-thirds of the local sedimentary columns supposedly being formed, reads as follows:

Invertebrate Paleontology and Evolution, by E. N. K. Clarkson: George Allen and Unwin, 1979, 323 pp.; *Treatise on Invertebrate Paleontology* — Published by the Geological Society of America; many editors; forty volumes now available and some still in process of preparation. The volumes which describe the taxonomic groups referred to in this section are: *Coelenterata, Supplement 1, Rugosa and Tabulata*, Part F, 2 vols., 1981; *Bryozoa (Revised) vol. 1*, Part G, 1983; *Brachiopoda*, Part H, 2 vols., 1965; *Mollusca 3*, Part K, 1964; *Mollusca 6*, Part N, 2 vols., 1969; *Echinodermata 2*, Part S, vol. 2, 1967; and *Echinodermata 2, Crinoidea*, Part T, 3 vols., 1978.

> Visualize, then, a great hydraulic cataclysm bursting upon the present world, with currents of waters pouring perpetually from the skies and erupting continuously from the earth's crust, all over the world, for weeks on end, until the entire globe was submerged, accompanied by outpourings of magma from the mantle, gigantic earth movements, landslides, tsunamis, and explosions. The uniformitarian will of course question how such a cataclysm could be caused, and this will be considered shortly, but for the moment simply take it as a model and visualize the expected results if it should happen today.
>
> Sooner or later all land animals would perish. Many, but not all, marine animals would perish. . . .
>
> On the ocean bottom, upwelling sediments and subterranean waters and magmas would entomb hordes of invertebrates. The waters would undergo rapid changes in heat and salinity, great slurries would form, and immense amounts of chemicals would be dissolved and dispersed throughout the seaways.
>
> Eventually, the land sediments and waters would commingle with those in the ocean. Finally the sediments would settle out as the waters slowed down. . . . (Morris, 1974, pp. 117-18).

If Morris were correct in this scenario of how the sedimentary cover of the earth was formed, then God would have had to perform a very specialized miracle to keep the scleractinian corals out of the lower strata. A similar miracle would also have had to be performed in order to exclude the diatoms of the earth from the same strata, as we will see in the section on microfossils below.

Students of creation doctrine may here ask concerning the actual time when the scleractinian corals and the diatoms appeared on earth. Were they *not at all* in existence until the Mesozoic Era? This we cannot answer; but it is obvious that they did not become common or dominant forms of sea life until Mesozoic times. In nature we often observe that it is possible for a particular form of life to be very rare as to its development of a population, and yet survive. So it could be that many life forms and species which do not appear in the fossil record until after the Paleozoic Era were actually in existence long before they became sufficiently numerous to be discovered by paleontologic research.

However, this is not a problem in dealing with the nature of fossil distribution as invalidating the "Flood geology" hypothesis of the formation of the sedimentary cover of the earth. If a certain form of hard-shelled, marine animal were abundant at the time of the Flood, then it would obviously show up in some of the strata that were formed during that event. Those species which were rare would obviously not be common in the record, and so might be overlooked. So, when we say that certain forms of life were "not present" during parts of the geologic record, we are not asserting that they did not exist at all during those times.

3. More Concerning the Fossils Which Supposedly "Stayed Down"

Let us come back a moment to the great, worldwide groups of brachiopods, crinoids, bryozoans, and mollusks that are found only in the Paleozoic and Lower Mesozoic strata systems. The description of the Flood which we have just quoted from Morris defies all possibility of these forms of life having been restricted to these strata systems—and yet they *are in fact* restricted to these systems, worldwide. If these fossil forms were rare in the fossil record we might suppose that their absence from the Upper Mesozoic and the Cenozoic systems is only a problem of their not having been found.

But this is not at all the case. In Paleozoic times, brachiopods, crinoids, and bryozoans were exceedingly abundant, and some of the forms of mollusks such as the extinct cephalopods were at least very common. In many places on the earth, as frequently in the Appalachians, there are broad areas in which at least one out of ten rocks which you may pick up when taking a walk will contain several brachiopods and/or crinoids. And a high percentage of our paved highways contain hundreds of thousands of these extinct Paleozoic fossils per mile—from the rock quarries. If they were that abundant, and if the earth's sedimentary strata were practically all formed by the Flood, why are these fossil kinds—and individuals—restricted to only approximately half (the Paleozoic half) of the rock formations? The forces of upheaval and mixing of the components of the earth's crust in Morris's Flood scenario could not possibly have permitted such a restriction without a special miracle. This is even more obvious when one considers that the crinoids grew on long, fragile stalks which were *very* easily swept along by strong water currents (like tangled weeds), and also that the shells of the brachiopods were no more dense than those of the more recent types of clams which are found *only* in the Cenozoic strata systems. (The brachiopods lived in the same type of sea-floor environment as did the clams.)

4. Microfossils*—No Possible Way to Have Hidden

Morris attempted, in his *Scientific Creationism* (1974), to lay down the principle that "it is the fossils which speak most clearly of rapid formation [of the geologic strata]" (1974, p. 95). If he had had any idea of what impossible problems he would have to face in trying to defend such an assertion, he surely would not have made it. We have already seen that some types of fossils, such as corals and diatoms, give strong evidence of having been formed and deposited slowly; and others give evidence of having been deposited rapidly but intermittently by debris flows, storms on the seacoasts, and other natural processes. Thus "Flood geology" does not provide a plausible way of explaining the formation of these fossil deposits. Now we will consider another aspect of fossil distribution for which "Flood geology" cannot account, unless it resorts to saying that God restricted selected types of fossils to certain stratigraphic levels by special miracles.

It is well known that the world's oceans are teeming with microorganisms which produce shells (or "skeletons") of various types in which to live. The fact that the shells are composed of minerals which are more dense than water is really no problem for the floating existence which most of these organisms have. Gas bubbles are usually maintained in the protoplasm of the single cell of the shell's occupant in order to provide buoyancy.

Some of these microorganisms, such as the coccolithophores and the foraminiferans, produce a calcium carbonate shell, while others—mainly the radiolarians and diatoms—have a silicon dioxide shell. Either of these two great groups could be used to illustrate the fact that the shells of some subgroups of marine microorganisms are restricted to the Mesozoic and Cenozoic strata systems, while other subgroups are found abundantly not only in these systems, but throughout the Paleozoic strata as well—or at least down into the Middle Cambrian. This is of special significance because most of these organisms live in the same marine* ecological zone, namely the pelagic.* And, of the ones which do live down on the bottom (benthic environment), many are totally absent from the *deeper* marine-type rock formations. For example, here in the Appalachians none of the thousands of oil wells drilled into Paleozoic rock systems have produced any diatoms—either pelagic or benthic ones—from those systems.[18] Yet diatoms are very abundant in the rock systems from the Cretaceous (Upper Mesozoic) on up. (Chapter 6 of this book includes a rather extensive amount of data on how fabulously abundant the diatoms of the ocean are *and have been*, and how they have produced extremely thick accumulations on the ocean floors for many millions of years.)

Perhaps someone will say, "There may have been some influence or force which kept this great accumulation of diatom shells from being mixed into the lower rock layers during the Flood." One might be tempted to accept such a hypothesis were it not for the fact that the oceans are also teeming with microfossils of the Order Radiolaria ("radiolarians") which have an average size very similar to that of diatoms and have shells composed of the *same* mineral as that of the diatoms (SiO_2). Up to this point I have been emphasizing the accumulations of diatoms on the ocean floor, but the drillings of the Deep Sea Drilling Project have also located very widespread and thick deposits of radiolarian ooze in the ocean floor, practically worldwide. Just one example (not unusual) of the radiolarian deposits found was a continuous thickness of 190 meters of almost pure radiolarian ooze at Site 166 in the ocean floor southwest of the Hawaiian Islands (Winterer, Ewing, et al., 1973, pp. 103, 118-24).

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[18]Someone who is unfamiliar with the way that drilling sample investigations are carried out might suggest that geologists have actually found diatom shells in the Paleozoic strata, but that they have concealed the information in order to protect evolutionary theory. Even if they could conceal the information, it would be no advantage for evolutionary theory, since these are only one-celled organisms. Organisms much more complex than these were abundant early in the Cambrian Period.

In summary, we here have two great categories of one-celled, marine microfossils, both about the same size and abundance, and both have shells of the same composition (silicon dioxide). They both live in the same ecological zone (pelagic), *except that* a very considerable proportion of the diatoms live on the sea *bottom* in areas where the water is not too deep to badly restrict the sunlight which they require for photosynthesis. The fact that some diatoms are bottom dwellers, whereas radiolarians are all pelagic, would lead us to expect, according to the "Flood geology" hypothesis, that the diatoms would be found in all systems of sedimentary rock but that the radiolarians would be restricted to the upper systems. Exactly the opposite is true. Radiolarian shells are abundant in the rock systems all the way down into the Cambrian, but the diatom shells have *never* been found below the Jurassic.

Why then *are* radiolarians found all the way down into the Cambrian, but diatoms not? There is no logical conclusion but to recognize that at least practically all species of diatoms just *did not exist* at the time that the pre-Jurassic rock systems were being formed. If all the rock systems (Cambrian through Tertiary) had been formed by the Biblical Flood, as Morris and other young-earth creationists believe, then all of the rock systems would contain *both* radiolarians and diatoms. This is true because both were exceedingly abundant at the time of the Flood, and neither group had any characteristic, such as a distinctly different density, shape, or size, which would restrict it to the upper layers of rock being formed.

If any young-earth creationists want to contest the fact that both groups were very abundant at the time of the Flood, let them examine and recognize the abundance of both, in terrestrial sedimentary strata which they take to have been formed during the Flood. After all, they at least recognize the vast deposit of diatom shells in the Lompoc, California area which we discussed in the previous chapter, as having been in existence at the time of the Flood. Or, if anyone might still try to suppose that these diatoms and the great, thick beds of them in the oceans grew *since* the Flood, they will have to face the fact that such prolific growth is wholly unnatural, and that no provision for it was included in the natural laws of biological growth which God ordained. It is true that many kinds of algae occasionally, when environmental conditions are right, multiply with unusual rapidity, forming what biologists call "algal bloom." But always, with no known exception, this prolific growth comes to a hurried end—usually within a few days. The algae, whether they be diatoms or another group, "upset the balance of nature" by their rapid increase. That is, they succumb to such imbalances as the accumulation of excess waste products of their own metabolism, the lack of raw materials in the water, and diseases or other abnormalities which arise in the cellular population.

Furthermore, even if there were some way that diatoms could multiply and produce discarded shells as fast as would be required for forming one to two thousand feet thickness of them on the ocean floor within a thousand years, the physical laws of settling of such small objects through the long column of ocean water are not such as to allow anything like *that* rapid a settling rate. (The very slow settling rates of small particles in even tranquil ocean water are well known, and are discussed in oceanography and physical science textbooks under the heading "Stokes' law of settling.") So, the distinctive distribution of these and other microfossils in the geologic column demands that we recognize the sedimentary strata systems as having been formed naturally and in an orderly manner.

5. The "Ecological Zoning" Hypothesis

(a) The Hypothesis as Related to Deposits of Macrofossils

During the early 1970's young-earth creationists began to popularize their hypothesis of "ecological zoning" in order to try to explain the worldwide absence of certain kinds of fossils in various strata systems. This hypothesis was obviously of no value in dealing with marine microfossils, but the adherents of "Flood geology" felt that they could use it for explaining the distribution of macrofossils of most of the invertebrate* phyla, as well as of vertebrates. It is now a well-known idea among young-earth creationists, and many followers of young-earth creationism suppose that it has been tested and scientifically verified. Of course such is not the case. The fact that this hypothesis ignores the real extent of the sedimentary cover of the earth—both vertical and horizontal—and also ignores the pelagic,* marine microfossils—invalidates any attempts that its adherents might make to test it. Nevertheless, many creationist leaders continue to use the ecological zoning idea as an attempt to dispose of the problems they face concerning fossil distribution.

Thus, Morris and Parker (1982, p. 130) present a neatly arranged diagram of this hypothesis as an explanation of why the fossils appear as they do. This diagram shows a seashore with swampy land nearby, and higher land farther away from the shore. Different kinds of animals are shown in each of three basic kinds of environment: sea-shell animals and trilobites on the sea bottom; amphibians, reptiles, and insects in the swamps; and larger reptiles and mammals on the higher ground. The accompanying explanation tells the reader that the reason we find certain kinds of sea-shell animals and trilobites fossilized only in the deeper, older strata of the earth is that they lived down on the bottom and got buried *there* by the Flood; and the reason we find amphibians, reptiles, and insects farther up in the strata is that they were living a few feet or meters above the water level, and got buried there; and the reason we find the mammals only in the upper, younger strata of the earth is that they were living higher up away from the swamps. This explanation may sound reasonable at first glance, but it is absolutely contrary to what we see when we examine the rock strata of the earth.

The assemblage of organisms which we have just described, together with the soft sediments and soil in and on which they live, if buried in a great flood, might produce 10 or 15 feet of thickness of sediments. But, what about the vast areas back away from the seacoasts which have 20,000 or more feet of sediments, with thousands of feet of this thickness being highly fossiliferous? Where could all these sediments and fossils—often spread out in broad, uniform layers—have come from? This question becomes especially difficult for anyone who tries to use the ecological zoning hypothesis, because in *it* the animals are supposed to have been buried at or very near to where they were living. In the 20,000 or more feet of sedimentary layers which cover thousands of square miles in parts of the North American continent, approximately the lower two-thirds of the strata have only the old types of marine animals and plants. (Nearly always, at least a few thousand of this 13,000 feet consists of limestone which contains a high percentage of biogenic components from shallow-water, marine sea floors.) Then the upper 7,000 feet (approximately) of sedimentary rocks include nonmarine, brackish, and marine deposits with different Mesozoic* and Cenozoic* forms of terrestrial, swamp, and marine fossil types.

Here then is a "mind-boggling" problem for "Flood geology" to face. How could 13,000 feet of sea-shell-animal sediments be "stacked up" all over a contiguous area as large as the state of West Virginia by using just a thin layer of ocean-bottom off-shore from the land? The Flood would have had to collect sediments and sea-shell animals from at least 1,000 square miles just to build up the 13,000-foot deposit on *one* square mile of the inland area.

In thinking about this, remember that almost none of the sea-shell animals are from the *deep* sea. These are the clam, snail, brachiopod, crinoid, coral, and bryozoan types; so they are the inhabitants of shallow seas and continental shelves. Thus, the area around the continents which could furnish such animals for the 13,000-foot-thick sediment deposits is very limited. This means that there would be no place to find 1,000 square miles of clams, brachiopods, etc. for the Flood to use in building each square mile of a 13,000-foot-thick expanse the size of the state of Ohio or larger (a contiguous area as large as West Virginia, plus other areas in the eastern part of the United States).

Of course, to visualize the production of this thick expanse of strata in this manner is illogical for several other reasons. One of these reasons is the impossible problem of how the surging waters of a mighty flood could transport the many square miles of sediments inland in an orderly manner and spread them in neat, uniform layers over the one square mile to form the thick series of strata we see now. A further problem is that aspect of the ecological zoning hypothesis which requires that the animals be buried very near to where they were when the Flood came upon them. So, young-earth creationists have no place in their hypothesis for the necessary, long-distance transport.

But suppose we were to go ahead and assume that the Flood collected sediments and organisms from an unrealistically large area of continental shelf to form the more than 25,000 square miles of 13,000-foot-thick marine deposit we find in the Central Appalachians? While the flood waters were collecting the sediments and organisms, and sweeping them inland to form these 13,000 feet of strata, how were all the *later types* of clams, snails, ostracods, and other shell-type animals *held in reserve*, ready to be added to the deposit after the older types had been laid down? We must not forget that, as we find the fossils today in vertical sequences of strata, the lower strata contain many hundreds of species of shell-type animals, each in great abundance, which became extinct before the upper strata were laid down, with their more recent types of aquatic animals.

Another of the problems which completely eliminate the possibility of such a rapid buildup of 20,000-foot, neatly-layered sediment masses, is that of the required time for cementation, to which we have already referred in earlier sections. One year affords no time for the cementing of the sediments into stable rock. Four miles of soft sediments in a single mass would produce sufficient pressure to crush all delicate fossils in the lower layers, and to amalgamate the layers into a hopelessly confused mixture—especially since the great earthquakes and crustal upheavals which are said to have accompanied the Flood would have had a profound mixing effect.

So, from a whole series of aspects, the ecological zoning idea is an absolutely impossible explanation of the laying down of the earth's deposits of fossiliferous sediments. Perhaps the greatest reason that the young-earth leaders fell into this "trap" was the fact that they have habitually failed to take into account the real extent of the fossiliferous sedimentary cover of North America and other continents.

(b)The "Ecological Zoning" Hypothesis as Related to Deposits of Marine Microfossils

In the subsection entitled "Microfossils—No Possible Way to Have Hidden," we gave a somewhat detailed explanation of how the distribution of radiolarians and diatoms invalidates the hypothesis that most or all of the sedimentary strata were formed within a short period of time. At this point we want to consider some of the other types of marine microfossils and how their distribution gives additional evidence for slow, natural deposition of many of the sediment layers of the world. The distribution of these additional types of microfossils is actually another example of how the data of earth-science research show the ecological zoning idea to be incorrect, but the principles by which the distribution is recognized and used are somewhat different from those which we have considered in the discussion on radiolarians and diatoms.

