EDITORIAL

IS TRUTH DEAD?

Probably the most colorful of the Cynic philosophers was Diogenes of Sinope. This imaginative, charismatic figure of the 4th century B.C. did much to promote the Cynic philosophy of virtue as the only good. This belief was often accompanied by extreme asceticism as appears to be exemplified in the life of Diogenes. Many stories are told about him. Some of them are no doubt apocryphal; nevertheless they serve to illustrate the enormity of the gap that sometimes exists between conventionality and ideals. Diogenes is reported to have discarded his last possession — his bowl — after watching a boy drink from his hands. He lived in a borrowed wooden tub, getting the idea from a snail living in its shell. His often-biting sarcasm came forth when Alexander the Great offered him anything he wanted (an offer that had less risk with Diogenes than with most!). His only request was that Alexander the Great move so that he would not block the sunshine. One of the most famous of Diogenes' activities was his trek through Athens, carrying a lighted lantern in broad daylight in a futile search for an honest man.

How successful would Diogenes be today in his search for honesty? Recently, a number of false statements by creationists, progressive creationists, and evolutionists have come to my attention. These unsupported pronouncements indicate a real danger that, to some, winning one's viewpoint can become more important than a correct evaluation of data. One scholar states that after many years, creationists do not have even the beginning of a flood model. Another states that evolutionists are hiding dinosaur skeletons that contain human skulls in their jaws, while another states that sedimentation rates are in agreement with other age-dating techniques. Still another states that creationists fancy that all species were generated by supernatural fiat. These unfortunately erroneous assertions make one wonder if Diogenes and his lamp might not be headed for a long sojourn.

One is loath to say that deliberate falsification is involved in the examples given above. They could be caused by a lack of knowledge. Different views can and do occur in scholarly pursuits, but one would expect a reasonable acquaintance with readily available information before dogmatic pronouncements are made. One should be especially careful about this when one's desire to defend a particular view appears more important than concern for truth. Truth is more important than our private views; further, it is truth whether we like it or not. The question of integrity is even more significant when one considers that by selecting certain data

one can infer more support for a particular view than the facts warrant, thus giving the appearance of scholarly support to that view, even though it may be false. This problem deserves much more attention than is customarily afforded.

Truth is not dead, but there is a real danger that to some minds it may be. In the area of origins, as in many other areas, we must improve in the matter of intellectual integrity if we want efficiency in arriving at truth. The alternative is bleak. It simply means that we will expend a lot of energy just waving our false statements around, while truth remains undiscovered.

Yours for more integrity,

Ariel A. Roth

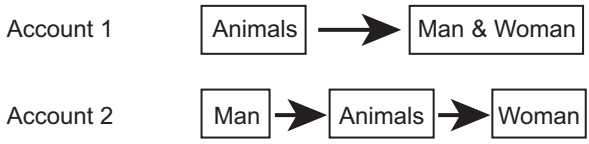
REACTIONS

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

RE: SHEA: THE UNITY OF THE CREATION ACCOUNT (ORIGINS 5:9-38)

I appreciated the analysis of the literary structure of the two accounts of creation, but I was disappointed that Dr. Shea did not deal with the problem of the different order of events in the two accounts.

Genesis 1:24-27 apparently has man and woman created after the animals, for it describes the creation of animals and says, "*then* God said, let us make man ... male and female created he them" (Revised Standard Version). In the second account, Genesis 2:7, 18-20, the animals are created *after* man, as we are told that God recognizes man's need for companionship, so He creates the animals, but not finding a suitable helper, woman is then created. It seems, therefore, that we have in chronological order:



Since we otherwise attach so much importance to the order of events of creation as evidenced by children's Bible lessons and by the struggle over reconciling Genesis 1:3 and Genesis 1:14-18, it seems that the apparent discrepancy of order of events in chapter 1 and 2 needs explanation. My Bible commentary confirms the order of events, but does not seem to recognize the discrepancy. Perhaps Dr. Shea would be willing to respond to this question in a future issue.

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ARTICLES

THE STRUCTURE OF THE GENESIS FLOOD NARRATIVE AND ITS IMPLICATIONS

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WHAT THIS ARTICLE IS ABOUT

*In a previous article (*Origins *5:9-38), Dr. Shea examined the literary structure and content of the first two chapters of Genesis to see if source critics were justified in claiming the existence of two antithetical accounts of creation. His analysis revealed ample support for a unified account of God's creative acts as recorded by one author.*

Applying these same principles of literary criticism to Genesis 6-9, scholars have dissected the flood narrative into small, discrete segments. According to their analyses, these units come from two different sources, J and P, and subsequently have been woven together in a complex pattern. With a multiple authorship, separated by centuries, it would be easy to conclude that the Genesis flood account contains duplications and contradictions and therefore does not necessarily provide a factual account of the sequence of events that took place in one major episode.

Dr. Shea begins this article by dividing the flood account into eleven sections, each representing one thought or sense unit. His rhetorical analysis of the overall literary structure reveals these units to be the building blocks of a detailed, organized narrative, suggesting a single author. Further evidence against a multiple authorship is found when the author examines some of the "proofs" used by source critics. The passages citing the numbers of animals taken into the ark are usually considered to be duplications and are attributed to different sources. Here, Dr. Shea shows that these so-called duplications actually provide evidence for parallelism, a literary technique employed by the ancient Semites in their poetry and prose.