During the past 20 years the presence or absence of certain genera and species of marine, shell-producing, calcareous microorganisms in the sediment layers of the sea floors has been used extensively for the purpose of dating the layers. I would not propose to defend all of the dates and time periods which are assigned to the layers by this means; there is some disagreement among paleontologists on the details of these. But the basic fact that these organisms form a distinctive microfauna and microflora in upper layers as contrasted with deeper layers *at each drilling site* is a truth which cannot be denied. Cores and other samples of at least several hundred feet of highly fossiliferous sediments have been collected from hundreds of drilling sites in all of the world's oceans, by the Deep Sea Drilling Project and by offshore petroleum drilling operations. The genera and species of planktonic* algae known as coccolithophores, and of protozoans of the Order Foraminifera (some planktonic, but mostly benthic in habitat) are identified and compared in the samples and cores from various levels in each drill hole. The variation in fossil genera and species forms distinct zones of taxonomic isolation in practically all local sediment columns drilled in the world's oceans. The fossil species are also cataloged and compared with genera and species found at other drilling sites. Because the coccolithophores, and also some very abundant species of foraminiferans, are planktonic, the ocean currents have distributed them widely. Thus, fairly accurate time correlations can be made for many sediment levels over a very broad areal extent, based on which species are present and which are absent.

At many of the drilling sites there are hundreds of feet thickness of almost continuous calcareous ooze, made up largely of the skeletons or shells of these organisms. (The coccolithophores produce skeletal, calcareous plates, of distinct designs, rather than an actual shell. These plates are called "coccoliths," and the general name for the preserved remains of the coccolithophores is "nannofossils." The name coccolithophore means "coccolith-bearing.")

There is an amazing diversity of form in the shells of the foraminiferans, and in the coccoliths produced by the algal microfossils, making identification of them into genera and species relatively easy. There are also hundreds of living species of foraminiferans and at least 150 living species of coccolithophores with which the fossil species can be compared. In each drill hole there are usually at least a dozen species of these organisms in the deeper layers which are absent in the upper layers, and a similar number in the upper layers which are not present in the deeper strata. This condition of taxonomic isolation is present in very deep strata of Mesozoic ocean-floor sediments as well as in the upper few hundreds of feet in the local columns. Even though the microfossils have distinct, minute characteristics which make it relatively easy to distinguish one species (or at least genus*) from another, there are no characteristics which would make it possible for one set of kinds to be restricted to deeper or shallower sediment layers produced by a catastrophic flood or other strong currents.

The natural, vertical zoning of the various species of foraminiferans and of nannofossils* has, since the beginning of the Deep Sea Drilling Project, made possible many time correlations of the strata sequences in the ocean floors, and also in chalk deposits now lying high above sea level, in widely separated parts of the world. The *Initial Reports of the Deep Sea Drilling Project* volumes, as well as nearly all journals of sedimentology, oceanography, and paleontology, now have many articles dealing with these correlations by means of nannofossil biostratigraphy (for example, Roth, 1973; Bukry, 1973; Hsü, et al., 1984; and Aubry, 1985). Also the book *Nannofossil Biostratigraphy* by B. U. Haq (1983), presents a very good treatment of the different types of photosynthetic nannofossils which are present in the successive layers of marine sediments, both in the ocean floors and in oil-bearing, marine strata on the continents.

So, we cannot ignore the ever-present fact that the immeasurably vast numbers of these planktonic organisms which lived at various times in the past are separated in the strata according to *when* they lived, died and settled to the ocean floor below. They are *not* mixed up into a homogeneous mass of older species with later species, as they would be if they had been deposited from a suspension of flood waters. The only logical conclusion possible concerning their burial is that their deposition was natural, and not by the convulsions of a great flood that was tearing the sea floor apart and scattering the sediments in many directions, as Morris visualizes.

Just as in the case of the radiolarians and diatoms described above, in the subsection "Microfossils—No Possible Way to Have Hidden," these fossils are extremely abundant, existing in astronomical numbers per square kilometer over wide areas, deep in the ocean floors. Thus, no one can logically make the accusation that the various species are now being assigned to time zones merely because individuals of the earlier (or later) species have been overlooked in the sediment cores.

In the light of all the discoveries concerning fossil distribution, during the past three decades especially, we must conclude that all forms of the ecological zoning hypothesis are illogical and contrary to the observed scientific evidence. Since we as Christians recognize the importance of adhering to truth, we should face our responsibility not to propagate ideas which are in opposition to thousands of definite and careful observations of what the earth's fossiliferous strata are really like. How can an ignoring of physical and biological realities be a proper testimony of the quality of Christianity? During the past four or five years, since creationism became prominent in the courts and in the news, we have seen a flood of examples in scientific and educational publications of how our refusals to recognize scientific data have given the world the impression that the Bible is a hopelessly outdated, unscientific book. This disgrace will continue until we openly confess our wrong methods and put our teaching of creation on a sound basis which is both Biblical and scientific.

Christians must stop fearing the results of systematic, scientific examination of the earth's strata. God is *absolutely* consistent, and thus would never produce a natural world which contradicts his special revelation. We can thus feel free to recognize the obvious conditions we find in the rock formations. For example, when we find clear-cut evidence for scores of *preserved* sea-shore or shallow-water environments lying one above the other in the strata systems, without their showing evidence of catastrophic disruption, we can safely conclude that they were naturally formed and preserved in the locations in which we now find them. At least most of the strata in the areas we have been describing, such as in the Appalachians, give every evidence of being a natural record of the life and sediment deposition through a long period of time.

CHAPTER 8

EVAPORITES*—OCEAN-FLOOR AND CONTINENTAL TYPES OF SALT DEPOSITS

One of the most obvious and easily understood forms of sedimentary evidence for very long periods of time in earth's history is the existence of multiple-layer, thick beds of evaporite* minerals in many parts of the world. Nearly all of these layered deposits are composed mainly of salts which very obviously have been deposited by extensive evaporation of seawater in ancient shallow seas. The multiple (and diverse) layers of these cyclic deposits show that there were many changes of environment during the depositional process, and both seasonal and long-term climatic changes are represented in the layering of most such evaporite formations. (It is highly significant that sedimentologists have now reported on at least several places where this kind of deposition of evaporites is *now occurring*, forming annual couplet layers of evaporite and other related sediment season-by-season. One of these research reports is that of Kushnir (1981), and others will be cited farther along in this chapter.)

The existence of these ancient deposits—some of which are hundreds of feet in thickness and of wide areal extent—is of course a very perplexing problem for those who try to explain the earth's sedimentary cover as having been formed by the Flood. Consequently, most young-earth creationist writers have not referred to these formations, and apparently have not studied the geologic research reports which describe either ancient or recent evaporite deposition.

1. Halite (Sodium Chloride) Deposits of the Deep Ocean Floors

Henry Morris, realizing that geologists have described some kinds of salt deposits as having been formed by natural evaporation, has included a few pages of discussion on the great, non-cyclic deposits of halite (sodium chloride) in his *Scientific Creationism* (Morris, 1974, pp. 105-07). He cites certain evidences which indicate that at least some of these halite deposits were likely formed deep in the ocean floors from the release of salt "from great depths along faults during tectonic movements" (p. 106). Morris's main source of information for this is the Soviet scientist V. I. Sozansky, who made a careful study of halite deposits which lie in the deep ocean floor of the western Atlantic. Morris uses Sozansky's work in an attempt to nullify the evidences for the formation of evaporite deposits by natural evaporation.

What Sozansky has said about the halite deposits observed in his study appears to be correct, but Morris has erroneously assumed that a description of how halite salt deposits which lie deep in the ocean were formed *also applies to* the cyclic deposits of anhydrite* (calcium sulfate), gypsum, calcium carbonate, and some halite layers, which are found far inland on the continents. (These continental deposits are found extending across broad areas which were once covered by shallow inland seas, in Canada, the United States, Australia, and other parts of the world.) Actually, there is little resemblance between these and the deep-ocean halite deposits.

Because Sozansky's studies of salt formations were restricted almost entirely to halite deposits found in ocean floors, he himself has tended to deny the reality of extensive evaporite deposition in ancient times. (Due to his unfamiliarity with such deposits, and his ill-informed statements about them, his works have not been well received among sedimentologists of the U. S., Canada, and Australia, where abundant cyclic, evaporative deposits of anhydrite, gypsum, calcium carbonate, and halite are found. Apparently the very restricted "climate" in which Soviet scientists are required to work has not allowed him to learn the actual nature of the continental, cyclic deposits of evaporites and the fundamental differences between them and the thick, ocean-floor halite deposits which he has studied.) Thus, it is very unfortunate that Morris has supposed that he can safely use the writings of Sozansky to support his notion that extensive evaporite deposits of various salts do not exist.[19]

2. Precipitation of Evaporites in Relatively Deep Bodies of Water on the Continents

Another source which Morris used in his discussion of evaporites was a set of experiments performed by Omer B. Raup. The results of the experiments were reported in Raup (1970). The work of Raup in no way contradicts, or attempts to contradict, the necessity of intensive evaporation of the seawater by wind and sun *before* the layers of cyclic evaporite rock which are so well known could be formed. In his research report (1970) Raup repeatedly states that his experiments were an attempt to approximate the conditions which existed in ancient *evaporite basins* where extensive *evaporative* concentrations of seawater had already occurred. But Morris seems to have misunderstood the purpose, results, and most of the methods of the experiments, supposing that they were an attempt to demonstrate that layers of evaporites could be formed from seawater without time or opportunity for evaporation to take place.[20] The truth is that these were experiments made with *marine brines* which had been prepared in the laboratory. Raup (1970) explains, on pp. 2247 to 2251, that the experiments were performed with the use of 57 liters of normal seawater which were brought from the California coast and evaporated down to concentrated brine solutions. He then says, "The sea water brines were prepared

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[19]All that Morris says about Sozansky's work in his *Science, Scripture, and the Young Earth* (1983, pp. 10-11) is a further demonstration of the fact that he very seriously misinterpreted Sozansky's writings and thus concluded that all of the world's evaporite formations are very similar to the halite deposits in the floor of the Atlantic Ocean.

[20]Misunderstandings of this type are usually due to failure to read the research report carefully, or to mere dependence upon the abstract and conclusion of the paper. This must certainly have been the case here, because Raup's report is very clearly written.

by evaporation to eight stages of concentration: specific gravities of 1.146, 1.166, 1.183, 1.201, 1.219, 1.280, 1.313, and 1.326" (p. 2247).

It should be noted that the specific gravity of 1.146 represents a solution which was evaporated down to approximately 17% of the original seawater volume. (Normal seawater has a density of 1.026.) In his experiments Raup used *some* brine solutions which were made from water, pure sodium chloride, and pure magnesium chloride, but all of these were of concentrations greater that 1.12 specific gravity. Thus, Raup's experiments were being made with concentrated brines of types and densities such as are formed in stagnant seas by natural evaporation—not with unconcentrated seawater or with waters obtained from hydrothermal sources.

In this research report Raup keeps pointing out that the results of the experiments support the principle of the formation of evaporite deposits by natural evaporation. The distinctive feature of his research was that it demonstrated that it is not necessary for evaporation of a body of water—such as a stagnant part of the Red Sea—to proceed *all* the way down to the saturation point of sodium chloride, for example, (sp. gravity 1.219) in order to bring about precipitation of that salt, *if* the concentrated brine moves to other levels in the body of water which possess another type of brine.[21]

3. Organic Matter in Ancient Evaporite Deposits

A further basic error in this treatment of evaporites by Morris is his statement that there is "the complete absence of organic material in 'evaporites.'" (1974, p. 106). This is completely erroneous, and his inclusion of it in the chapter is unaccounted for. Probably Morris was again thinking only of the great halite deposits such as salt domes and some of the ocean-floor salt bodies. But there are large areas in the United States and Canada, as well as in other continents, that are underlain by ancient, cyclic evaporites which contain abundant and very obvious organic remains. There are hundreds of research reports by petroleum geologists which describe these cyclic deposits.

We want to examine evaporite deposits in some detail in this and the next chapter, *not* merely to demonstrate the failure of Morris to understand the great majority of them, but also to see what a decisive and *positive evidence* for great age most of them are. In the next chapter we will consider a few of these large inland evaporite deposits at some length, but at this point we will briefly describe two areas in North America that are well known for their ancient evaporite strata which contain definite and obvious organic components.

(1) There are extensive deposits of thin-bedded anhydrite (calcium sulfate) in the Middle Devonian of western Canada. These evaporite layers underlie a large part of both

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[21]For additional information which complements Raup's work see Sl oss (1969); Schmalz (1969); and Davies and Ludlam (1973), pp. 3527-46.

Alberta and Saskatchewan, in Canada, and regularly contain thin, dark laminae* of organic matter alternating with the anhydrite laminae (Fuller and Porter, 1969, pp. 922-25). This alternating of salt and organic laminations is typical of many of the evaporite formations found in the oil fields of the world. The reason that the organisms which produced the organic matter (mostly algae) could not thrive during the *entire* period of evaporite deposition is that each time the water became concentrated enough to begin precipitating the salt (calcium sulfate in this case), the algal growth was inhibited by the high concentration. The seawater has to be concentrated to slightly less than 20% of its original volume before precipitation of calcium sulfate (gypsum and anhydrite) can begin. Some species of algae are able to survive in saline waters of this concentration (Sloss, 1969, p. 779), but the large volume of growth necessary for producing a noticeable, dark organic layer in the anhydrite deposit can occur only at lesser concentrations. All evidence supports the assumption that these lesser concentrations existed during seasons when rains and other influx of water diluted the inland seas in which these evaporite deposits were formed. Many of the evaporite formations of North America, including the Middle Devonian of Alberta and Saskatchewan, have thicknesses of evaporite salts which contain some thousands of regularly alternating evaporite and organic laminae.

In most of these organic laminae it is impossible to distinguish the remains of the specific organisms which produced the organic substances. This is because the bottom waters of hypersaline* seas are nearly always anoxic, containing very little oxygen. When the algal cells, algal filaments, and other planktonic organisms sink to the bottom, anaerobic species of bacteria bring about a partial decomposition of the organisms. Since very few species of planktonic algae have mineralized cell walls of a kind which would survive the periods of decomposition, the cells are only occasionally identifiable in the organic laminae (compare paragraph 3 of Section 4, (b), below). This decomposition process has been observed and studied in great detail in several of the hypersaline lakes and seas of the world, and is explained in Kirkland and Evans (1981, pp. 187-88). The paper by Kirkland and Evans also gives a great deal of information on the intensity of algal growth (productivity) in the evaporite-producing hypersaline lakes and lagoons which they studied in various parts of the world. It also states the percentages of salinity at which certain algal species readily grow. The high productivity which is often found in hypersaline waters has led Kirkland and Evans, as well as other authors, to postulate that the large amount of algal growth in the ancient evaporative seas provided an appreciable part of the organic matter which was converted into petroleum to form the oil that is so often trapped beneath the evaporite layers.

Another recent source which describes intense algal growth in a brine pool is Jacob Kushnir's "Formation and Early Diagenesis of Varved Evaporite Sediments in a Coastal Hypersaline Pool" (1981). In his detailed study of a hypersaline pool on the coast of the Red Sea at the southern tip of Sinai, Kushnir identified a series of annually-produced, algal-gypsum couplet layers (laminae) extending chronologically from the time of his taking cores of the floor sediments, back at least 15 years. There are 15 easily identifiable couplets in the cores, showing an algal layer and a gypsum layer in each couplet (Fig. 3,

p. 1195). Since Kushnir's studies extended over a period of several seasons he was able to observe that the algal growth, and layer of deposited algal remains, developed in the winter when the brine was not so concentrated; and then that the calcium sulfate—gypsum in this case—formed as a layer in the summer when the increased evaporation rate had further concentrated the brine (pp. 1194-95).

He also observed that the algal remains were identifiable in the younger laminae, but that in the organic laminae of the couplets in the deeper sediments the cell walls were no longer identifiable, because of further disintegration over the longer period of time. However, the dark, organic compounds remain in a preserved state. This seems to exactly correspond to what we find in the many ancient evaporite deposits which have organic laminae alternating with the calcium sulfate.

(2) One of the world's best-known, ancient evaporite formations which contains a large, laterally extensive, vertical sequence of laminated evaporites is the Castile Formation of west Texas and southeast New Mexico. This formation lies deeply buried throughout most of a 90- by 160-mile basin which contains a great number of oil wells, and includes in its thickness approximately 200,000 evaporite "couplet" laminations across most of the basin. (See Figure 6, and see "basin" in glossary.) These thin "couplets" (actually triplets) regularly contain a layer of calcium carbonate ($CaCO_3$), a layer of anhydrite ($CaSO_4$), and an organic layer, in each. (R. Y. Anderson, et al., 1972.) The layers are usually called either "microlayers" or "laminae" (singular "lamina"). The mean thickness per couplet was found to be 1.1 to 2.0 mm, depending on the depth from which the core being studied was taken, in the well.