Another argument for multiple sources is found in the chronological statements of the flood account. Source critics have attributed statements about time periods to J, while assigning the more precise chronological data of Noah's life to P. The writer of this article believes them to be inconsistent in applying this methodology and offers a scheme for all the data in which the patterns for both the periodic and specific chronological data contribute to the literary structure of the narrative. This harmonious integration makes multiple authorship seem unlikely.

In the final section, Dr. Shea discusses certain chronological elements from four Mesopotamian flood stories. Though these stories are similar in literary construction to the flood account, no Assyriologist would see any reason for separating the stories into multiple sources. This shows a definite dichotomy in methodology between biblical and ancient Near Eastern studies, and Dr. Shea suggests that biblical literature should be evaluated in comparison with the literature of the ancient Semites who were contemporary with the biblical Hebrews.

In an earlier issue of *Origins* (5:9-38) I discussed the literary critical problem posed by the parallel recitations of God's creative acts in Genesis 1 and 2. The problem is relatively straightforward: either there are two creation stories from the J (Yahwist) and P (Priestly) sources, as literary critics would have it, or there is one creation account told in two parallel and related passages, as I concluded.

The analyses proposed for the flood narrative of Genesis 6-9 are of a different nature. Here, literary critics see many small and discrete textual units from the J and P sources that have been woven together in a rather complex pattern. In a relatively representative work, Speiser divided these three chapters into 24 units which range in size from portions of verses to a series of consecutive verses, alternating them between his J and P sources and assigning a dozen such units to each.[1] From his analysis of the sources, Speiser concluded that "we are now faced not only with certain duplications, but also with obvious internal contradictions, particularly in regard to the numbers of the various animals taken into the ark, and the timetable of the Flood."[2] Since Speiser dated P some four centuries later than J, his supposed internal contradictions are only a natural outgrowth of his theory of the composition of this narrative.

By atomizing the text into miniscule segments, source critics have missed its overall structure, which actually represents a remarkably powerful and detailed organization of the literary vehicle in which the flood account was told. Detection of that structure also contradicts the thesis that the flood narrative represents a series of statements from two sources that were woven together. Furthermore, an overall structural analysis of Genesis 6-9 provides some interesting explanations for its various features, including the supposed contradictions mentioned above. The basic work of analyzing the overall structure of the flood account was done by U. Cassuto,[3] a conservative Jewish commentator. Considering the conclusions to which he came, it is not surprising that he rejected the standard documentary approach to this and other narratives in the Pentateuch. More recently, B. Anderson has presented a new study of the structure of the flood narrative.[4] It was this study which stimulated my thinking on this subject, and while I am indebted to him for the basic idea worked out below, I differ with both Cassuto and Anderson in working out some of the details in this analysis.[5]

Both Cassuto and Anderson divide the flood narrative into 12 units, but the 12 units are divided somewhat differently in their respective outlines, as can be seen in Table 1. My own analysis is included for the purposes of comparison which is discussed later.

Table 1 shows that Anderson has made two additional sections by dividing one of Cassuto's original sections, and he has reduced five other

TABLE 1

Cassuto	Anderson	Here
1) 6:9-12	1) 6:9-10	1) 6:11-22
	2) 6:11-12	
2) 6:13-22	3) 6:13-22	
3) 7:1-5	4) 7:1-10	2) 7:1-5
4) 7:6-9		3) 7:6-10
5) 7:10-16	5) 7:11-16	4) 7:11-16
6) 7:17-24	6) 7:17-24	5) 7:17-24
7) 8:1-14	7) 8:1-5	6) 8:1-5
	8) 8:6-14	7) 8:6-12
8) 8:15-17	9) 8:15-19	8) 8:13-19
9) 8:18-22	10) 8:20-22	9) 8:20-22
10) 9:1-7	11) 9:1-17	10) 9:1-7
11) 9: 8-11		11) 9:8-17
12) 9:12-17		

sections to two. He has also included the genealogical information in 9:18-19 in his outline whereas Cassuto excludes it. Anderson is more consistent than Cassuto, because 6:9, with which their outlines begin, also includes genealogical information. I have excluded both genealogical notices (see the discussion of the individual units from my outline below). Each section in these outlines constitutes a discrete sense or thought unit in the flood account. To separate the J and P sources, literary critics commonly cross the boundaries of these sense units, a procedure which is both unnecessary and unwarranted, as should become evident from the structural study of the flood narrative which follows.

If this were merely a study in dividing the thought units of the flood narrative, such an exercise would not be of special importance. The value of this preliminary step is accentuated by the fact that these sense units are used as building blocks in the structure of the flood account in a very specific way, as Cassuto notes:

> *The series of paragraphs is composed of two groups, each comprising six paragraphs: the numerical symmetry should be noted. The first group depicts for us, step by step, the acts of Divine justice that bring destruction upon the earth, which has become filled with violence; and the scenes that pass before us grow increasingly gloomier until in the darkness of death portrayed in the sixth paragraph there remains only one tiny, faint point of light, to wit, the ark, which floats on the fearful waters that have covered everything, and which guards between its walls the hope of future life. The second group shows us consecutively the various stages of the act of Divine compassion that renews life upon the earth. The light that waned until it became a minute point in the midst of the dark world, begins to grow bigger and brighter till it illumines again the entire scene before us, and shows us a calm and peaceful world, crowned with the rainbow that irradiates the cloud with its colours — a sign and pledge of life and peace for the coming generations.*[6]

Here Cassuto has described an elaborate literary chiasm in which the units correspond in the pattern of A:B:C:D:E:F::F:E:D:C:B:A. Thus there is not only a development of the flood account in the form of a crescendo to its greatest height, followed by a decrescendo, but the units with which this crescendo-decrescendo narrative is told are thematically paired between its first and second halves. Cassuto describes this phenomenon:

> *There is a concentric parallelism between the two groups. At the commencement of the first, mention is made of God's decision to bring a flood upon the world and of its announcement to Noah; and at the end of the second, reference is made to the Divine resolve not to bring a flood again upon the world and to the communication thereof to Noah and his sons. In the middle of the first group we are told of the Divine command to enter the ark and its implementation is described; in the middle of the second, we learn of God's injunction to leave the ark and of its fulfillment. At the end of the first group the course of the Deluge is depicted, and at the beginning of the second its termination.*[7]

Anderson has come to the same general conclusion, though differing in some details, in his summary outline of the flood account.[8]

Transitional introduction (6:9-10)
1. Violence in God's creation (6:11-12)
2. First divine address: resolution to destroy (6:13-22)
3. Second divine address: command to enter the ark (7:1-10)
4. Beginning of the flood (7:11-16)
5. The rising flood waters (7:17-24)
GOD'S REMEMBRANCE OF NOAH
6. The receding flood waters (8:1-5)
7. The drying of the earth (8:6-14)
8. Third divine address: command to leave the ark (8:15-19)
9. God's resolution to preserve order (8:20-22)
10. Fourth divine address: covenant blessing and peace (9:1-17)
Transitional conclusion (9:18-19)

My remarks will build upon the observations of these two scholars and are merely meant to amplify and refine some of their conclusions.

I. THE STRUCTURE OF THE FLOOD NARRATIVE

A. The Frame or Envelope for the Flood Narrative

1. The Primary Genealogical Inclusio (5:32 // 9:28-29). The genealogy of Genesis 5 gives only the first half of its standard formula related about Noah — his birth age and the names of his three sons born thereafter. This formula, completed at the end of Genesis 9 where Noah's death age is given, forms the link between the genealogy of Genesis 5 and that of chapter 10, which records the Table of Nations descended from Noah's sons. Both halves of Noah's genealogical formula enclose the lengthy

narrative about the flood; thus this bipartite genealogical statement functions specifically as a frame, an envelope, or an inclusio around it.

2. The Prologue and the Epilogue (6:1-8 // 9:20-27). Cassuto stresses the connection of 6:1-8 with the passages it precedes. In fact, 6:1-8 is the last passage treated in the first volume of his commentary on Genesis, whereas his second volume begins with 6:9 and the story of the flood.[9] Anderson's evaluation of the position of this passage is more perspicacious, since he notes how well it balances with 9:20-27.[10] I am indebted to Anderson's analysis for the almost self-evident terminology of "prologue" and "epilogue" for these passages. Beyond that, however, I would suggest that both are enclosed by secondary genealogical statements (see below) and that the theme of the prologue tells why the epilogue was included in the text.

God and man are the two major elements in 6:1-8. Four statements are made about God in this passage: His view of the wickedness of man, His sorrow for creating man who had become so wicked, His determination on that account to blot man and the animals from the surface of the earth, and His designation of 120 years as the period of time to elapse until His purpose was to be accomplished. Of this passage Speiser has noted:

> *The story of the primeval titans emerges as a moral indictment, and thereby as a compelling motive for the forthcoming disaster. And the period of 120 years becomes one of probation, in the face of every sign that the doom cannot be averted. All of this accords with the separately established fact that the Flood story in Genesis, unlike its Mesopotamian analogues, was morally motivated.*[11]

This passage also records five significant facts about antediluvian man: the sons of God married the daughters of men; the daughters of men bore sons to those sons of God; the wickedness at this time was very great; and among the men of that time Noah found favor in God's sight. The term "sons of God" has occasioned much discussion in the commentaries. These sons of God are commonly thought to be divine-like beings, i.e., angels, because the identification of the sons of God as human beings does not otherwise occur until considerably later in biblical literature, whereas in non-biblical Canaanite texts, members of the pantheon were known as sons of El, the chief God.

Such an interpretation can only be held at the expense of doing considerable violence to the contents and context of this passage. The first line refers to the time when man (*'adam*) began to increase on the earth. This introductory statement puts the sons of God in relation to those men who spread over the earth and furthermore is a direct connection with the two genealogical lists which precede this passage. The list of Genesis 4 presents the "sons of men" to whom those daughters were born, the line of Cain that perpetuated his wickedness and violence.

Genesis 5 presents the contrasting line of Seth, the line of faith, as the sons of God. Luke saw this connection when he wrote up his genealogy which ended with "Adam, the son of God" (Luke 3:38). Juxtaposing the reference to the sons of God and the daughters of men immediately after the genealogies of Genesis 4 and 5 strongly implies that these two groups belong to the two groups identified in those lists. Yet these two groups obviously included more than just the persons named in the genealogies, as there was an ever-expanding but otherwise unnamed population related to the persons identified in those lists. To inject angels into this scene is to insert an extraneous element into this passage and its context.