Because of the presence of the calcium carbonate (calcite in this case) laminae of the "couplets," we are forced to conclude that the surface layer of the body of water which was precipitating the calcite and anhydrite was periodically restored to at least close to 50% of the volume and concentration of normal seawater—possibly even closer to normality. Then, during the season of high evaporation rate, the concentration again increased to where $CaCO_3$ precipitated out; and when the volume was further reduced to approximately 20% of that of normal seawater the $CaSO_4$ began to precipitate out. (The $CaSO_4$ probably precipitated as gypsum first and later was dehydrated to the anhydrite form.) (See p. 81, Table 1, in Wonderly, 1977, for details of the percentages of concentration at which the precipitation takes place.) It is evident that the organic lamination which each "couplet" usually contains consists mainly of the remains of the planktonic* algae which grew prolifically during the time when the brine concentration at the surface of the body of water was low. This is in agreement with the fact that, throughout this great deposit of thinly laminated evaporites, the thicknesses of the alternating calcite and anhydrite laminae are *in a proportion similar to that* of the dissolved $CaCO_3$ and $CaSO_4$ in seawater. (Seawater normally contains a much smaller percentage of $CaCO_3$ than of $CaSO_4$—see Wonderly, 1977, pp. 101-03 for details.) Thus

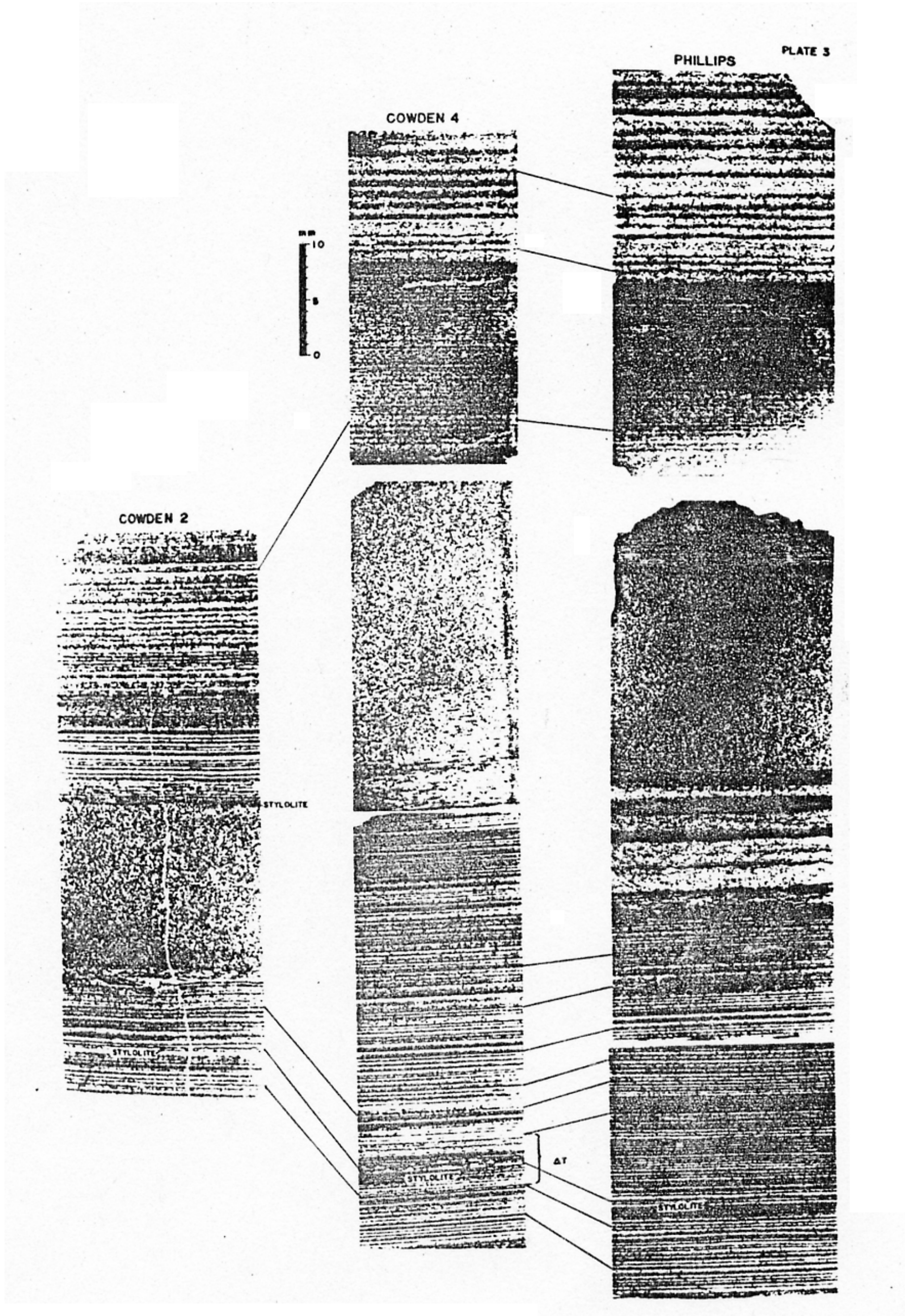

Figure 6. Photographs of three vertical-column thin sections of the well cores used by Walter Dean in his studies of the Delaware basin. The strips of well core were ground thin enough for light to pass through for photographing. The light layers are anhydrite, and the dark layers calcite; thus many evaporitic couplets are seen in each column. Note the scale bar near the top, of length 10 millimeters. The slanting lines connecting the core sections identify the *same* couplet in two (or three) wells. The wells, designated as "Cowden 2," "Cowden 4," and "Phillips," are approximately 6.5 and 15 miles apart, respectively, in Culberson Co., Texas. From W. E. Dean, Jr., *Petrologic and geochemical variations in the Permian Castile, varved anhydrite, Delaware basin, Texas and New Mexico*, Ph.D. dissertation, University of New Mexico, 1967, 326 pp., Plate 3. (By permission of the author.)

the layering of the Castile Formation provides us with a physical record of the periodic—probably annual—changes of seawater concentration and the rise and fall of the organic productivity in each period. It is important also to note that the high degree of purity and distinctness of the laminae over broad geographic areas completely rules out the possibility that the deposition occurred during a period of water turbulence such as evidently existed even in the late stages of the Biblical Flood. And obviously the drying up of the waters of the Flood, as described in Genesis 8:13-14, could not have produced anything like the repetition of laminations which we find in the Castile Formation.

Walter Dean made a very detailed study of the couplet layers of this Castile Formation throughout almost the entire basin (Dean, 1967). He actually measured and recorded the thicknesses of the microlayers in 12,800 "couplets" which are vertically sequential in the 200,000 couplet series of the Castile Formation, in Texas and New Mexico (Dean, 1967, pp. 213-87). The measuring of these thicknesses in the well cores from different parts of the Castile Formation (which fills the ancient evaporative basin) made it possible to check to see how far individual laminations could be traced across the basin. The result was that several sets of laminations (e.g., those shown in Fig. 6 of this book) were distinctly correlated for a distance of 60 km (37 miles). Thus Dean states that "results of this investigation indicated that individual laminae within the Castile Formation could be traced with remarkable uniformity for a distance of at least 60 km" (1967, p. 15; pp. 73-75 explain the procedures of these correlations). Very uniform thicknesses of the laminae of the "couplets," as well as a consistency in the chemical content and in the organic matter, had been preserved across this 60 km distance. A report of the extensive chemical tests which were made on all three types of laminae in the "couplets" is given in the dissertation (1967, pp. 29-60). Correlative work done later in this same basin traced individual laminae, and also beds of nodular, laminated anhydrite, for distances up to 113 km (Anderson, et al., 1972, pp. 61, 70; Handford, et al., 1982, p. 325).

Dean's observations concerning the relationships between the organic layer and the two mineral layers of the "couplets" are very significant. He says:

> A microcrystalline calcite lamina is usually followed by one or more very thin organic laminae separated by carbonate-free sulfate laminae which frequently contain "flakes" of organic matter concentrated at the top of the sulfate lamina. These organic "flakes" often form a lacy network immediately below a microcrystalline calcite lamina. (Dean, 1967, p. 37)

This gives us the information that, during the long period when these couplets were being deposited, the organic matter usually sank through the water to rest loosely on the $CaSO_4$ microlayer which had formed the year before. Then, since the seawater had become sufficiently concentrated for the $CaCO_3$ to precipitate out, a microlayer of calcite was formed on top of the organic matter. Finally, when the volume of the water became reduced to 20% or less of its original, a new layer of $CaSO_4$ precipitated, covering the calcite lamina. Dean found some variations in the order of laminae in the "couplets," but none that cannot be explained by natural fluctuations in the environment.[22]

Thus we are forced to conclude that the layers of the Castile Formation were formed naturally by evaporation and periodic algal growth. Morris has made his denials of the reality of evaporative deposition (Morris, 1974) without knowing or understanding the nature of the evaporite deposits or of the processes of evaporite deposition. Unfortunately, there is no change in this in the new, 1985 edition. (The section on evaporites is pp. 105-07 of both the 1974 and the 1985 editions.)

Sometimes there is a question of why small, hard-skeleton fossils are so infrequently found *in* the organic laminae of evaporite deposits. It must be remembered that very few of the marine animals which produce such skeletons are able to live in hypersaline waters. It is mainly the algae which have this capacity; and even they, as pointed out above, come practically to a standstill in their growth during parts of the year when the water has become sufficiently concentrated to precipitate gypsum or anhydrite.

However, there are many laminated anhydrite formations which contain identifiable fossils in black shale layers which are interbedded with the sets of organic and evaporite laminae. For example, in the Paradox Formation in Utah, fossilized conodonts, brachiopods, and plant remains are found in the black shale layers which alternate with sets of evaporite and organic laminae (Duff, 1967, p. 204). (The shale layers obviously were formed during the longer periods when the water in the evaporative basin was less saline, allowing these organisms to grow.)

[22]For example, occasionally a couplet was found to have the organic lamina on top of the calcite. This apparently means either that, in that particular year, conditions were unusually favorable, so that the algal growth could continue until the calcite had precipitated out; or that the percentage of CO_2 in the surface layer of water dropped so low, due to the algae's use of the CO_2, that the precipitation of $CaCO_3$ was triggered earlier than usual (Dean, 1967, p. 148).

CHAPTER 9

CYCLIC EVAPORITE STRATA UNDERLYING LARGE AREAS OF THE CONTINENTS

1. Introduction and Regional Setting

In order to assist the reader in more clearly visualizing the nature of ancient evaporite formations which show that they were laid down in natural cycles, we will now consider a typical, evaporite-sealed, oil-producing area in Alberta, Canada. Evaporite minerals—mainly anhydrite* and halite*—were very frequently deposited as a series of rock layers covering ancient carbonate buildups which serve as reservoirs for petroleum. Since evaporite rock layers are practically impervious to the passage of liquid petroleum and natural gas which accumulate in the pores of the carbonate formations, they have effectively sealed these resources into the carbonate reservoirs, preventing their deterioration and escape. Approximately 50% of all the world's petroleum reserves are capped by evaporite layers. Kirkland and Evans state:

> Evaporites, a mere 2% of the total volume of the sediments in the platforms of the continents (Ronov, 1968), overlie carbonates that contain an estimated one-half of the world's reserves of petroleum. . . . Evaporites are associated with reservoirs or form the trap in 53% of the fields that have an ultimate recovery of 500 million barrels or more and in 38% of the gas fields that have an ultimate recovery of 3.5 trillion cubic feet or more. . . (Kirkland and Evans, 1981, p. 181).

This abundance of evaporite strata in association with hydrocarbon reserves provides us with a truly immense amount of information on the characteristics and exact stratigraphic relationships of the evaporite strata. Petroleum drilling corporations are very careful to collect and permanently catalog cores and drill cuttings from all levels of the evaporite layers and of the oil-bearing strata in each oil field, as an aid in predicting further petroleum discoveries lateral to the wells being drilled. Also very accurate seismic surveys, which easily identify and distinguish subsurface evaporite and carbonate bodies, are made and studied along with the drilling records. Published research reports giving these data for the oil fields of North America are very numerous, and are available to anyone who wants to read them. Also many of the drilling core samples are kept at the State Geologic Survey warehouses and are available to the public. (Unfortunately young-earth creationist authors almost never cite data from these sources of information. So, people who are interested in the relation between geology and the Bible usually do not find out that the data sources exist.)

As stated in Section 3 ("Organic Matter in Ancient Evaporite Deposits") of Chapter 8, laminated anhydrite (calcium sulfate) deposits are found underlying large areas of

Alberta and Saskatchewan, Canada. There are also several other types of bedded evaporites in this same geographic area. Together they make up a geologic unit (in the Middle Devonian System) which is called the Muskeg Formation, in Alberta. The southeastern parts of this formation which extend into Saskatchewan are known as the Prairie Formation. A. M. Klingspor's article, "Middle Devonian Muskeg Evaporites of Western Canada" (Klingspor, 1969) is helpful in understanding the nature and extent of these evaporite strata. He says:

> Examination of cores, samples, and mechanical logs from several hundred wells throughout western Canada showed the formation [Muskeg-Prairie Formation] to consist of several diverse strata conveniently divisible by distinct marker beds. Individual beds are continuous for very long distances and can be arranged in very orderly vertical sequences, corresponding to progressive and regressive* saline phases [of the ancient seas in this locality] (Klingspor, 1969, p. 927).[23]

In this article a series of figures (Figs. 13 to 16) show not only the lateral distribution from the northwest corner of Alberta to the southeast corner of Saskatchewan, but also the thicknesses (usually between 400 and 600 feet) along this NW-SE, 950-mile distance. In the geologic literature this area is known as the Elk Point *Basin* (Fig. 7), because the earth's crust there sank sufficiently, prior to Middle Devonian times, to allow the deposition of the thick formation of limestone and dolostone which underlies the Muskeg-Prairie Formation (see "basin" in glossary). This underlying carbonate formation, which includes a large number of true-coral reefs and other organically-built carbonate mounds in its upper parts, has been named the Keg River Formation in Alberta, and the Winnipegosis Formation in Saskatchewan. It is this formation which contains the petroleum reserves of the region—mainly because of the porous nature of the reefs and other carbonate buildups in it.

For our purposes here we will focus mainly on the northwest part of Alberta, where a great amount of research has been done on the characteristics and precise origins of the different layers of the Muskeg Formation. Bebout and Maiklem made an extensive study of these as a part of a larger study on the environments of anhydrite deposition. This study was initiated and carried out as a joint Imperial and Esso Production Research Company project, from 1968 to 1972. (It was in this period of time that most of the major studies on the sedimentary characteristics of the northern end of the Elk Point Basin were made.) The work of Bebout and Maiklem gave special attention to the Muskeg evaporite deposits in the Rainbow and Zama subbasins, both of which are in the northwest corner of Alberta (Fig. 7).

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[23]See Alonso (1991) concerning the great contrasts between evaporite deposits such as these, and evaporites formed by waters of hydrothermal origin. Both normal-marine and continental evaporites are very different from the latter.

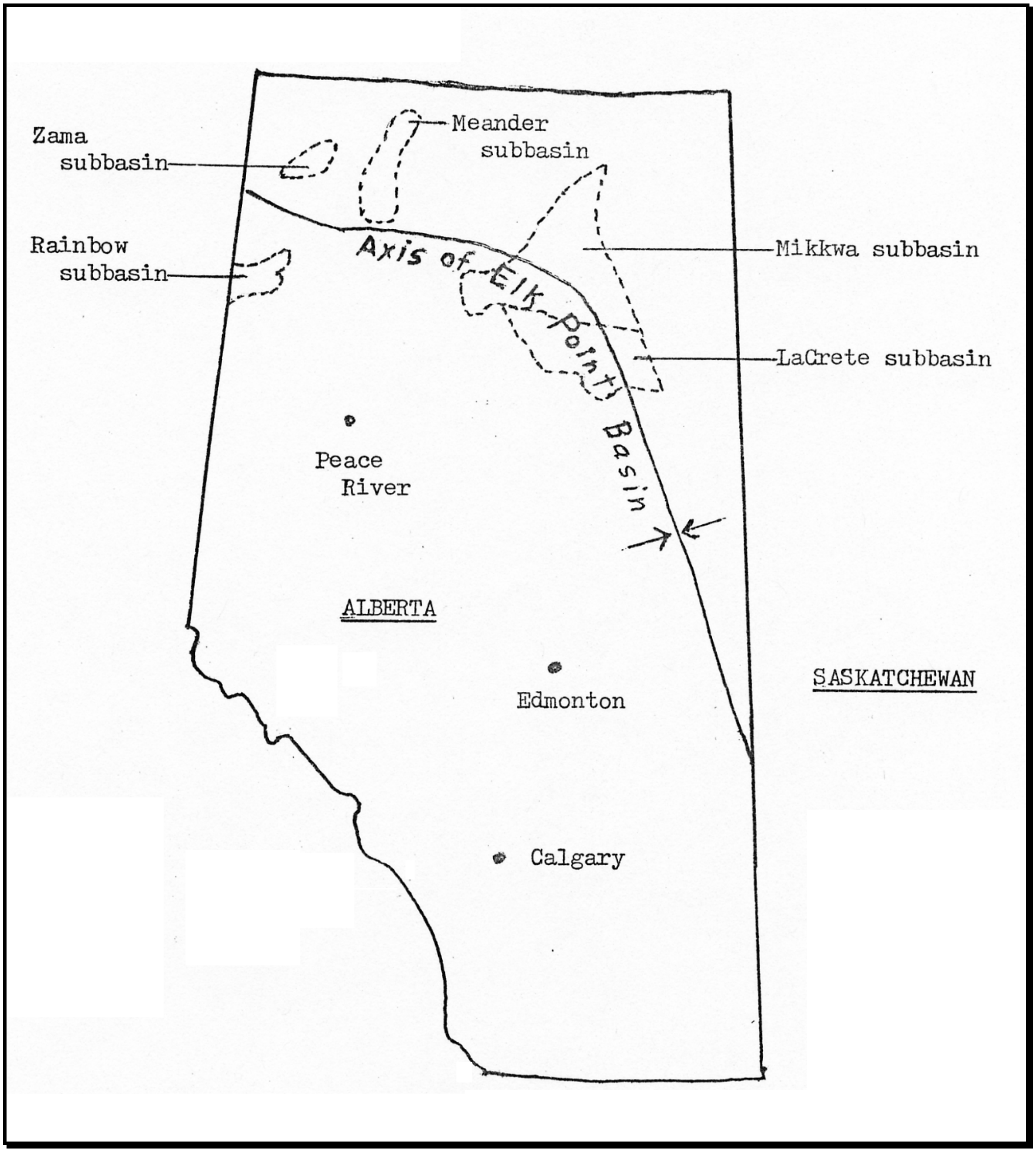

Figure 7. Map of the Devonian, Elk Point Basin, with its subbasins, in Alberta, Canada. (See Glossary for definition of "basin.") These subbasins contain carbonate mounds which are petroleum reservoirs. The carbonate reservoirs lie at a depth of approximately one mile below the surface, in the Rainbow and Zama oil fields, and are sealed over by evaporite layers. Redrawn from McCamis and Griffith (1968, Fig. 2), Bebout and Maiklem (1973, Fig. 29), and Davies and Ludlam (1973, Fig. 1).