This passage begins and ends with two groups of men, the sons of God and the sons (fathers-daughters-sons) of men. The former is represented by Noah who found favor in God's sight, while the latter, more inclusive group received the condemnation and sentence of God for its wickedness. The principal purpose of this passage is to show that the wickedness of antediluvian man was the cause for the flood. Some relations with this theme are evident in the Epilogue to the flood narrative in 9:20-28. Mankind is not yet divided into the two great groups of good and evil, but the seeds of such a development and division already were laid in Noah's drunkenness and Ham's conduct toward his father. These were the best men whom God could find to bring through the flood. The correspondence in theme between the Prologue and the Epilogue to the flood narrative is, therefore, that of the wickedness of man before the flood and the wickedness of man — even the best of men but on a lesser scale — after the flood. The relationship between these two passages provides an additional explanation for the presence of the latter in the text when it has previously been interpreted largely in terms of the fate of Canaan (v 25). Verses 25-27 parallel the patriarchal poetic prophecies given in terms of blessings and cursings by Isaac (Gen 27:27-29), Jacob (Gen 49), and Moses (Deut 33).

3. The Secondary Genealogical Inclusio (6:9-10 // 9:18-19). Both Cassuto and Anderson include the genealogical notice in 6:9-10 with the central narrative in their outlines of the flood account. Since 6:9-10 and 9:18-19 stand in similar positions at opposite ends of the narrative, they should be treated alike. Anderson is consistent in including both with the central body of the narrative; I prefer to exclude both. If the divided genealogical notice in 5:32 and 9:28-29 forms an inclusio around the flood account as a whole, these parallel genealogical notices should be evaluated in a similar way. Genesis 6:9-10 demarcates the Prologue from the central narrative which follows it, and 9:18-19 divides the central narrative from the Epilogue which follows it. Both of these brief passages contain lists of Noah's sons. The first list is identified as the "generations" (*toledoth*) of

Noah, while the second refers to their exit from the ark and states that the world was populated (literally, "dispersed") from the three sons.

To summarize, up to this point we have detected the following structure for the envelope around the flood narrative proper — primary genealogical inclusio:Prologue:secondary genealogical inclusio::(central narrative discussed below)::secondary genealogical inclusio:Epilogue:primary genealogical inclusio. We turn now to consider the sections with which the central narrative was composed.

II. THE BODY OF THE ACCOUNT, THE CENTRAL FLOOD NARRATIVE

A. Preceding and Following the Flood

1. The First and Last Divine Speeches: The Pre- and Post-Diluvial Covenants (6:11-22 // 9:8-17). The first and last sections of the body of the narrative contain the first and last — and longest — of the statements made by God to Noah. The first speech begins with the announcement of God's intention to destroy all flesh because of the violence and corruption that had spread abroad on the earth. No element in the final section corresponds directly to this theme, but, as Cassuto and Anderson have noted, linguistic relations are involved in the use of the word *shaḥat*, "corrupt, destroy." The first section contains a play on the different meanings of this word: the corruption of the earth and all flesh in it is noted three times and God stated twice that He would destroy all flesh because they had corrupted their way. In the final section the same verb is used twice of God's non-activity, for He covenanted never to destroy all flesh again with a flood. In a sense, therefore, antithetic parallelism exists between these two sections — yes, a flood; no, no more floods. There is no parallel to the instructions for the construction of the ark in the final section, because the ark had already served its purpose.

Immediately after instructing Noah to build the ark, God described His plan to destroy man and the animals by a *mabbûl*, a "flood." This interesting word, used 13 times in the Hebrew Bible, refers solely to the Noachian flood. It occurs once in the first section (6:17) referring to what God would send, and then is used three times in the final section, as if to emphasize the point, referring to what God would not send (9:11, 15).

Then follows the most direct link between these two sections — their covenants. The word "covenant" occurs only once in the first section (6:18), and seven times in the final section (9:9, 11-13, 15-17), as if to reemphasize the point. The verb used with the covenant in the first section, "to establish" (literally, "to cause to raise up"), is again used with the covenant three times in the final section. While the terms of these two covenants may not appear to be very similar at first glance, in actuality

they are essentially the same in character. In both instances protection from a flood was offered — during the flood in the first instance and from any future flood in the second.

The parties involved in these two covenants are also similar. The first covenant was made only specifically with Noah, but his immediate family and the animals are connected directly in the text as sharing in its benefits with him. In the second instance the covenant was made with Noah (four times), his descendants (once), the animals (once), and "every living creature of all flesh" (four times). The word for covenant does not occur in any other section of the flood narrative. These two sections are related most specifically, therefore, by means of the records of the covenants which they contain.

Both Anderson and Cassuto begin the central section of the flood account with 6:9-10, whereas I have separated the genealogical notice in these verses from what follows, for the reasons explained above. In addition, Anderson has divided 6:11-12 from the rest of this first section. Since God's initial statement to Noah in verse 13 stems directly from what He saw as recorded in verses 11 and 12, there is no reason for dividing the earlier verses from the latter.

2. The Preservation of and Second Purpose for the Animals (7:1-5 // 9:1-7). Cassuto concludes the first of these two sections with 7:5, whereas Anderson extends it to 7:10. Cassuto's arrangement is preferable, because the first five verses convey God's command to enter the ark, while the next five verses describe the first of two parallel statements about Noah's compliance with His command. The first section ends with the statement that Noah did all that Yahweh commanded. The second begins with a dateline and ends with a similar statement, that Noah went into the ark as God commanded him. This command, as reported in God's second speech to Noah, was given because a 40-day rainstorm would begin in 7 days and would blot out every land-based animal outside of the ark from the face of the earth.