2. The Basal Laminites of the Muskeg Formation

The lower part of the Muskeg Formation consists of thinly laminated anhydrite and carbonate. In most of the thickness of this unit the laminae are arranged in couplets or triplets very similar to those of the Castile Formation in Texas and New Mexico. (Bebout and Maiklem, 1973, pp. 291-92; Davies and Ludlam, 1973, pp. 3530-32, 3541-42; Kendall, 1979, p. 160.) This laminated unit is usually at least ten meters thick over the floor of the deeper subbasins of northern Alberta, and often laps up onto the bases of the carbonate mounds in these basins. Sometimes the thickness is up to 30 meters between the mounds. (Davies and Ludlam, 1973, pp. 3530-31, 3542, and Figs. 3 and 4; McCamis and Griffith, 1968, p. 1909 and Fig. 11.) The position of these laminated layers can be seen at the base of the Muskeg Formation in Fig. 8 of this book, though the figure does not mark the subdivisions of the Formation. (Figure 8 shows all of the formations of the Upper Elk Point Subgroup, beginning with the Keg River at the bottom.)

The couplets in this basal laminated part of the Muskeg evaporites usually are made up of a layer of dolomite or calcite, a dark organic film or layer, and an anhydrite layer. The layers (laminae) in the couplets vary in thickness from a fraction of a millimeter to approximately 1 cm. (Davies and Ludlam, 1973, pp. 3530-32.) There are strong indications that these laminite layers were deposited in relatively deep water—perhaps 50 meters in depth (Davies and Ludlam, 1973, pp. 3541-42). There is also abundant evidence in the core samples to show that the water in these subbasins was periodically restricted as to circulation, and thus extensive evaporation greatly increased the salinity at times, allowing precipitation of the carbonate and anhydrite laminae.[24]

The organic laminae of the couplets in these laminites show evidence of having been formed from finely divided planktonic algal remains settling into place after the water at the surface became too saline for the algae to grow well. (Compare the discussion on the organic layers of the Castile Formation couplets in Section 3 of Chapter 8.) Davies and Ludlam (1973, p. 3532) cite two careful studies of the organic components of these Muskeg basal laminites; in both, microscopic algal components were found. This, together with the lateral uniformity of the laminae over broad areas (Davies and Ludlam, 1973, pp. 34-35), leaves no doubt that these laminites were laid down cyclicly, in relatively quiet seas which had a high salinity at certain times and a much lower concentration of salts at others.

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[24]One difference between these basal, laminated parts of the Muskeg Formation and the laminated Castile Formation is that, in the couplets of the Muskeg, the carbonate laminae are more often composed of dolomite rather than calcite, as in the Castile Formation. This is not a major difference, however, as calcite ($CaCO_3$) deposits are sometimes altered to dolomite ($CaMg(CO_3)_2$) either soon after deposition or considerably later. Whether this diagenetic change will be early or late depends upon a number of environmental factors, including, importantly, the availability of the necessary magnesium ions from circulating pore water.

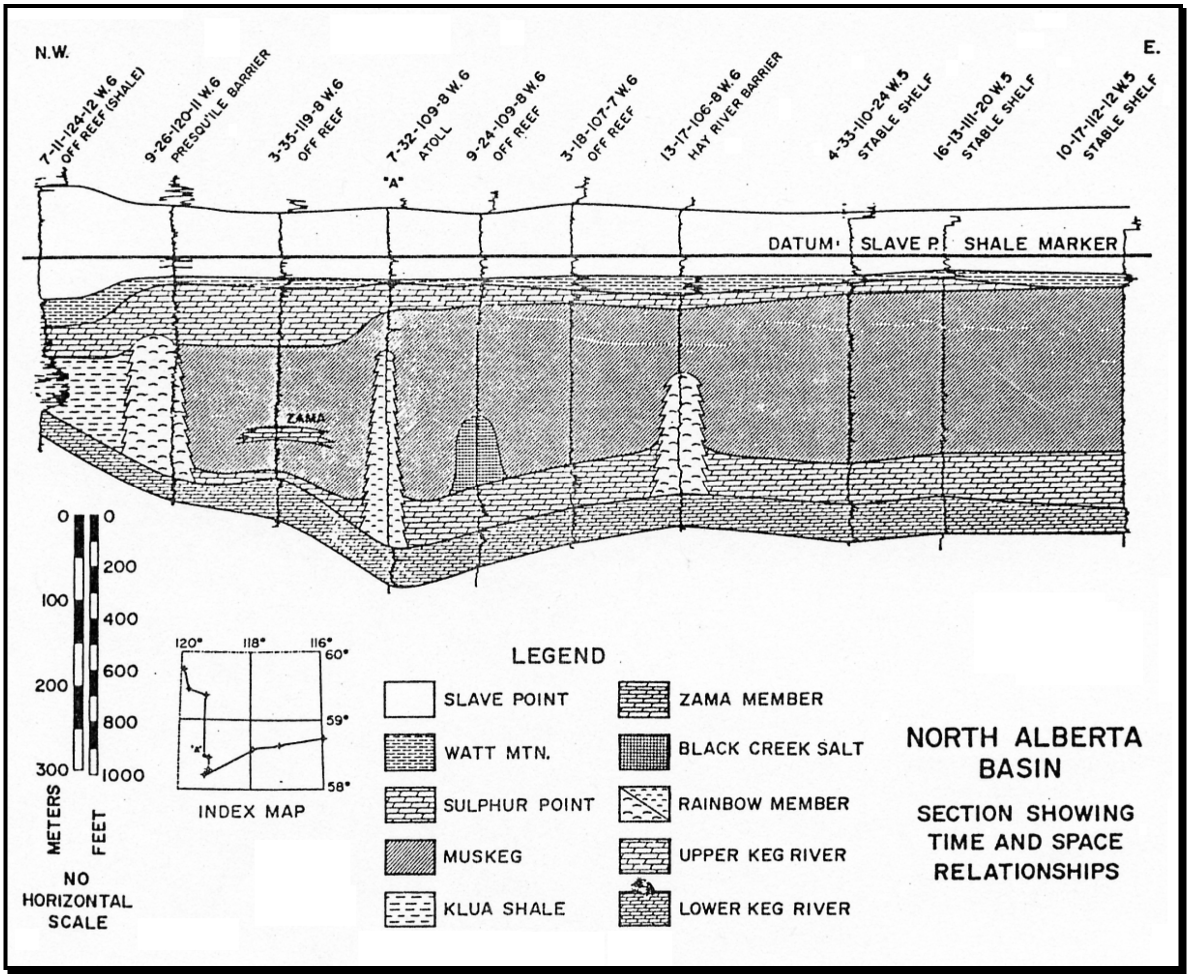

Figure 8. A vertical section through the deeper rock layers of one of the Rainbow area oil fields in Alberta, Canada. The blocks in the "Legend" identify the geologic formations, which appear in their natural order in the vertical section. All of the formations named except the "Slave Point" belong to the Upper Elk Point Subgroup, in the Middle Devonian System. Note the three reefs, shown as white towers with small, curved stipple marks. (These reefs and the beds which surround them are vertically exaggerated in the diagram, so as not to crowd the diagram horizontally . However, their heights are as indicated on the vertical scale at the left.) Ten wells are shown penetrating this vertical section, and are also shown on the small map in the lower part of the figure. Note also that the reefs are embedded, primarily in evaporites of the Muskeg Formation. A part of this thickness is laminated anhydrite. From D. L. Barss, et al., in *Geology of Giant Petroleum Fields*, M. T. Halbouty, ed., American Association of Petroleum Geologists, Memoir 14, 1970, p. 29, Figure 9. (Reprinted by permission of the American Association of Petroleum Geologists.)

3. The Limestone Formation and Reefs on Which the Muskeg Evaporites Were Deposited

In order to understand the middle and upper parts of the Muskeg Formation it is necessary to briefly consider the nature of the limestone and dolostone formation which was covered by the evaporites. We mentioned this near the end of section 1 of this chapter, stating that this lower set of sedimentary layers is called the Keg River Formation, in Alberta (Fig. 8). This Formation has been penetrated by hundreds of wells in the Rainbow and Zama subbasins in northwestern Alberta (Fig. 7) and lies at a depth of approximately 5,000 ft in the Zama area. It is composed primarily of types of carbonate rock the components of which are produced in open-marine (not stagnant) environment. The main types of carbonate-secreting macrofossils in it are crinoids, brachiopods, and stromatoporoids* in the lower parts of the formation; and stromatoporoids, corals, crinoids, and coralline algae in the upper parts. (Langton and Chin, 1968, pp. 1930-31; McCamis and Griffith, 1968, pp. 1903-07.) The thickness of the Keg River Formation in the subbasins of northwest Alberta which we are considering varies from approximately 200 ft at the basin edges to 900 ft in the centers. (Hriskevich, 1970, pp. 2261-64).

Since the main oil reserves of this area are contained in the Keg River carbonates (over 2 billion bbl, as of 1970, in the Rainbow subbasin alone [Hriskevich, 1970, pp. 2280]), the drilling cores from this formation have been studied in great detail. The upper part of the Keg River Formation, in the subbasins of northern Alberta, includes the ancient coral reefs and other carbonate mounds which we have mentioned above. They are especially good reservoirs of oil, because their organically-built structures include an abundance of pores and cavities which contain the oil. The study of these carbonate mounds made by J. R. Langton and G. E. Chin was a fabulously detailed and systematic research project (Langton and Chin, 1968). As of August, 1967, 56 of the carbonate mounds in the Rainbow subbasin had been drilled, and many more were discovered later (cp. Halley and Loucks, 1980, p. 47). Langton and Chin have carefully described several of these mounds which have all the characteristics of a true coral atoll, including the gross structure and shape, as well as an abundance of specifically identified coral fossils. Those mounds which can truly be designated as reefs rise sharply above the basin floor and contain the proper organically-produced components to show that they grew as wave-resistant structures in a shallow sea (Fig. 8). Several of them rise to a height of 800 feet above the basin floor. Some are merely conical in shape, while others developed the shape and structure of various living coral atolls in the Pacific Ocean. (Langton and Chin, 1968, pp. 1930-43.)

Identification of the characteristics of these reefs was made by a detailed study of cores from 45 of the wells which penetrated them, with 15,000 linear feet of polished core slabs being studied under binocular microscopes, and by extensive seismic surveys (Langton and Chin, 1968, pp. 1928-29). It was of course necessary to study the actual reef cores to determine the organic make-up and types of cementation* found in the reefs, but the shape, size, and slopes of the reefs were determined from seismic* survey reports. Seismic methods are very accurate for determining these characteristics of limestone and dolostone structures.

Actually, most of the carbonate mounds in the Rainbow subbasin were found to have true reef characteristics. Langton and Chin classified them into four basic types, “large pinnacle reef,” “small pinnacle reef,” “large atoll reef,” and “crescent atoll reef.”

These types are described in Langton and Chin (1968, pp. 1937-43). Schmidt, et al., comment on the larger atoll reefs in the Rainbow subbasin as follows:

> The multi-well pools [oil-producing reservoirs] occur in elliptical buildups of the atoll-type which are larger and display greater facies* differentiation, including a lagoonal area [with typical fine-grained lagoonal sediments] behind a peripheral rim which is best developed on the northeast side. (Schmidt, et al., *in* Halley and Loucks, 1980, p. 47).

Since most or all of the atoll-type reefs showed better development on the northeast side, it is assumed that the prevailing wind was from the northeast at that time. (Modern reefs typically grow best on the side of the prevailing wind which brings freshly oxygenated water and planktonic organisms for food.) The drilling cores taken from the reef rims of the northeast side contain a special abundance of colonial septate corals, tabulate corals, and stromatoporoids. Each of these is a kind of metazoan which was capable of building wave-resistant reef parts (James, 1979, p. 125). Some of the other kinds of macrofossils which were abundant in these reefs are brachiopods, crinoids, gastropods, ostracods, and several species of limestone-building algae. (Langton and Chin, 1968, pp. 1933-43; Machielse, 1972, pp. 204-06, 212, 218.) Concerning limestone-building algae in the reefs of Alberta, including the Rainbow subbasin, see the section entitled "Skeletal Algae," on pages 214-18 of Machielse (1972). Many of the atolls of the Rainbow subbasin are very similar in form to living atolls which have been studied in the Great Barrier Reef north of Australia (Barss, 1970, pp. 34-35).

At this point we should mention that Schmidt, McDonald, and McIlreath (*in* Halley and Loucks, 1980, pp. 43ff) emphasize the role of early carbonate cementation* in the production of the reefs in the Rainbow subbasin. The language used by these authors might at first sight be taken to mean that they do not accept these as true reefs which actually grew in the basin. This is not at all the case, as will be seen from a study of pages 45-52 of their chapter. These authors cite most of the sources which I have been citing, and readily recognize that the reefs were growing naturally in the Rainbow subbasin; and also that many of the organisms producing them were wave-resistant "builders." Schmidt, McDonald, and McIlreath call these atolls and some of the other reefs in the Rainbow area, "cementation framework reefs" (p. 48) and explain that early cementation "transformed mechanically deposited skeletal carbonate sediments [which had slid partway down the reef slopes] into wave resistant rocks before they were covered by intercalations* of evaporitic carbonate" (p. 51). The study made by these authors had to do mainly with the upper one-half of the atolls and pinnacle reefs which are found in the Rainbow subbasin. (It was the upper one-half, approximately, of these reefs which was subjected to extended growth-stoppage periods.) What was obviously different and distinctive about the growth of these reefs, as compared with the reefs now growing in the modern oceans, is as follows. During at least the latter half of the time the Rainbow area reefs were developing, there were periods when the water became too saline for the reef to continue to grow, because of the relatively shallow nature of the seas in that area and high rates of evaporation.

These conditions are definitely recognized in the sources we have been citing regarding the reefs in Alberta. The presence of the intercalations of evaporitic sediment at various levels as one progresses upward along the reef slopes gives clear testimony to the fact than an evaporitic environment developed several times during the reef growth. (Remember that the evaporite "laminites" which were described in section 2 above were being deposited during these times of hypersalinity.) Each time a high-salinity phase occurred, the productivity of most if not all of the organisms growing on the reefs was curtailed and the calcium carbonate parts which had already been built, and were exposed by the low water level, began to disintegrate and break loose. Thus, there was much gravitating of reef fragments from their original location to sites from one to a few meters down the reef slope. These fragments were then cemented[25] into a permanent position on the edge of the reef, because they were now submerged in an environment which promoted high rates of cementation—as is observed on arid coasts today. Of course this does not mean that all of the original skeletal framework was broken up, but at these times of non-growth a great amount of damage was done to the coral and other skeletal structures which had been formed.

Thus Schmidt and his colleagues, by emphasizing the cementation which took place during the periods of high evaporation rate, have helped us to understand how the coral reefs and other carbonate mounds of northern Alberta could keep on becoming thicker in spite of the periods of high salinity which plagued them. During periods when conditions were favorable to the growth of the reef organisms (which we have named in previous paragraphs of this section) wave-resistant reef material was added. Then when "hard times" came, much of this newly built skeletal carbonate underwent partial deterioration and traveled down-slope to where it could be firmly cemented in position as a part of the reef. The petrographic* studies of Schmidt, McDonald, and McIlreath, and the earlier studies of Langton and Chin (1968) and of Machielse (1972), have identified many well-core components from the reef edges and slopes which bear out the reality of this description. However, the earlier authors did not study the types of cement with which the reef fragments were bound together sufficiently to realize that a high percentage of the cementation was that of an evaporitic environment, rather than the usual cementation which binds the parts of a growing reef together. Also, the work of Schmidt and his colleagues has made possible a better understanding of the evaporite-mineral layers which are found penetrating the sides of the reefs as intercalations at various levels. These were laid down while evaporite deposition was going on and the growth of the living organisms of the reefs had become curtailed because of the high salinity.