Then Noah was told to take into the ark seven pairs of clean animals and birds but only single pairs of unclean animals. Source critics have long posed a numerical contradiction within the flood account, since in the preceding section only single pairs of all the animals were cited as candidates to board the ark. The difference in the number of animals, according to their analysis, stems from different sources, P and J respectively, but the methodology employed in differentiating such sources is inconsistent. The dimensions of the ark in the preceding section belong to P, because he "loves to fiddle with figures."[12] By the same line of reasoning the numerical values attached to the different groups of animals that were to enter the ark should also be attributed to P, who should have

been the most interested in the distinction between clean and unclean animals, but instead this passage is generally attributed to J. In such a bind, the source critic proposes that P has reworked J, but that admission means there really is no valid basis for distinguishing between such supposed sources here.

There are better explanations for this difference. First, it should be noted that 120 years passed between the events described in these two passages. At the end of Genesis 6, God referred to animals in more general terms when He commanded Noah to build the ark. The more explicit command came when the ark was completed presumably 120 years later. Thus a logical progression with the passage of time is seen. The same point is applicable to the flood itself. In the preceding section God only told Noah that He would blot out life on the earth by a flood. Now Noah is told that the flood would begin in 7 days and last for 40 days, another case of increasing specificity with the progress of the narrative.

Parallels for a progression of thought can be found in the prophets. Note, for example, the development of the theme of the remnant in the book of Jeremiah. In the early chapters are found only hints or brief statements about the remnant to be saved from the Babylonian destruction. By chapters 30-33, a detailed picture of the restoration of the remnant — known as the Book of Consolation — has been fully developed. In Genesis 6, Noah was given in essence a prophecy concerning the flood and was told to make provision to preserve a remnant — his family and the birds and animals — in an ark.[13] That more specific information was given later to Noah about the remnant and the flood through which they would be saved is no more surprising than that more specific information was given to Jeremiah later in his ministry about the remnant that was to be saved out of the Babylonian destruction.

A further explanation for the mention of the number of clean animals and birds comes from. the parallels between this section and its corresponding member in the second half of the flood account, which gives the instructions to Noah concerning the diet of mankind after the flood. At this point one might expect to find provisions being made for the new diet which was to include the flesh of animals. It is interesting to note, therefore, that relatively greater quantities of clean animals were provided to meet this need. While there is no explicit command at this time to abstain from unclean meat, a portent of such future instruction is contained in the differentiation between the relative quantities in the two groups of animals.

The other main point in Genesis 9:1-7 is that man was prohibited from taking the blood or life of other men, i.e., the permission given to slay animals (for food) was not to be extended to slay man for whatever reason. Perhaps this question arose because God was the one who slew

mankind with the flood, according to the first of these two passages. Could man then slay his fellow man with impunity in view of such divine conduct? The answer is: No, that prerogative was to be left to the judgment of God alone. Thus these two sections share synthetic and antithetic themes. The synthetic theme is the preservation of the animals in order to provide man's post-flood diet. The antithetic element is that God could blot men from the face of the earth (i.e., with the flood), but man was not to usurp the divine prerogative of judgment by taking the life of a fellow man.

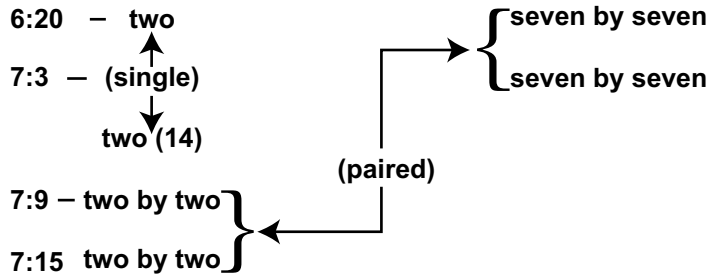
3. The Preservation of and First Purpose for the Animals (7:6-10 // 8:20-22). Both Cassuto and Anderson conclude the first of these two sections with 7:10. My contents for the second of these two sections correspond to Anderson's, while Cassuto's section includes Noah's departure from the ark with his offering of sacrifices. Noah's departure from the ark fits better with the preceding verses, as the response to God's command to leave the ark, which leaves the sacrifice scene standing alone as a separate unit.

Once again the birds and animals provide the thematic link between these two sections, and once again the clean and unclean are divided. Before the onset of the flood, four passages deal with the number of animals that were taken into the ark. The difference between 6:20 and 7:3 has already been discussed above. In 7:9 the distinction between the clean and the unclean animals continues, and they went into the ark "two (by) two." The same numerical value accompanies the reference to the animals in 7:15. Source critics commonly attribute the references to two (6:20) and two by two (7:15) to P, while the seven by seven in 7:3 is attributed to J. Because the two by two in 7:9 does not fit well with the rest of the formulae in 6:20 and 7:15, it is usually attributed to a later editor or redactor (R) and is thus disqualified as a primary source. No textual evidence is available to support this interpretation; it rests solely upon a hypothesis of this mode of literary criticism.

The animal formulae of these four passages contain three main elements: numerical values to quantify them, the phraseology employed for the animals themselves, and distributional terminology which categorizes the animals according to their types. Taking the numerical values first, we find the following distribution for these units in the Hebrew text:

The link between 6:20 and 7:15 as proposed by source critics does not hold up when analyzed from the viewpoint of their numerical values, since the numerical value of 7:15 is reduplicated, as are those of 7:3 and 7:9, whereas the only specific numerical link of 6:20 is with 7:3, where the unclean animals are still quantitated by the number two written singly. Thus the numerical portions of these formulae cross their proposed sources, since 6:20 and 7:3, supposedly written by P and J respectively,

are the only passages that contain the number two written singly, and both 7:3 and 7:15, J and P supposedly, contain reduplicated numerals.



Neither is there any valid reason to attribute 7:9 to J and 7:15 to P, since they both reduplicate the same numeral two. The way in which the numerical values were written in these four passages lends no support to separating any J and P sources, for they form an interrelated and progressive series. Nor is there any conflict between the two by two of 7:9 and 15 and the seven by seven of 7:3. The best way to translate the "two by two" of 7:9 and 15 is probably "by pairs," referring to the male-female pairs, while 7:3 indicates specifically that seven of those "clean" pairs were to be taken into the ark.

All four passages use the same word for beast or animal (*b^{e}hemah*) and for fowl (*^{c}ôp*). In 7:3 "heaven" is added, while 7:15 adds a new phrase — "every bird of every wing." Both this reference to the birds and the one in 6:20 have been attributed to P, but this position can only be maintained by interpreting the additional phrase for the birds in 7:15 as an expansion or gloss upon the more abbreviated reference in 6:20. A similar expansion must also be posited for the animals that creep upon the ground. Reference to this class of animals is only found in 6:20 and 7:15, not in 7:3 and 9. In 6:20, however, this class is identified as the "creeper of the ground," whereas in 7:15 it is identified as the "creeper that creeps upon the earth." The root for "creep" is reduplicated in the second passage and contains a different word for earth which is used with a preposition rather than in a construct phrase as is the case with 6:20. In order to relate these two passages by source, therefore, one must contend with the fact that the phrases which refer to the birds and the animals that creep on the ground differ by a total of seven Hebrew words.

Analysis of the distributional terminology employed in these formulae provides an explanation for the presence of the creepers of the ground in the first and fourth passages and their absence from the second and third. In general, they fall into the category of unclean animals. Thus in the two

passages in which the clean and unclean are differentiated, the creepers of the ground are not distinguished, whereas in the two passages in which the clean and the unclean are not differentiated, the creepers of the ground are present. The same distinction applies to the use of the phrase "according to its kind" (*l^{e}mînēhû*) which also appears only in the first and fourth passages. When the "kinds" are broken down into clean and unclean, as in the second and third passages, the distributional term is not employed.

Thus these four passages divide into two pairs according to their distributional terminology. This does not mean that they should be attributed to different sources; it indicates instead the pattern in which they were used through this portion of the flood account: according to its kind:clean/unclean::clean/unclean:according to its kind, or A:B::B:A. Thus the first and fourth general statements were connected with the initial command to build the ark for these animals and the final statement that they had entered the ark. When Noah was commanded to enter the ark, these classes were broken down more specifically, as would be expected on that immediate occasion, and a parallel statement of compliance to these specifications is given also in those terms. Source critics commonly refer to such passages as duplicates and attribute them to different sources. In so doing they have missed the literary technique of parallelism employed by the ancient Semites in their poetry and prose. Thus the formulae employed in referring to the animals in these four passages do not provide criteria, by which they should be separated into sources. On the contrary, they provide evidence for the design of literary structure in the account. Additional evidence for the structure comes from considering the parallels that are found in the four sections which follow the central-most elements of the account.

The reference to the clean animals in 7:9 is of importance in evaluating the relationship of this section with its parallel member from the second half of the flood account, in which Noah selected his sacrificial offerings from the clean birds and animals. Just as God provided the clean animals in greater abundance for man's food after the flood (see the preceding section), He also provided them in greater abundance for their use in sacrifice. An obvious practical point is also involved. Had Noah sacrificed a member from the pairs of the unclean animals, there would have been no mate for the remaining member of those pairs; consequently none of the unclean animals would have been able to propagate after the flood.

When the references to the animals in these four sections are compared with their parallel sections in the second half of the account, it can be seen that the distinction between the clean and unclean animals is made in the two sections which correspond to the two sections in which that distinction was most vital to man after the flood — those referring to the use of

animals for sacrifices and for food. The parallel members to the two sections which lack this distinction deal with all of the animals coming out of the ark and all of the animals enjoying the benefit of the covenant that God made with Noah and his descendants — never to destroy the earth again by a flood. Since both clean and unclean animals participated in these two events, there was no need to distinguish between them in the parallel sections earlier in the flood narrative.

4. Entering the Ark and Leaving the Ark (7:11-16 // 8:13-19). The major parallels between entering the ark and leaving the ark are self-evident. The verbs employed for these actions, *bô'* and *yasa'*, are reciprocals. To expand upon the parallels between these two sections, it may be noted that both begin with a rather precise date in terms of Noah's life:

7:11	8:13
In the 600th year of Noah's life, in the 2nd month, on the 17th day of the month.	In the 601st year, in the 1st month, the first day of the month....

These are the only two passages in which this full-date formula occurs in the flood account. Immediately after these dates the first section tells how the waters came upon the earth, and the second section states that the waters had dried from off the earth. Both sections continue with references in the same order to Noah's family and the birds and animals. For further reciprocal actions between these two sections, note that Yahweh shut Noah in the ark at. the end of the first section, whereas Noah removed the covering from the ark at the beginning of the second. Similar sounding verbs are used to describe these two actions. The first section describes the two sources from which the waters of the flood came and the second section tells of the drying of the earth in two stages. The departure from the ark is described in terms of the divine command to depart from the ark and the statement of Noah's compliance with that command. The reference to the birds and animals being fruitful and multiplying upon the earth harks back to the record of creation. Thus the repopulation of the earth after the flood parallels the population of the earth at creation.