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[25]See Chapter 3 for an explanation of some principles of this type of rock cementation.

The tendency of young-earth creationists to deny the reality of these and other ancient, buried coral reefs which are found in the subsurface of many oil fields of the world is very difficult to understand. H. Morris has published the statement, “As far as coral reefs are concerned, it should be realized that fossil ‘reefs’ are probably not reefs at all” (Morris, 1983, p. 8). He then cites two different authors who have commented on the well-known “Capitan Reef” of Texas and New Mexico, pointing out that it is not a true *coral* reef (since there are relatively few fossil corals found in it). However, neither of these authors denies the existence of the true coral reefs we have been describing above, or of those in the Michigan Basin and in other oil producing areas of the world.

Morris states further, “A true coral reef contains the binding framework of the coral organisms themselves. Fossil reefs, however, are ‘inorganically’ bound, not ‘bioconstructed.’ That is, the evidence indicates that coral and other fossil organisms were simply transported into place by sedimentary processes . . .” (Morris, 1983, p. 9). Obviously Morris was completely unaware of the many research reports describing true coral reefs, buried in the oil fields, which *do* have organic binding framework. No scholar or serious student who knows the characteristics of these ancient reefs which have been described in so many high-quality, objective research reports could reject them as myth or imagination. These are *not* structures or models which have been produced on a computer screen. They are real, with real fossilized communities of framework-secreting, marine animals and skeletal algae which formed solidly interconnected masses of calcium carbonate. (See above, in this section, for references.)

It is extremely difficult to ignore the reality of approximately 100 well-formed atoll and other conical coral reefs in the Rainbow subbasin alone, nearly all of which are isolated bodies rising above a basin floor which is composed of entirely different carbonate and evaporite layers. In fact, there is a feature of rock distribution around these conical reefs which even further supports the obvious fact that each reef grew as a distinct entity and retained its position and basic shape until it was later covered over. Barss refers to this feature, explaining that the many drillings in the Rainbow area have shown that the reefs have reef-derived detritus (skeletal reef parts) around their bases, but that such detritus is not found in the areas of the basin *between* the reefs (Barss, 1970, p. 35).

Those young-earth creationists who refuse to believe in naturally-formed, distinct reefs, buried in the oil fields, should also consider the reef characteristics cited in the following quotation from Noel p. James:

> *Superimposed reefs*. Reef structures in the rock record are often impressive because of their size, not only laterally but vertically. Careful examination of stratigraphically thick reefs, however, often reveals that they are not a single structure, but a series of superimposed or stacked reefs that grew on top of one another in more or less the same place. Individual episodes of reef growth are commonly separated by periods of exposure, reflected in the

rock by intensive diagenesis, * calcrete horizons, or shales (paleosols). (James, 1979, p. 124)

Some proponents of "Flood geology" who realize that there are deeply buried reefs have suggested that perhaps they developed rapidly into mature reefs during the short period between the creation of Adam and the Flood, and then were covered over by the Flood or by subsequent deposition (Myers, 1984, p. 55). But such a hypothesis is futile, because of the characteristics and thicknesses of the rock layers both above and beneath the reefs. There are thousands of feet of thickness of sedimentary rocks above the reefs which are of types which could not have been produced by the Flood, or by post-Flood deposition, because the Flood was so recent.[26] There are also many hundreds of feet of thickness of marine strata lying beneath the reefs, forming the foundation on which they grew, which are of types which required long periods of time for development. In the Rainbow subbasin these include the entire Chinchaga Formation, of several hundred feet thickness, which is *evaporitic* as to its rock types; and also the consistent thickness (100 to 160 feet) of Lower Keg River, fossiliferous (crinoidal), marine limestone all across the basin floor beneath the reefs (Hriskevich, 1970, p. 2261; Langton and Chin, 1968, p. 1930; and McCamis and Griffith, 1968, pp. 1904, 1905).

4. Desert-Coast Evaporite Cycles Covering the Reefs

(a) Desiccation and Cementation of the Reefs

We have already described the lower layers—the "laminites"—of the Muskeg evaporite formation as they lie in the Rainbow and other subbasins of northern Alberta and lap up onto the reefs (section 2 of this chapter). Figure 8 shows a vertical section of the Muskeg Formation surrounding three of the Rainbow area reefs which have been penetrated by wells. (By using the "Legend" of the figure one can get a fairly accurate idea of the relationship of the Muskeg Formation to the reefs and to the other formations above and below them. Parts of this vertical section which are marked in such a way that they resemble a brick wall are composed primarily of limestone and/or dolostone. The block of the legend which is labeled "Rainbow Member" represents the reefs, which are classified as a "member*" of the Keg River Formation.)

A study of the Muskeg Formation, and of the surfaces of the reefs which are being covered by it reveals a recorded history of the progressive desiccation and burial of the reefs, after extreme evaporative conditions developed in the area. Schmidt, McDonald, and McIlreath (1980) cite very strong evidence that this desiccation and burial of the Rainbow area reefs involved several major evaporative periods during which typical evaporitic diagenesis* took place. By a great deal of petrographic* research on specimens from

[26]For a table of the sedimentary rock units which lie above the reefs of the Rainbow subbasin in northern Alberta, and a discussion of the sediment types, see Wonderly (1977), pp. 83-84.

various parts of the reefs they confirmed the earlier observation of Langton and Chin (1968, pp. 1943-44) that the early diagenesis during evaporative phases included not only evaporitic cementation of the limestone of the reef, but also extensive dolomitization* of that limestone. (Schmidt, et al., *in* Halley and Loucks, 1980, pp. 50-55.) Thus the sides of the reefs were becoming dolomitized progressively during the times that the above-mentioned intercalations of anhydrite were being incorporated into the outer parts of the reefs.

Bebout and Maiklem (1973) made a thorough study of evidences for the environmental changes (from marine to evaporitic, etc.) which took place during the time when the Rainbow area reefs were being covered by evaporites. They make the following summary statement:

> Geological evidence that [the] water level did drop in the Elk Point basin is found in the existence of vadose* zones on the carbonate reef and shoals (Maiklem, 1971), the location of stromatolites* on the flanks of the Rainbow reefs (Machielse, 1972), and the existence of zones of early diagenetic fracturing on the crests of the bioherms (Schmidt, 1971).

Bebout and Maiklem (1973) give an extensive and thoroughly documented description of the external characteristics of the reefs of both the Rainbow and Zama subbasins and of the different states of their development and final burial by the evaporite strata of the Muskeg Formation.

The presence of stromatolites on the exterior parts of these reefs is of great significance. The stromatolite rock layers were built onto the sides of the reefs during periods when the water was low but not too saline for the algae which produce them to grow. (See the section "*In Situ* Growth Structures..." in Chapter 2 of this book concerning stromatolites and the individual stromatoids* which are found in them.) Distinct algal filaments of some of the stromatoids of the Rainbow reefs have been found in a moderately good state of fossilization (Machielse, 1972, pp. 202, 204). The beds of stromatolites in the Rainbow area are found only on the sides of the *upper* parts of the reefs, which are the parts that formed during the alternating marine and evaporative periods, and the thickness of the stromatolite beds ranges from "very thin" to 25 feet

(Machielse, 1972, p. 204). The stromatolites are found only on the outside of the reefs and "do not occur interbedded with the reef sediments; they are not present within the central part of the reef complex" (Machielse, 1972, p. 207 and Fig. 7). This shows that at least most of the stromatolites were forming only "during periodic cessations of reef growth during which a lowering of sea level occurred" (Machielse, 1972, p. 207)—and this is a well-known, normal characteristic of stromatolite growth of modern seacoasts.

(b) Evaporite Cycles—Modern and Ancient

After evaporative conditions finally became too extreme for stromatolitic algae to resume growth, additional layers of evaporites of the Muskeg Formation were deposited gradually until all except the highest parts of the reefs were completely buried by evaporitic sediments. This part of the Muskeg in northwest Alberta consists of alternating anhydrite ($CaSO_4$) and dolomite ($CaMg(CO_3)_2$) layers, with some intervals of halite (NaCl), and is up to 500 ft in thickness (Klingspor, 1969, p. 938; Bebout and Maiklem, 1973, pp. 302-05, 322-27).

The drillings in the Rainbow oil fields revealed that this unit includes successive sabkha-type* cycles of evaporite layers extending across the subbasin and over most of the ancient reefs. ("Sabkha" is the Arabic term for a salt-encrusted sedimentary flat, along an arid coast.) These sabkha cycles of the Muskeg Formation are of profound significance in revealing the types of environment which existed during the time that the Rainbow subbasin was being filled. They reveal that the general nature of the environment was that of a desert coast, and that major fluctuations in the water level and salinity of the sea formed different types of layers in the cycles. (See Fig. 9 for a typical cycle as found in the Rainbow subbasin.) These cycles of anhydrite* and dolomite* closely resemble those now being formed on desert coasts in some parts of the world. Because of this similarity it is appropriate that we briefly describe one of the best-known of these coasts where sabkha cycles are being deposited. Afterwards we will come back to the cycles found in the Rainbow area. By observing the desert-environment characteristics of these sedimentary layers we can easily understand that it is not reasonable to postulate that they were laid down in the midst of a massive flood. We say "in the midst of" because there are nearly 6,000 feet of thickness of additional sedimentary strata —many of which are normal-marine in character—lying on top of these sabkha cycles in Alberta. So there is no logical way to assume that the strata which are characteristic of a desert environment were formed at the end of, or after, the Flood.

Coastal sabkhas in the Persian Gulf (also called Arabian Gulf) region have been the object of intense study by petroleum geologists ever since the 1960's. A knowledge of these is valuable because of their similarity to some of the cyclic, sedimentary layers found in evaporite deposits which make up the impervious retaining cover over the petroleum reserves in many oil fields. A modern sabkha, such as is seen in the Trucial Coast of the Persian Gulf (Fig. 10), is a salt-encrusted flat, lying a short distance inland from the usual water's edge. It is at an elevation just above high tide, except that it is flooded over occasionally due to higher water resulting from storms. These inundations supply salt water which, when evaporated, adds to the sabkha's thickness. Also, there is some lateral seepage of salt water from the shore inland. In some places these "coastal sabkhas" are rather wide, extending inland as much as 8 or 10 miles. Also, there are older salt flats further inland with a width of as much as 60 miles. At one time they were nearer to the sea, but the production of carbonate sediments by the corals and other calcium-secreting marine organisms has now added some miles of width to the shore (progradation*). The present rate of this horizontal seaward movement of the shoreline is from one to two meters per year. The sabkhas which are presently next to the coast are thus believed to have been

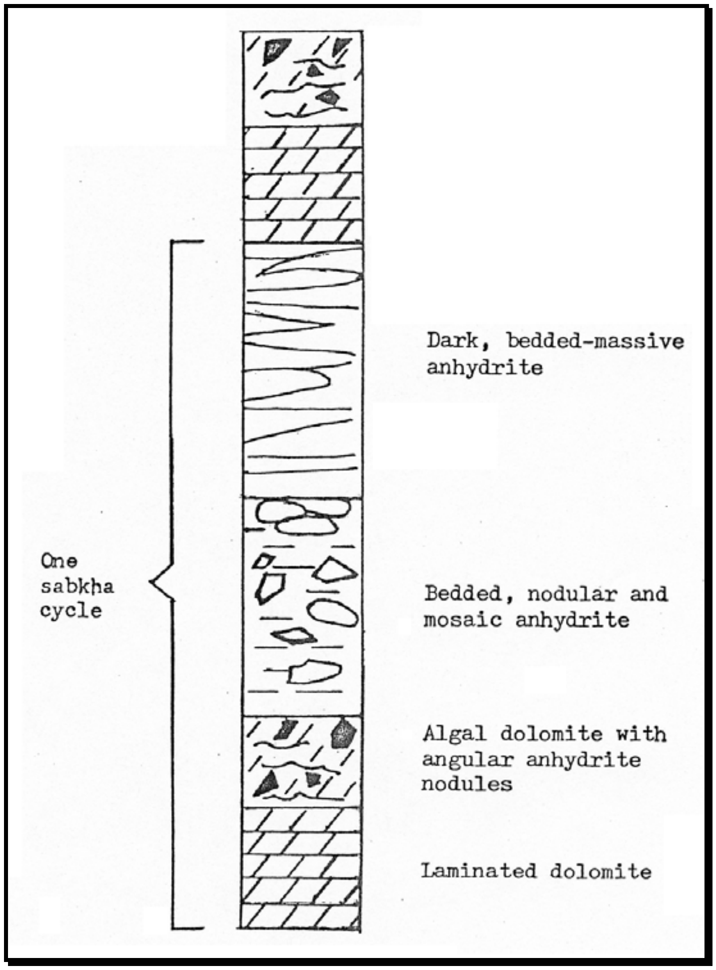

Figure 9. Diagram of the layers of a sabkha cycle of the type found in the Rainbow area of Alberta, Canada, at depths of slightly more than 6,000 feet. Adapted from D. G. Bebout and W. R. Maiklem, "Ancient anhydrite facies and environments, Middle Devonian Elk Point basin, Alberta," *Bulletin of Canadian Petroleum Geology*, vol. 21, no. 3, 1973, Figures 3 and 24.

formed within the past 4,000 to 5,000 years (Kinsman, 1969, pp. 832, 839). At least one of these sabkhas is two *cycles* in thickness (Butler, 1969, pp. 71-72).

So, a sabkha is made up of a specialized suite of sediments which are formed as a result of an arid-coast environment. Sabkhas are not found in other types of environment. In his section on "Supratidal* Evaporites," A. C. Kendall (1979) nicely summarizes some of the processes which come into play in forming a modern sabkha:

> In areas of arid climate and low eolian sand influx the seaward progradation of subtidal* and intertidal facies generates broad coastal flats (or sabkhas) that lie just above high tide level and extend between the offshore water body (commonly with coastal lagoons) and regions of arid continental sedimentation. This environment is a product of both depositional and diagenetic processes, the most important of the latter being

> the displacive growth of early diagenetic calcium sulphate (or halite). The sabkha is an equilibrium geomorphic surface whose level is dictated by the local level of the groundwater table.... Offshore sediments are washed over the sabkha during storms that periodically inundate seaward parts with marine floodwaters. Depressions (filled and buried tidal channels) act as conduits for flood and seepage waters.
>
> Groundwaters beneath the sabkha are responsible for transporting [ionic] materials precipitated as solid phases (evaporites, dolomite) and for removing by-products of diagenetic reactions and non-accumulating ions. These waters become progressively concentrated as they advance into the interior of the sabkha and all but the very seaward and landward margins may be saturated with respect to halite. Concentration occurs by evaporation from the capillary fringe and by dissolution of earlier-formed evaporites (particularly halides). Groundwaters lost by evaporation are replenished by 1) downward seepage of storm-driven floodwaters (flood recharge), 2) gradual intrasediment flow, fluxing from the seaward margin, and 3) intrasediment flow, fluxing from a continental groundwater reservoir that affects landward parts of the sabkha. (Kendall, 1979, pp. 150-51)

Because of the continuous loss of water and consequent concentration of the seawater minerals, precipitation and diagenetic processes occur within the accumulated

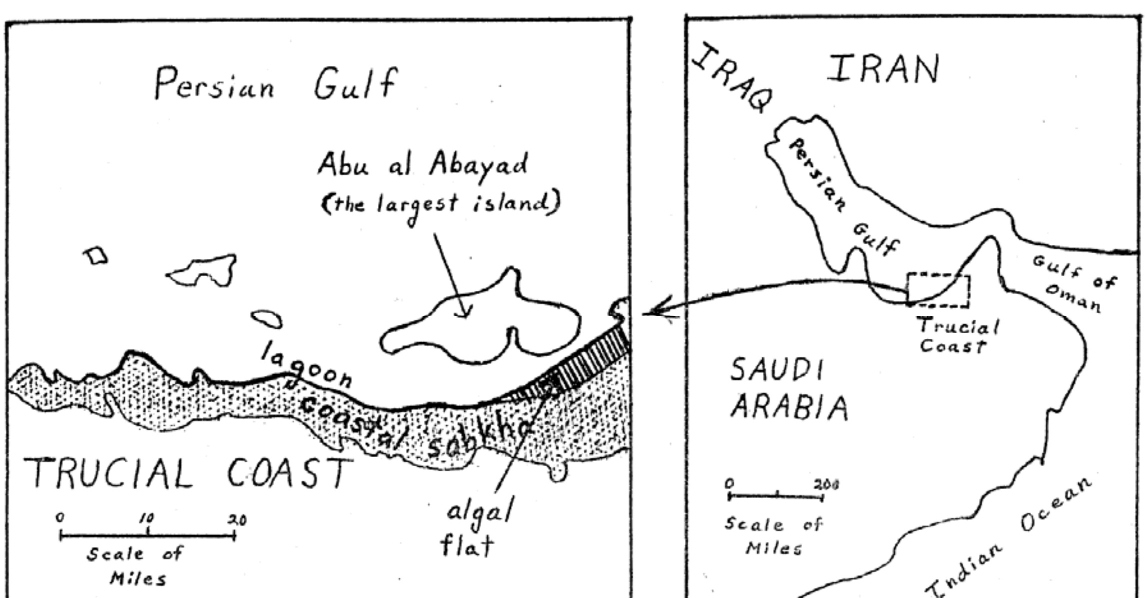

Figure 10. Location and structure of the Trucial Coast, where extensive studies of modern evaporite formation and dolomitization have been made. In the larger figure, the coastal sabkha is a broad band along the coast, which lies just above the high-tide level. Redrawn from D. J. J. Kinsman, “Modes of formation, sedimentary associations, and diagnostic features of shallow-water and supratidal evaporites,” *American Association of Petroleum Geologists Bulletin*, vol. 53, no. 4, 1969, Figure 2; and other sources.

sediments of the sabkha, resulting in the formation of alternating layers of gypsum (calcium sulfate) and dolomite. Algal mats which grow at the sediment surface of the more seaward parts of the sabkha play an important role in determining the final characteristics of the sabkha, as explained by C. G. Kendall and Skipwith (1969, pp. 844-52 and Fig. 16). In thinking about the large area of a sabkha as it extends back from the coast, one must realize that all of it was once at the water's edge, with an abundance of fine, filamentous strands of algae growing over the surface of the wet sand. These filaments of algae produce a protective slime for themselves that later becomes mixed with the finer beach sand which washes up over it as the tide comes in. Thus a thin, rather durable layer is produced, and a thickening series of successive layers (called a "laminated algal mat") is formed as the algal filaments continue to grow. Since these mats have a high percentage of carbonate sand, they are eventually converted to a layer of laminated dolomite or dolostone, if they are exposed to strong brines on the sabkha for a considerable period of time. The laminated dolostone layers, with the remnants of the algal mats, thus become a part of the permanent rock record as they are buried more deeply with time, and the beds of dolostone are spoken of as having "algal laminations." In the sabkha cycles of the Muskeg Formation in the Rainbow subbasin the algal-mat characteristics are prominent, as will be explained below.

We referred above to the alternating of gypsum layers with the dolomite layers in modern sabkhas. However, the gypsum is eventually converted to anhydrite, the more permanent form of calcium sulfate. (Practically all calcium sulfate in the older rock strata systems of the world is in the anhydrite form.) On the Trucial Coast, the sediments of the coast prograde out into the sea—usually at a rate of from one to two meters per year. This progradation eventually results in an isolation of the gypsum from the influence of the sea sufficient to allow it to be converted to anhydrite. Concerning this transformation, A. C. Kendall states:

> In the Abu Dhabi sabkha [on the shore of the Persian Gulf], anhydrite first appears one km inland from the normal high water mark, in the capillary zone. It occurs as discrete nodules and as bands of coalesced nodules, some of which may take the form of ptygmatic (enterolithic) layers. Growth of nodules occurs by host sediment displacement (1979, p. 152).

This development of layers and of anhydrite nodules within the many modern sabkhas which have been studied gives us a very helpful understanding of the developmental processes which formed the sabkha cycles of the Muskeg Formation in western Canada. The similarities between the present-day sabkhas and the ancient are so consistent that practically all sedimentary geologists accept the similarity of their origins. There is an abundance of geologic literature describing both the modern and ancient. Detailed explanations of the deposition and diagenesis of sabkhas and their cyclic components are found in Kendall, C. G. and Skipwith (1969) and in Kinsman (1969). For those who want a less technical description of sabkha formation on the Trucial Coast, see Wonderly (1977), pp. 85-87, which is based on these two articles plus other sources. Also see Reading, et al. (1986, pp. 195-200, 213-17) for a good, brief explanation of modern sabkhas and their relation to ancient ones.

In thinking about the deposition and development of sabkhas—whether modern or ancient—we need to keep in mind that the primary source of the minerals which are deposited is the seawater itself, and that these minerals are made available for deposition by the evaporation process in the coastal area. Thus the formation of any appreciable thickness in a sabkha cycle requires a considerable amount of time. The evaporation of seawater cannot produce a precipitation of more solid mineral amounts than are contained within the water. The thickness (depth) of water column which is evaporated on hot, arid coasts is usually between two and three meters per year (Dean, 1967, p. 144; Kushnir, 1981, p. 1194). The most rapid rate of evaporation known for anywhere in the world is approximately five meters per year (Kinsman, 1969, p. 830). If this is seawater of "normal" (average) mineral content, five meters could precipitate only about 1.8 mm of anhydrite ($CaSO_4$). If the seawater were *saturated* with respect to $CaSO_4$, then approximately 1.4 meters of water could precipitate 1.8 mm of anhydrite (Duff, 1967, p. 211). The only known way that the amount of calcium sulfate precipitation per year could be increased would be for some hydrothermal source to supply it in the local evaporite basin. However, no such supply to any of the modern areas of sabkha-cycle deposition on earth is known, and the ancient evaporite basins of Alberta which we have been discussing show no signs of appreciable influence from volcanic action or hydrothermal springs. If there had been such, there would be recognizable indications of it, as in the Yellowstone National Park, where recognizable hydrothermal mineral deposits are formed. However, the Yellowstone deposits have almost no resemblance to those of either the modern or the ancient evaporite deposits we have cited.

Also, we have to discount the possibility of any sizable amount of minerals being contributed to these deposits by hydrothermal circulation of seawater from submarine rift systems of the oceans. The rift openings are in the deep ocean floor, far from the shallow, epicontinental seas where the evaporites of Alberta were being deposited. The only effect the submarine rift systems can have on shallow-water deposition of evaporites is to contribute to the total mineral content of the seawater which eventually arrives at the coastal areas.

If one should wish for even further evidence that ancient stratified evaporites which are found on the continents were formed in coastal areas and inland seas by slow, natural evaporation, he should consider the following. There is an abundance of pollen grains and other spores from the higher phyla of plants, uniformly distributed over wide areas in many of the evaporite layers of the world. These pollen grains and spores are found at many stratigraphic levels in the evaporite formations. (Klaus, 1969, pp. 30-32). This fact, together with the usual uniform distribution over a wide area, shows that the pollen and spores could not have been deposited by the Flood, or by subterranean hydrothermal springs—because each of the many depositional levels was being supplied from living forests (most likely by at least relatively dry winds, carrying the pollen and spores out over the evaporative seas). Klaus points out that in most evaporite deposits the pollen and spores are very well preserved and readily identifiable, because of the preserving effect of the salt (1969, pp. 30-31). It is significant also that, in most evaporative basin deposits, the "salt clays" which lie closer to the edge of the basin than the concentrated salts which formed near the center, possess from a few to many times the spore concentration found in the salts near the center. This is to be expected because the edges of the basin were closer to the forests where the spores were being produced. (Klaus, 1969, p. 32)

(c) The Lateral and Vertical Extent of the Alberta Sabkha Cycles

In the Muskeg Formation which extends across the Rainbow subbasin of Alberta, the successive sabkha-type cycles which we mentioned above are definite and continuous for a breadth of more than six miles. (Their layers can be matched from well to well.) This breadth of the Muskeg cycles is not surprising in view of the fact that some sabkhas on modern coasts are several miles in width. In both the Rainbow area and several other oil-producing parts of Alberta these evaporative cycles are found superimposed upon one another, forming a sequence of as many as 20 cycles. This indicates that there was enough change of environment at various times during the burial of the reefs that a whole new sabkha layer series (cycle) was begun on top of the old. Fuller and Porter (1969, pp. 910-13) observed and described 13 such cycles in 50 feet of core from a well near Calgary, Alberta. Bebout and Maiklem (1973) made a detailed study of a sequence of 20 sabkha cycles which cover what has been designated as the "South Rainbow B Pool" (an oil-producing coral atoll in the Rainbow subbasin). The suite of 20 sabkha cycles which covers this oil reserve lies at a depth of approximately 6,000 feet subsurface, but because of several wells drilled into it, and the thorough seismic surveys made, a detailed and accurate description of the cycles could be made. A description of the cycles of this area, complete with several diagrams and maps, is given by Bebout and Maiklem (1973, pp. 302-05, 322-27). We have summarized some of the most important parts of it in the following two paragraphs.

In the study of the cycles in the Rainbow area, Bebout found that each cycle usually has a thickness of from two to four feet. Those cycles which are complete are made up of four zones or layers which are similar to the zones of the modern Trucial Coast deposits. (See Figure 9 for a drawing of these, accompanied by a description of the contents of each zone.) In the text, Bebout and Maiklem (1973, p. 322) explain:

> Both the dolomite and the anhydrite occur on-reef and off-reef but are slightly thinner on-reef. The dolomite is laminated throughout but contains more intraclasts, mud cracks, and algal laminae on-reef than off-reef. In the anhydrite the angular nodular, nodular, nodular-mosaic, and mosaic types are more common on-reef and the dark-coloured bedded-massive,* off-reef.

The cycles recur, one upon another, their combined thickness in the Rainbow area being approximately 150 feet, including some layers of salt. In most of the cycles the sediment-laden algal mats of the ancient coast were converted to laminated dolostone, which lies in the lower part of the cyclic deposit. Some of the cycles are incomplete, having one or another of the four zones missing. However, this is to be expected, since the natural changes of climate which have occurred in the past could easily alter the sedimentation processes which were going on in the sediments of the salt flats.

Immediately above the series of 20 sabkha cycles are 15 more cycles which are similar, but less complex. These are made up of two main components: nodular anhydrite layers alternating with dolostone. Their total thickness is somewhat more than 100 feet. It should be noted that nodular anhydrite such as this (with large nodules) is a very reliable indication of coastal deposition. These nodules form at or very near the surface of the salt flat which is exposed to the wind and sun.

As for the length of time involved in the forming of these 35 vertically sequential cycles in Alberta, we should note the total of their thicknesses (about 250 feet) and compare this to the small amounts which can be deposited in one year, discussed above. Also we should consider the length of time required for each cycle, as seen in the Persian Gulf area. The very nature of the sedimentary components of the cycle demands a period of at least a few thousand years for forming such a salt flat of even six miles width. According to the studies made by D. J. Kinsman on the Trucial Coast of Arabia, to which we referred earlier, the present rate of shoreline progradation (increase of land) would broaden the sabkhas approximately one mile each 1,000 years. He estimates that the flats which are six miles wide have required about 5,000 years for their formation. (Kinsman, 1969, pp. 832, 839.) These six-mile expanses of organized salt flat are only one or two sabkha cycles thick. So, *even if* the 35 sequential cycles of northern Alberta could have developed without any interruptions, this indicates that a *minimum* of 87,500 years (35/2 x 5,000) were required for their accumulation. (Because of several depositional limiting factors, this figure is unrealistically small.) Note also that this relatively brief time span is in addition to all the time for development of the Lower Muskeg Formation, the extensive carbonate buildups, and the earlier evaporitic deposits below the reefs. And this is all in addition to the vast amount of time required for adding the nearly 6,000 feet of other types of sedimentary rock which lie above the Muskeg Formation. (For a discussion of the latter, see Wonderly, 1977, pp. 83-84, 90-91, and the references cited there.)

It may be that some young-earth creationists will object to the above estimates of depositional time periods, saying that they are too dependent upon uniformitarian principles. Such persons frequently hypothesize that in former times climatic conditions were entirely different from what they are now, and that this made it possible for practically all types of sedimentary deposition to occur at rates many times faster than those we see today. This is false reasoning which leads only to erroneous conclusions.

Remember that we are here dealing with *arid-climate* deposition, as is abundantly obvious from the sabkha-cycle sediments in the Rainbow and other subbasins of Alberta. We must also realize that we are considering the past history of an earth which *remained at least reasonably hospitable* to animal and plant life after these were created. Exceptions to this were the year of the Biblical Flood and perhaps a few earlier periods when asteroid impacts produced temporary changes in the climate. Neither of these exceptions was anything which would produce sabkha-cycles or evaporite strata. If we keep in mind that we are dealing with an earth which remained reasonably hospitable to plant and animal life, we *cannot* postulate that the arid climate necessary for producing sabkha cycles and several other types of evaporite deposits was intensified to where the deposition occurred in a mere thousand years instead of 87,500 or more. Hot sun and high evaporation rates such as exist in the Persian Gulf region are fundamental elements in the production of such deposits. Try intensifying those conditions by a factor of 87, or even 8.7, and you will have an earth without plant and animal life on it. So, glibly assuming an intensification of ancient environments for the purpose of "speeding up" depositional rates in prehistoric times is an irresponsible and futile exercise. We should never *blindly* apply uniformitarian principles; but, on the other hand, we must avoid making assumptions which will lead the scientific community to conclude that *we are blind* to the survival requirements of plant and animal life.

In a consideration of the evaporite deposits of the oil fields of Alberta it is important for creationists to note the fact that the layers and cycles are nearly always characterized by a lateral uniformity and sedimentary content which is typical of normal evaporite deposition. There is no logical way to postulate that these strata were deposited by the Biblical Flood, for several reasons. We have already discussed some of these reasons; two others which we should at least mention are: (1) Since anhydrite and halite are readily soluble in water, floods *dissolve* rather than deposit them. (2) In practically all of the layers of the Muskeg Formation, over the broad areas covered by it, coarse terrigenous* components such as quartz sand and gravel are rare, if present at all (Klingspor, 1969). In a convulsive flood such as the Bible describes, great amounts of these non-marine components would have been mixed into any covering layers which were deposited over the reefs of the basins. (Of course there are many such terrigenous components in some of the thick formations which lie above the Muskeg Formation, but these were unrelated to—and later than—the evaporite era.)

Whitcomb and Morris, in their early work (1961) mentioned stratified evaporite beds, and said that they were likely formed by non-evaporative processes. In their words, "Modern writers are gradually coming to the opinion that even the stratified evaporite beds are very largely the result of metamorphic processes. . . ." (pp. 416-17). But this statement is completely inapplicable to the evaporite beds we have been discussing. Neither of the geologists they quote (from the 1950's) was referring to evaporites of the types which are so widespread in the oil fields of Alberta and many other parts of the world. In fact, most of the evaporite deposits which have been described to date were either unknown or completely undescribed in 1961 when the Whitcomb and Morris book was published. However, during the 1960's an astonishing number of research projects on evaporites were carried out, with the publication of great amounts of data. These provided clarifications concerning the environmental relationships between the deposition of the many carbonate petroleum reservoirs which were biogenically produced and the periods of desiccation which interrupted their growth and laid down evaporite layers over them.

Unfortunately, the writings of Whitcomb and Morris, even to the present time, show no indication that they have studied any of these research reports. Except for Morris's statements on halite deposits in the ocean floors, their treatments of the subject of evaporites are wholly unreliable, and are not based on any appreciable amount of scientific data. Thus the young-earth creationist community has not only failed to understand most of the evaporite deposits but has missed out on one of the strongest positive evidences for great age that we have in the earth's sedimentary cover.

5. Cyclic Evaporites and Reefs in the Michigan Basin

Another well-known geographic area of cyclic deposition such as we have described in Canada is found in the southern and central part of Michigan. Here, in what is called the Michigan Basin, many forms of carbonate mounds, including a great number of relatively small, conical reefs, are covered with repeating beds of evaporites. This area was a large inland sea during much of the Paleozoic Era, and then later somewhat uplifted. The conical reefs which developed in the basin are called "pinnacle reefs," though their sides are not as steep as the name would imply. They contain abundant, identifiable, frame-building corals, and their positions, sedimentary and fossil make-up, and other characteristics give indisputable evidence that they grew *in situ*, just inside the north rim and south rim of the basin. Their carbonate components and the progression of the fossil components from the lower-to-upper levels shows that their growth was in stages, interrupted by long periods of low sea level with evaporative conditions. Thick layers of anhydrite and halite thus lap up onto the sides of these reefs, and intertongue with the reef layers which developed later. Many of the reefs have vertically sequential zones which are dominated by crinoids, corals and algae, and stromatoporoids, respectively (Mesolella, et al., 1974, pp. 34, 43, 45, and 52). Also of great significance is the presence of stromatolites* which grew on the surface of some of these reefs at times when there was a low water level and the proper environmental conditions for growh of the algal mats which form stromatolites (Mesolella, et al, 1974, p. 45).

Because these Michigan Basin reefs have a high porosity and are sealed over by evaporite layers, they are significant oil producers, and therefore have been the subject of detailed studies by geologists for the past three decades. They lie at a depth of approximately one mile, subsurface, and have been extensively cored in many of the drillings. There is thus an abundance of high quality reef and evaporite materials for study of the cyclic sequences. One of the best papers describing these is the one cited in the paragraph just above (Mesolella, et al., 1974). Other very helpful sources are Jodry (1969), Gill (1977), and Reading, et al. (1986, pp. 218, 225-26). As was mentioned in the Mesolella paper, p. 35, there is some controversy among geologists concerning details of the order and causes of deposition, but there is abundant agreement on the fact that the evaporites and reefs were deposited naturally, by stages, in response to definite changes in the environment in the Basin. (To disagree on that would be a brazen rejection of immense amounts of easily-understood core samples and other data.) Many of the reasons for the earlier controversy over the type of evaporite deposition which prevailed in this basin have now been clarified. As Reading, et al. (1986, pp. 225-26) explain, research during the past decade has revealed many unmistakable evidences for the "desiccated-basin model" as applying to at least most of the evaporite deposition of the carbonate-reef-and-shelf area.