B. The Course of the Flood: The Central-most Sections of the Flood Narrative

5. The Flood Waters Rise and Abate (7:17-24 // 8:6-12). My sections resemble Anderson's, but, I have ended the second section two verses earlier. The dateline in 8:13 is best interpreted as the heading for this next section. Cassuto considers all of 8:1-14 to be one section, overlooking the dateline of forty days with which both sections begin. The first chronological reference delimits the period of time during which the flood waters increased upon the earth until they covered the mountains. The second

period of forty days began when the tops of the mountains first reappeared and Noah sent out the first of the birds with which to test the state of the world outside the ark.

Thus the first section tells of the disappearance of the last trace of life outside the ark, retelling it four times over to emphasize the point. The story of the reappearance of life outside the ark is also told four times, each time involving the appearance of a bird outside the ark. These two parallel constructions can be outlined as follows:

1. "And all flesh died that moved upon the earth, birds, cattle, beasts, all swarming creatures that swarm upon the earth, and every man" (7:21)	1. The raven sent out (8:7)
2. "Everything on the dry land in whose nostrils was the breath of life died" (7:22)	2. The dove sent out (8:8-9)
3. "He blotted out every living thing that was upon the face of the ground, man and animals and creeping things and birds of the air; they were blotted out from the earth" (7:32a)	3. The dove sent out again after seven days. Returns with an olive leaf (8:10-11)
4. Only Noah was left, and those that were with him in the ark (7:23b)	4. The dove sent out again for the last time after another seven days (8:12)

Comparing the subdivisions of these two sections with the preceding and following sections shows that four sections lead up to the flood and four sections follow it, while within each section describing the rise and fall of the flood are found four statements or subsections that relate to the disappearance and reappearance of life outside the ark. With this balance between these two sections it seems very unlikely that 7:17-24 should be divided into four sources (P/J/P/J) and 9:6-12 should be divided into three sources (P/J/P), as literary critics have proposed.

6. The Apex of the Flood, the Climax of the Flood Account (8:1-5). Anderson has called attention to this section as "the turning point of the story with the dramatic announcement of God's remembrance of Noah and the remnant with him in the ark."[14] I differ with Anderson and Cassuto as to the structural expression of this climax. In their analyses both Anderson and Cassuto subdivide the flood account into twelve sections, which gives them six even sets of "two by two." Yet if the preceding analyses have been correct, the narrative approaches this climax through the crescendo of the flood waters in 7:17-24 and their decrescendo through 8:6-12. Since these two sections parallel each other, 8:1-5 stands alone at the climax of the story — the apex of the flood waters — figuratively, on the very tops of the mountains of Ararat. This pattern which peaks at this point thus emphasizes the manner in which the structure of the narrative

contributes forcefully to its intent, i.e., its form complements its function. The complementary themes of this section are expressed in three brief statements: the flood crests, the ark rests, and God remembered Noah. Arriving at this climax brings us to a review of the overall structure of the flood account (Table 2).

TABLE 2

An outline summary of the structure of the flood narrative.

6. The flood crests
   The ark rests
   God remembered Noah } (8:15)

5. The flood rises (7:17-24) ... 7. The flood abates (8:6-12)
V. The flood proper ..... VI. After the flood
4. Enters the ark (7:11-16) ..... 8. Exits the ark (8:13-19)
3. Brings in clean animals (7:6-10) ..... 9. Noah's sacrifice (8:20-22)
2. Brings in clean animals (7:1-5) ..... 10. Noah's diet (9:1-7)
1. My covenant with you (6:11-22) ..... 11. My covenant with you (9:8-17)
IV. Preliminary to the flood
III. Secondary genealogy (6:9-10) ..... VII. Secondary genealogy (9:18-19)
II. Prologue: man's wickedness (6:1-8) ..... VIII. Epilogue: man's wickedness (9:20-27)
I. Primary genealogy (5:32) ..... IX. Primary genealogy (9:28-29)

III. THE CHRONOLOGICAL ELEMENTS IN THE FLOOD NARRATIVE

The biblical account of the flood contains a number of chronological references which can be divided into two categories. The first gives the length of time for certain periods between different events in the account, such as the 7 days, the 40 days, and the 150 days that elapsed between such events. The second gives more specific reference to certain points in time that are dated in terms of the day, month, and year of Noah's life.

A. Literary Criticism of the Dates in the Flood Account

Source critics have posited discrepancies between some of these chronological data in order to separate the J and P sources for the account. It is held that these two sources were not reconciled chronologically when they were fused together editorially. The statements about time periods have been credited to J, and the more precise chronological statements given in terms of Noah's life are attributed to P.

Source critics are inconsistent in applying this methodology, because they credit the 7 and 40 days to J while attributing the 150 days to P. If the time-period statements are characteristic of J, then the 150 days should also be given to J, but to do so would erase the desired distinction between the length of the flood in J and P.