Creationists who have asked about the possibility of the evaporite coverings of the reefs being the result of volcanic or hydrothermal activity will find, upon studying the Michigan Basin, there is no possibility of this. Igneous* activity occurred in the Late Precambrian times, but there is no sign of such in the *Paleozoic* systems of that area—in spite of very extensive drilling explorations and commercial production for many years in the Michigan Basin (W. B. Harrison III, a professor in the Dept. of Geology of Western Michigan University, Kalamazoo; personal communication, 1986). There are a few thin layers of ash-containing sediment—sometimes called bentonite—in the Devonian, Silurian, and possibly Ordovician Systems in the Michigan Basin, but these are evidently from atmosphere-transported ash derived from volcanoes which were in the eastern part of the Appalachians. (The bentonite layers become more evident farther east as one traces them across Ohio, West Virginia, and Virginia, to the source area.) No evidence for either intrusive or extrusive igneous processes is found in the Paleozoic systems of the Michigan Basin. (W. B. Harrison III, personal communication, 1986.)

So, the Michigan Basin cyclic evaporites and reefs effectively provide us with another overwhelmingly clear body of evidence for the deposition of thick formations of carbonate and evaporite rock layers by organic growth alternating with marine evaporation. There is really no way that we could honestly reject the implications of the immense body of data which he have from both the Canadian and Michigan petroleum explorations.

CHAPTER 10

CONCLUSIONS

The basic issue with which this book deals is, What attitude are we going to take toward the earth-science data which reveal the nature of the earth on which we live? This issue is of momentous importance to the teaching of Biblical creation. Evangelical Christians have traditionally taught that God is consistent and that his creation and revelations contain no contradictions. Yet we now have widespread teaching, among evangelicals, of positions on creation which are in direct opposition to vast amounts of carefully collected, non-radiometric data which show us what the sedimentary cover of the earth is like. Earth-science research centers have published thousands of high-quality reports of research projects which were carried out adhering to standard research methods which young-earth leaders endorse and profess to use themselves. The data contained in these reports which relate to age demand—if we are going to be consistent and logical—a great age for the earth.

Thus, those creationists who insist that the Bible teaches that the earth is only some thousands of years old have to squarely fact the question of whether or not God is inconsistent and illogical. These creationists usually insist that there are scientific evidences *for* an earth only a few thousand years old. Are we to suppose then that God has given us some few evidences in the fields of theoretical physics or astronomy which contradict the realities of what we are able to go out and observe directly in the earth's crust? How could we reply other than in the negative? God cannot contradict himself, nor has He "jumbled the evidences" in such a way that they cannot be understood by rational mankind whom He has created. The earth is full of *positive* evidences for an *old* earth, a number of which we have explained in Chapters 1-3 and 7-9. Therefore we should expect that any alleged evidence for a young earth will be based on one or more of the following: (a) a failure of the investigator to take all the data into account; (b) arbitrary extrapolations or hyper-uniformitarian thinking (as in Barnes' magnetic-field-decay argument); (c) inadequacy or failure of instruments with which readings were collected; (d) the use of false logic—such as the idea that if one seam of coal somewhere on the earth shows evidence that it is young, then all coal is young—or that the *absence or scarcity* of some particular substance in the ocean shows that there was not *time* for it to accumulate; or (e) the emphasizing of some surface or near-surface rock formation which "looks young" without studying the many thousands of feet of older, fossil-bearing formations which usually lie directly beneath.

In this book we have shown that the most obvious problem in the work and activities of young-earth creationists is that their leaders have been content to neglect the vast body of scientific observations dealing with what the crust of the earth is actually like. We have extensively documented the fact that, because of this neglect, the published works of prominent creationist leaders are full of error concerning the actual nature of the geologic formations upon which they have sometimes focused their attention. Perhaps the most fundamental lack in their work has been the failure to study and understand rock lithification processes, nearly all of which require long periods of time—e.g., cementation.* Thus, practically every time they look at a layer or formation of sedimentary rock, they wrongly assume that there is no reason why it could not have been formed rapidly.

By way of review we will here list the *general areas* of young-earth creationist error which this work has cited from creationist sources. All of these errors are characterized by a failure to make use of available data. (We assume that in most cases the problem has been that the authors were completely out of touch with research geology. This probably excuses the authors from the accusation of "willful neglect," but it still leaves the problem of how to help the readers who have been either confused or "turned off" from believing the Bible by their errors.) The errors listed below are *in the order in which they are first treated* in this book. The Glossary defines most of the technical terms used in the list. In considering this list one should keep in mind that most of the creationist leaders (commendably) refuse to invoke special miracles, e.g., during the Flood, as a means of bringing about geologic processes.

1. The assertion that the formations of rock strata in the earth grade imperceptibly into each other and do not have erosion surfaces or distinct physical boundaries ("sharp contacts") between them.

2. The assertion that unconformities never represent long periods of time unless they are worldwide, and that no worldwide unconformities exist.

3. Refusal to admit the existence of *in situ* biogenic deposits and structures at various levels in limestone formations—as in the Grand Canyon and throughout much of North America.

4. The assumption that great thicknesses of many types of alternating sedimentary rock layers could have retained their distinct identity (as we find them in such places as the Appalachians), without amalgamating into each other, if they had been deposited all in one flood year and then even tilted and folded. (This assumption is based on a lack of knowledge of the characteristics of the strata and of the principles of compaction, sediment movement, and fossil deposition.)

5. The assumption that many repeating layers of fine clay particles could have been naturally laid down rapidly by moving water during the Flood, without any need for the long, quiet periods of settling demanded by physical laws.

6. The assumption that the total amounts of limestone and of fossils in the earth's sedimentary cover are so small that they could have been laid down by the Flood.

7. The assertion that most limestones and dolostones of the earth are of types which could have been deposited by direct precipitation out of seawater.

8. Refusal to admit the reality of algal stromatoids in ancient rock formations.

9. Refusal to admit that major amounts of rock are being formed in the world today.

10. Failure[27] to realize what rock cementation is, and that most ancient sedimentary rock strata actually show (microscopically) the (slow) stages of cementation which occurred in the formation of the rock. Thus it is taught that the sediments of the earth rapidly became rock in some mysterious manner almost immediately after the Flood.

11. The assertion that the rock strata systems of the earth are not in any meaningful chronological order. This error is due to a failure to study the distribution patterns of the systems sufficiently to observe (a) the many geographic areas where several systems have clearly been eroded off, and (b) the effects of faulting and folding which have occurred in certain areas.

12. The assumption that the existing disagreements among sedimentary geologists concerning minor details of their research invalidates the major discoveries of sedimentary geology.

13. The statement that "there is no type of geologic feature which cannot be explained in terms of rapid formation..." (Morris, 1974 and 1985, p. 94). This shows a complete lack of knowledge of many types of geologic data.

14. The assertion that fossils are not being formed on the earth at the present time.

15. The assertion that there are and have been no naturally-occurring events which could have rapidly buried a significant number of marine and other organisms for fossilization.

16. Failure to realize that some types of fossils can be formed without rapid burial.

17. The assertion that there are no significant differences between the modern forms of life in the world, and those of the ancient Cambrian and Ordovician strata.

18. The assertion that the fossils of the earth's sedimentary cover are so mixed that the families and orders of the different phyla of fossilized animals are essentially the same in the Paleozoic rock systems as in the Mesozoic and Cenozoic.

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[27]In this and succeeding "Failure to'' items, a failure to realize or to observe is regarded as an error *because* it results, in each case, in the young-earth creationist author's taking a position which is in violation of the real condition as it exists in the crust of the earth.

19. The use of an "ecological zoning" hypothesis—which could possibly explain the fossil distribution *in only* a few feet of thickness of sediments near the seacoasts—to justify the existing distribution of fossils in vast areas far from the sea which have 20,000 or more feet of sediment thickness.

20. Failure to include planktonic microfossils in the attempts to explain fossil distribution—resulting in further misunderstandings and erroneous statements.

21. The assumption that the beds of anhydrite and other evaporite minerals which exist deep in the subsurface, inland on the continents, show essentially the same depositional characteristics as the great salt deposits which are found in the floor of the Atlantic Ocean.

22. The assertion that evaporite deposits do not contain organic matter.

23. Failure to observe that many of the kinds of depositional layers and structures in evaporite deposits are of types which could not have been formed either by flood waters or by brines from hydrothermal springs.

24. The assumption that coal atolls and other conical, high-relief, carbonate mounds which are found deep in the subsurface of some oil fields were not built by the corals and other lime-secreting organisms which are found within them.

25. Failure to observe that many of these reefs and other mounds have arid-coast-type stromatolites naturally cemented to their sides, still in the locations in which they were formed during periods of low sea level.

26. Failure to observe that many of the deeply buried, repeating cycles of evaporite layers which often cover petroleum-producing reefs are essentially the same in content and order of deposition as sabkha cycles of evaporites on modern, arid seacoasts.

Because of these and other deficiencies in knowledge of the earth's sedimentary cover, creationist leaders have badly failed in their attempts to guide the thinking of evangelical Christians concerning the nature of the earth and its past history. Creationists are thus in a state of tragic need to establish and maintain close connections with the geology profession, so that they can find out that geologic research is not just "a game," but a productive and valid way of learning the actual characteristics of the earth. The current disregard of available data of geologic research by most creationist leaders is truly incomprehensible, and is not in agreement with traditional standards of scholarship. In making use of reliable geologic institutions creationists could gain a respect for the vast amount of geologic research which they are now ignoring.

This is not a question of adopting the evolutionary theories which are embraced by most geologists. We are referring here to the need for acquainting ourselves with the data which tell us what the strata of the earth are like. One can attend the oral presentations of research reports throughout an entire four-day annual meeting of the Geological Society of America or of the American Association of Petroleum Geologists, learning about the physical nature of the earth's crust, and hearing practically nothing about evolution. (Usually some papers on the subject of evolution are given, but one can easily avoid them and attend other papers being given at the same hour, if he wishes to do so.)

A decision by creationists to take additional formal courses in sedimentary geology and to participate in field trips, seminars and professional meetings with well-recognized geologists, would be the first logical step in correcting long-held views which do not correspond to reality. Such a decision, if carried out sincerely, would also make it possible to begin mending the now-widespread bad image of the Bible as a book which is hopelessly irreconcilable with the data of science. (The rise of young-earth creationism during the past two decades has effectively cultivated this misconception—because the creationists usually emphasize their belief that the Bible is opposed to most of the discoveries of earth-science research.)

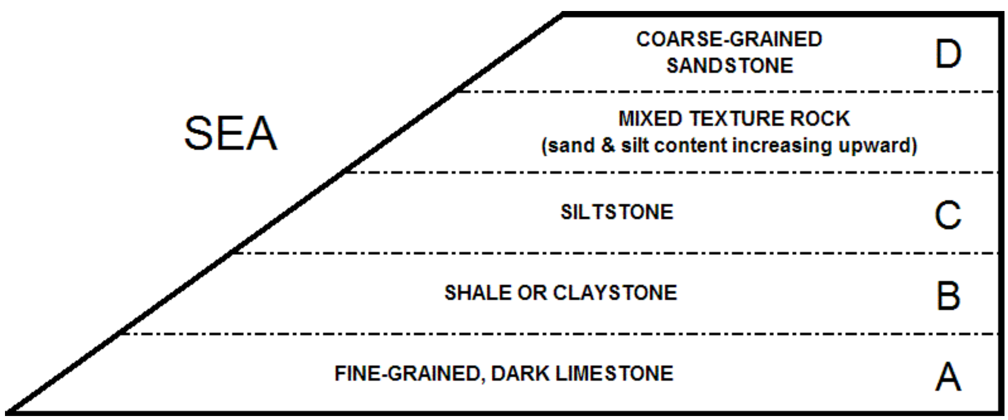
Until creationist leaders are able to establish an effective relationship with research earth-science, and to replace or thoroughly revise all of their publications which deal with the age of the earth and universe, it will be necessary for persons desiring reliable information on the nature of the earth to go directly to the literature of earth science and astronomy. In doing this we will have to use caution, realizing that it is the actual scientific data which we mainly want. Some scientific articles contain interpretations which are colored by an assumption that all things have come into being without the creative power and wisdom of God. However, it is very possible to use the data presented and disregard the objectionable interpretations. (But in the research papers which are devoted to a study of the sedimentary cover of the earth, interpretations which express an atheistic or agnostic bias are very rare.) Therefore, Christians who sincerely wish to know the real nature of the earth's crust are not facing an impossible problem. Reliable information on this subject is now much easier to obtain than it has been at any time since Adam and Eve lost their proper relation to God—and it is information in which Bible-believing Christians can truly rejoice.

APPENDIX

AN EXAMPLE OF THE GRADING OF FORMATIONS INTO EACH OTHER

(Compare pp. 24-25 of this book)

Sedimentary geologists now frequently use a model such as the following for explaining the deposition of those geologic formations which show a grading of one formation into another. This model is based on observations of present-day deposition on modern continental shelves where the results of marine transgression* and regression* are evident. Take for example a sequence of four formations. On the bottom, Formation A is a fine-grain dark limestone. Formation B is a shale or claystone, and Formation C is a siltstone. On top, Formation D is a coarse-grained sandstone with low-angle cross laminations. Between C and D there is a one foot thick zone of mixed sand and silt, such that sand content increases and silt content decreases upward from C to D. All other boundaries in the sequence are also gradational.



For many years, geologists looked at sedimentary strata such as A through D as layers in a cake. “Layer-cake stratigraphy” holds that each formation represents a horizontal time slice. That is, lines connecting equal age in the strata would be parallel to bedding, and thus no two formations could have been deposited synchronously. As discussed below, this is often an unreasonable assumption.

It is helpful to try to imagine the basin in which Formations A through D might have been deposited. Along the coast we encounter beaches of coarse-grained sand forming deposits much like Formation D (but keep in mind that the beach sands form a narrow coastal zone and Formation D extends as a layer over tens of miles). Out in slightly deeper water, the sediments become less coarse, containing silt-sized grains (like Formation C). In deeper water where waves and currents no longer move sediment, clays are deposited (like Formation B). In the deepest part of the basin, many miles from shore, the only material being deposited is pelagic-organism tests (skeletons) which settle to form a limey ooze on the seafloor (like Formation A). Thus, from the coast to the deepest part of the basin, there are different sediment zones which grade laterally from one to another. The seafloor, therefore, represents a time-line that is continuously being buried. If there is a great supply of sediment being introduced into the basin, it will begin to fill. As it fills it will begin to subside, due to both the weight of the sediment and to thermal properties of the underlying crust. If the subsidence rate is slower than the sedimentation rate, the basin will fill rapidly. As the sea level drops, such as in regression during an ice age, the shoreline would necessarily move some distance seaward, causing each sediment zone to move accordingly seaward. During a gradual sea level drop, the movement of the coastal zone would produce a sheet-like deposit of sand with "new" beach being deposited seaward of "old" beach. Furthermore, the "new" beach would be forming on top of sediments that were deposited in deeper water. Continued gradual regression would create a vertical succession of layers that were deposited in continuously shallowing water (i.e., Formation A at the base and D at the top). Time-lines in the layers would be subparallel to bedding and cross-cut gradational layer boundaries. This principle, that sedimentary sequences observed vertically are also found laterally, is known as Walther's Law of Succession of Facies.*

This explanation of gradational contacts in vertical sequences teaches us much about sedimentary analysis. Careful stratigraphic analysis not only reveals regional sediment distribution and correlations, it also reveals how ancient basins were filled by sediments. Volumes of sediments introduced, sea level fluctuations, tectonic movements, and basin subsidence are among the factors which determine the stratigraphic sequences that fill basins. "Flood geologists" might argue that we cannot employ uniformitarian principles to interpret ancient deposits. The fact is, however, the geologists routinely compare ancient sediments with modern sediments, right down to microscopic details. It is even possible to estimate the current velocities which formed ripple marks in sandstones (Blatt, Middleton and Murray, 1972, ch. 4). Petroleum geologists routinely chart the courses of ancient streams and reconstruct the paleogeographies of ancient shorelines (Matthews, 1974). With careful stratigraphic analysis they can predict the whereabouts of reefs and other porous rocks in the subsurface that contain petroleum and natural gas (Wilson, 1975). In addition to misunderstanding the basic principles of sedimentation and stratigraphy, young-earth creationists have yet to propose a convincing alternative explanation for even common stratigraphic sequences, within their Flood-geology and limited-time framework. (Stephen O. Moshier, personal communication, 1985.)

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GLOSSARY OF GEOLOGICAL TERMS

Note: This glossary has been prepared with the intention of providing help for readers who are not familiar with specialized geologic terms. It is not intended that the definitions will be exhaustive, but we have made an effort to include enough defining material for the purposes of this paper. Words which are adequately defined in medium-size, general dictionaries are usually not included in this glossary.

Asterisked (*) words are herein capitalized as a reminder that they are, in geology, often used as proper nouns, even though they are not usually capitalized in common usage.

Abbreviations used:

adj. - adjective	e.g. - for example
adv. - adverb	pl. - plural
cf. - compare	sg. - singular

aerial - pertaining to the air, e.g., aerial exposure of sediments.

alga (pl. algae) - a species of non-vascular plant, usually requiring an aquatic environment.

algal mat - a layer of thick algal growth which contains a significant amount of inorganic sediment which has collected in the mat. Usually it is the mucilaginous secretion of the algae which traps and binds the sediment. Simple algal mats often develop into stromatolites, as layers are added and cemented.

anhydrite - a pure form of calcium sulfate ($CaSO_4$), which is a salt. The main components are the same as those of gypsum, but each gypsum molecule has two molecules of water attached.

anticline - a longitudinal fold of rock layers which is usually convex upward. Frequently the younger rock strata are found to have been worn off from the crest of the fold.

areal - an adj. pertaining to position and horizontal extent on the earth's surface. Adv., areally. Cf. the noun, area.

basin - "A geological basin is an area in which rock strata are inclined downward from all sides toward the center" (*McGraw-Hill Encyclopedia of the Geological Sciences*). The downward inclination is due to subsidence. In many cases such basins have been filled in and then deeply buried by later addition of sediments.

biogenic - having a biological origin, e.g., due to the growth of lime-secreting plants or animals.

bioherm - a moundlike mass of rock composed of calcareous materials secreted or collected by animals or plants growing on the site. Ancient bioherms are normally found in limestone formations, but enclosed in rock of a lithological character somewhat different from that of the bioherm itself.

breccia - a coarse-grained type of rock composed of angular, broken rock fragments. Verb, brecciate - to break into fragments.

calcareous - adj., possessing at least an appreciable percentage of calcium carbonate ($CaCO_3$).

calcite - a pure form of calcium carbonate which is a rock-forming mineral. It commonly exists in the form of white, rhombohedral crystals of many size grades. White streaks of calcite are frequently seen in limestone strata.

carbonates - a general term used to refer to kinds of rock which contain a significant proportion of calcium carbonate or of calcium magnesium carbonate. Limestone, dolostone, and calcareous shale are three of the most common carbonate rock types.

carbonate shelf - a relatively level area of carbonate sediment (and eventually rock) which forms along a carbonate producing tidal area and seacoast. If a thick and extensive buildup is formed it is called a carbonate platform (J. L. Wilson, 1975, pp. 21-24, 33-36).

cementation - the process of building mineral crystals in between the grains of a sediment mass, resulting in lithification. The mineral crystals, e.g., calcite, are usually formed by precipitation from ions in the pore water flowing through the sediment mass.

Cenozoic - the uppermost of the three *Eras* of time since the Precambrian. The Cenozoic followed the Mesozoic Era and includes the Tertiary and Quaternary *Periods*. Cf. Mesozoic, Paleozoic.

clastic - an adj. used to describe kinds of rock or sediment which are composed principally of fragments derived from pre-existing rocks or minerals; e.g., quartz sandstones, siltstones, and shales are clastic rocks.

claystone - rock which is composed mainly of clay particles, but which does not break apart into separate laminations as does shale.

debris flow - a type of sediment gravity flow (water and sedimentary particles) in which there is only very limited sorting of the particles as to size or shape.

diagenesis - any of several types of basic changes which take place in a mass of sediment after its initial deposition; e.g., cementation, preferential dissolution, and replacement.

diatomaceous - adj., containing a significant proportion of diatom shells.

dolostone - a type of sedimentary rock which contains a high percentage of the mineral dolomite.

dolomite - calcium magnesium carbonate, $CaMg(CO_3)_2$.

endolithic - living *in* rock. Said of rock-boring organisms.

epifauna - fauna (animal life) living on the surface—e.g., of a rock layer.

estuarine - belonging to, or formed in, an estuary.

estuary - the widened mouth of a river, where fresh water enters the sea in a broad area affected by the tides.

evaporite - any mineral or rock layer which has been formed primarily by precipitation from solution as the water evaporates.

fabric - the general texture or arrangement and characteristics of the particles and cement crystals in a given rock.

facies - a term which has several rather complex uses. For a minimum, general definition one can think of a facies as the makeup or composition of a particular group of rock layers which, by its characteristics, shows that the entire unit was deposited in a given environment. Thus, the set of strata can be traced laterally by its suite of characteristics, or *facies*. For example, a deposit of limestone which has a high content of oöids throughout the rock is referred to as having an "oölitic facies." (Many authors speak of such a deposit of limestone as *being* an "oölitic facies.") Within a given geographic area, at a particular level, there may be two or more types of facies laterally adjacent to each other; and in any location where there is a thick sedimentary cover, the local geological column nearly always exhibits many vertically sequential facies types.

fauna - animal life forms, as seen either in the present, or as indicated by animal fossils in the rock strata.

***Formation** - a lithologically distinct and mappable body of rock layers or masses, representing an important depositional episode in the history of the region in which it was deposited. A Formation is a rock unit, rather than a time unit, and is sometimes divided into Members. See the top of p. 16.

genera (sg. genus) - subdivisions of a *family*, in animal and plant classification. A genus is made up of two or more *species* of organisms.

geosyncline - a large geographic area which has undergone subsidence and a filling in with sediments from surrounding areas.

grain - a small particle of sediment or rock, whether it be a fragment of an earlier rock, a small shell, a fragment of a shell, or a mineral crystal.

graywacke - a type of coarse-grained sedimentary rock which consists of poorly sorted grains of quartz, feldspar, and other lithic fragments. Since the matrix often contains dark-colored minerals, the color is generally gray.

***Group** - a subdivision of a rock System. Two or more Formations make up a Group.

halite - sodium chloride NaCl (common table salt).

hardground - a layer of sediment which has undergone early cementation on the sea floor. Hardgrounds are usually of carbonate composition with embedded fossils. Frequently the fossils undergo partial erosion before another hardground is added above. Such hardground strata are frequently found in ancient limestone deposits.

hypersaline - containing a relatively high percentage of dissolved salts.

igneous - a term used to designate a rock or mineral that was formed from molten material, rather than from sedimentary particles.

indurated - partially or fully hardened. Said of a mass or layer of sediment in which lithification processes have occurred.

intercalated - lying in between, thus forming an alternating series of contrasting layers.

in situ - in its natural place or position, as in the case of a fossilized organic structure which is found lying in its original growth position.

invertebrate - belonging to the subkingdom of animals which do not possess a vertebral column.

isopach map - a map which has enclosing lines showing the thicknesses of a particular kind or age of rock throughout a geographic area; e.g., an isopach map of a commercially valuable deposit of limestone throughout an area.

karst terrane - an area underlain by limestone or another type of soluble rock, which shows the definite effects of the dissolving action of water. Sinkholes, caves, and other cavities in the rock are some of these effects.

lacustrine - an adj. pertaining to lakes or ancient lake beds.

laminae (sg. lamina) - thin layers.

laminated - composed of very thin layers.

lithification - a *general* term for the several kinds of processes by which sediments become rock.

lithologic - having to do with rock types. For example, a "lithologic column" in a geologic research report shows the types of rocks which lie one upon another.

local column - the suite of rock layers which lie one upon another in a given geographic location; not to be confused with the general "geologic column."

log (drilling log) - a continuous record of the rock types and characteristics encountered, made as the drill proceeds down through the subsurface.

macrofossil - a fossil which can be seen with the unaided eye or with a common handlens.

marine - pertaining to seawater. For example, "marine strata" designates rock layers which were deposited in seawater rather than in freshwater lakes or streams.

massive - in the geologic sense, this term refers to a mass of rock which does not show thin bedding or other types of layering.

***Member** - a subdivision of the geologic *Formation*.

Mesozoic - the middle of the three *Eras* of time since the Precambrian. It consists of the Triassic, Jurassic, and Cretaceous *Periods*. Cf. Cenozoic, Paleozoic.

micrite - the finely-divided, carbonate matrix of a limestone, consisting of very small particles which would be called "lime mud" or "carbonate ooze" if it were not lithified.

microfauna - animal life forms which can be seen only with a microscope.

microflora - plant life forms which can be seen only with a microscope.

microfossils - fossils which are too small to see with the unaided eye. These are found in abundance, embedded in many types of sedimentary rock. Some of the most abundant are those of the protozoan orders Foraminifera (with calcareous shells), and Radiolaria (with shells or skeletons composed of silica). The most abundant algal microfossils are the coccolithophores (producing calcareous plates), and the diatoms (producing shells of silica).

mineral - a substance, usually an inorganic compound, which appears in nature. Minerals are the major components of rocks.

model - in science, a model is a proposed explanation, or carefully outlined hypothesis, which is subject to further investigation. After much observation and investigation the model may be verified as an actual description of reality, or it may be shown to be defective, and consequently abandoned. For example, a geologist may propose a model as a preliminary attempt to explain how a particular, ancient salt basin was formed.

nannofossil - one of many kinds of very small microfossils (Greek, *nanno* - dwarf). The term is used mainly of marine, calcareous, algal organisms. One of the most important groups is the coccolithophores (literally, “bearers of round, lithic plates”).

oöids - a spherical, carbonate, sedimentary particle or grain which is made up of thin, concentric layers around a very small nucleus. Oöids are being formed in large numbers in shallow, agitated water on the Great Bahama Bank. They are also found in many ancient limestone formations. Types of limestone which contain a considerable percentage of oöids are known as oölites.

orogeny - a major phase or period of fold-mountain building, e.g., the Acadian and Alleghenian orogenies of the Appalachians. Adj., orogenic.

order - a subdivision of a *class*, in animal and plant classification. An order is made up of two or more *families* of organisms.

Paleozoic - the oldest (lowest) of the three *Eras* of time since the precambrian. It is made up of all the *Periods* from the Cambrian up through the Permian. The next Era above the Permian Period was the Mesozoic.

pelagic zone - the part of the oceans which is *water*, in contrast to the ocean floor. Most of the organic growth occurs in the upper levels of the pelagic zone, because it receives sunlight which is needed for photosynthesis.

***Period** - a division of geologic time; cf. Paleozoic, above.

petrology - the division of geology which concentrates on the study of the types, characteristics, and origins of rocks.

petrographic - having to do with a detailed study of rocks; e.g., the study of thin sections of rock under a petrographic microscope.

phylum - a large subdivision of the animal kingdom or of the plant kingdom. A phylum may be divided into *subphyla*, each containing two or more *classes*.

planktonic - pertaining to organisms which live a floating existence in the sea; e.g., marine protozoa and algae which float near the surface.

pore water - water which percolates slowly through the pores of a mass of sediments or rock.

precipitation - the process involving the combining of ions present in a solution—such as in seawater—to form a solid phase (solid particles, which can then settle out). Precipitation should not be confused with the *settling* of particles out of suspension.

progradation - extension of land into the sea by deposition and accumulation of sediments borne by rivers or coastal currents.

regression - a retreat of the sea from coastal areas, due to a drop in sea level or a rise of the land.

sabkha - a salt-encrusted flat, lying a short distance inland from the usual water's edge, on an arid seacoast.

sediment gravity flow - a downslope movement (flow) of a mixture of sediments, and sometimes larger rock fragments, mixed with water. The finer sediments increase the density of the fluid mixture, and thus larger rock fragments can be transported. Two common types of sediment gravity flow are the debris flow and the turbidity flow.

seismic survey - a type of exploration which employs artificially produced shock waves which descend into the earth's crust and are reflected back from certain rock layers to a sensitive recording device.

***Series** - a subdivision of a System of rock strata (see System, below).

sharp contact - the joining surface between two definitely contrasting rock layers.

silica - a general term for the different forms of silicon dioxide which are found in sediments and rocks.

siltstone - a type of sedimentary rock similar to sandstone but composed of smaller-than-sand-sized particles. In most classification systems, "sand" ranges from 1/16 mm to 2 mm in diameter.

slurry - a highly fluid mixture of water and particles of solid matter.

strata (sg. stratum) - a general term for layers of rock or of unlithified sediment.

stratigraphic sequence - a series of rock layers lying one upon another. The word "sequence" here usually implies a known and meaningful order of arrangement or vertical relationship.

stromatoid - a single, relatively small, mound, dome, or column, composed of thin sediment layers, found in limestone deposits (see "stromatolite").

stromatolite - a type of rock containing mounds, domes, or columns which have been formed as a result of algal growth. The mucilaginous secretions of the algae collect carbonate sediment from the water, forming many-layered structures known as stromatoids. (Also see "algal mat.")

stromatoporoid - an extinct class of marine animals which grew in colonies, secreting calcium carbonate, and forming extensive deposits of the same. Their growth habits were similar to those of corals, and they often contributed to the growth of large carbonate mounds. The prefix *stroma*, used in this and several other geologic and biological words, is Greek, meaning "bed" or "bedding." It is thus used to indicate a flat, spreading growth.

subtidal zone - the zone of sea floor extending from low-tide level, near the shore, to the edge of the continental shelf.

supersaturated - pertaining to a solution which possesses a concentration of a given mineral, higher than the normal concentration needed for the beginning of precipitation. (Also see "precipitation.")

supratidal - the part of a seacoast which is above the normal high-tide level. It is covered with water only during storms and floods.

***System** (also called a rock system or strata system) - a major chrono-stratigraphic unit consisting of the rock layers formed during a Period of geologic time. Thus the Formations of the Devonian System were laid down during the Devonian Period, but the System is not a time unit.

taxonomic - an adj. having to do with the classification of organisms.

tectonic - an adj. pertaining to structural characteristics and movements in the earth's crust, either in the past or present.

terrigenous - derived from the land or a continent; said of sediments derived from the land rather than from the ocean floor.

thin-section - a specimen of rock which has been ground very thin for examination under a microscope.

transgression - an encroachment of the sea up onto the land, due to a general rise in sea level or a subsidence of the land.

truncation - the cutting off of a part of a structure, as of the top of a mountain by erosion.

tsunami (tsu nä′ m_ - Japanese) - any large-scale wave in the ocean caused by an earthquake shock in the ocean floor. When the wave reaches shallow water it steepens rapidly and may surge up onto the land margin.

turbidity current - a strong water current, moving downslope along the bottom, near the edge of a body of water; e.g., the turbidity currents which carry sediment down a continental slope.

unconformity - the general term for any break or gap in the geologic record in a geographic area, e.g., between a formation which has undergone a period of erosion of its upper surface and the next formation of sediments which were deposited upon it.

vadose zone - the zone of soil, rock, and sediment lying between the ground surface and the water table. This zone is usually not fully saturated, and is replenished by rains.

vertical section (sometimes spoken of as a “cross section”) - a side view or drawing of a sequence of geologic strata. For example, at a deep road cut one sees a vertical section of several strata. (The use of the term “cross section” for this is confusing, especially because of the use of “cross section” in biology and paleontology. For example, a cross section of a bone or of a linear cephalopod fossil is very different from a vertical section of strata.)

SUBJECT INDEX

BACKGROUND OF THE AUTHOR

Daniel E. Wonderly has had a lifelong commitment to the complete trustworthiness of the Bible, and a continuous interest in Bible-science relationships. He is the author of God's Time-Records in Ancient Sediments (Crystal Press, 1977), and has devoted a major part of the past 20 years to the study of sedimentary geology as related to the Genesis account of creation. He is currently active in Christian work, as well as in his scientific research and writing.

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TEACHING EXPERIENCE Southeastern Bible College – 3 years; Wingate College – 5 years (science); Grace College, Winona Lake, Indiana – 7 years (science).

ADDITIONAL FORMAL STUDIES National Science Foundation Institutes (biology and paleontology); Indiana University (geological science); Bermuda Biological Station (sedimentary geology).

FURTHER GEOLOGIC BACKGROUND Extensive and regular study of published reports of recent sedimentary research projects carried out by teams of petroleum geologists, oceanographers, and other earth scientists; regular attendance of professional geological meetings and participation in field trips prepared and led by the Geological Society of America and similar organizations.

MEMBERSHIPS Interdisciplinary Biblical Research Institute; The Geological Society of America (Sedimentary Geology Division); American Scientific Affiliation; Indiana Academy of Science; West Virginia Academy of Science.

NEGLECT OF GEOLOGIC DATA:
Sedimentary Strata Compared with Young-Earth Creationist Writings

By Daniel E. Wonderly

This work is an attempt to enlist creationists in a serious study of the actual characteristics of the earth's sedimentary strata. Creationist organizations are emphasizing some important truths about creation, but they have neglected the data of earth-science research to such an extent that disgrace has now descended upon the doctrine of biblical creation throughout the nation. In this carefully documented book the author encourages evangelical Christians to take an interest in the real data of earth science, and shows them how they can use such information to alleviate this problem.

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ABOUT THE AUTHOR

Daniel E. Wonderly has brought to this work almost a lifetime of study in Bible-science relationships. He holds graduate degrees in both theology and science and has had extensive teaching experience in both of these areas. Wonderly has spent a major part of his time in research-science studies during the past 15 years and is the author of *God's Time-Records in Ancient Sediments* (Crystal Press, 1977). He is an active member of The Geological Society of America and of several other professional societies.