Another defect of this method is the way in which these dates are excluded from the sections in which they are found. This occurs with

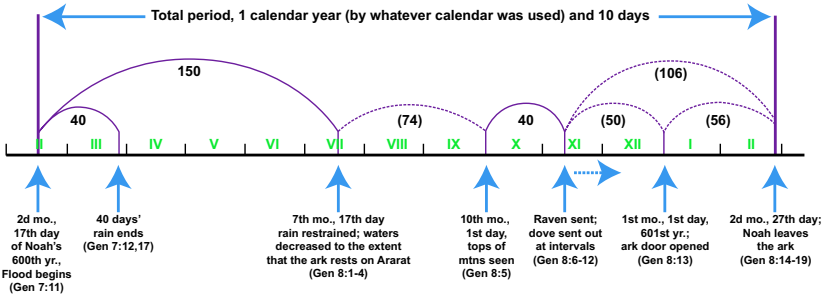
four dates from Noah's life for P (7:6, 11; 8:13, 14) and twice for the 40 days in the case of J (7:12, 17). Moreover, in 7:17 a chronological statement is severed from the sentence in which it occurs: "the Flood came down upon the earth (P)/40 days (J)."[15] Such treatment leads to a misunderstanding of the text as can be seen in a recent commentary on Genesis. The commentator observes that in the two differently dated statements about the drying of the earth (8:13-14), "we are confronted by two separate chronologies of the flood within the same source, a fact that should not too much disturb us in view of the complicated history of the legend."[16]

Closer attention to the Hebrew text would have prevented such an errant observation. This passage states that on 601/I/1 "the *waters* were drying up" (*ḥārbû hammayim*). Later, at an unspecified time, Noah removed the covering of the ark and saw that the "*faces of the ground*, were drying up" (*ḥārbû pᵉnê haʾᵃdāmâ*). By II/27, however, "the *earth* was dry" (*yābᵉšah hāʾāreṣ*). Since three different subjects occur in these statements and since the verbs used in the two dated statements are different, it is quite arbitrary and unfair to the ancient writer to state that all have the same meaning. We may not understand the degree of distinction intended in using these two different verbs for drying, but the philological distinction remains nonetheless.

B. The Calendar for the Flood

The preceding section has discussed some of the difficulties with the methodology which attempts to sort sources on the basis of supposed discrepancies between the different chronological statements in the flood narrative. These difficulties lie more, I believe, in the defects of this methodology than in the chronological data. As Figure 1 demonstrates, all these data can be harmoniously integrated into one chronological scheme for the flood, according to the calendar constructed by S.H. Horn.[17]

FIGURE 1. The duration of the flood. The total was 1 calendar year and 10 days, but the exact number of days cannot be calculated, since the exact length of Noah's year, 365 days or otherwise, is not known. Reproduced (color added) with permission of the Review and Herald Publishing Association.



C. The Pattern for the Periodic Chronological Data

An additional aspect of the chronological statements is their pattern which contributes to the crescendo of the narrative to its climax and the subsequent decrescendo. All references to the time periods can be encompassed in the following outline:

The flood crests, the ark rests, God remembers Noah (8:1)
4. 150 days prevail (7:24) ..... 5. 150 days waters abate (8:3)
3. 40 days of the flood (7:12, 17) .... 6. 40 days first birds sent out (8:6)
2. 7 days till the flood (7:10) ..... 7. 7 days next bird sent out (8:10)
1. 7 days till 40-day storm (7:4) ..... 8. 7 days last bird sent out (8:12)

D. The Pattern for the Specific Chronological Data

The chronological references given in terms of dates in Noah's life fit a similar pattern: two are given in the sections before the flood proper is described, two are given in the climactic section at the apex of the flood, and two follow the central-most sections of the flood narrative. Not all of the date elements (year/ month /day) are included in every reference, but their absences are also distributed according to a pattern which can be outlined as follows:

600 (I/1ff.)	VII/17	601/I/1
(7:6)	(8:4)	(8:13)
600/II/17	X/1	(601)/II/27
(7:11)	(8:5)	(8:14)

This outline and the preceding one shows a definite design to the way in which the chronological data of the flood were recorded. These two patterns follow and thus complement the pattern for the narrative that has been determined above from a literary analysis of its sections. Since all three elements — the literary units, the time periods, and the dates — are distributed according to similar and parallel patterns, it seems very unlikely that any one of the three should be attributed to a different documentary source. To attribute one kind of date to one source and the other kind of date to another source when they parallel each other so closely seems very unlikely from the viewpoint of valid literary analysis. No distinction between J and P can be derived from such data.

E. Literary Criticism of the Chronological Elements in Extrabiblical Flood Stories of the Ancient Near East

Four main flood stories from Mesopotamian sources are known: 1) a very fragmentary copy of the Sumerian version which dates to the early second millennium B.C.,[18] 2) tablets of the Old Babylonian version known as the Atra-hasis Epic, which can be dated to the last half of the 17th century B.C. according to their scribal colophons,[19] 3) an 8th or 7th century B.C.

copy of the Neo-Assyrian version known as the 11th tablet of the Gilgamesh Epic,[20] and 4) a flood story as recorded by Berossus, a Babylonian priest of the 3rd century B.C.[21] Because of its late date the last source will not be discussed here. The Sumerian flood story will only be mentioned in passing because of its fragmentary condition.

Of particular interest are the chronological elements in the Babylonian flood stories, because source critics have commonly attributed these elements to P, when analyzing the Genesis flood account. Can the same methodology be applied to these ancient Near Eastern sources? The Atra-hasis Epic is a comprehensive story, covering the creation of man to the flood. Seventeen chronological data occur in the surviving portions of this epic.

The first chronological datum in the Atra-hasis Epic refers to a period of 40 years during which the lesser gods of the pantheon toiled in the cosmos. When they rebelled, the decision was made to reassign their burdensome tasks to man, who was to be created from clay and the blood and flesh of a god named We-ila. To prepare for this event, the god of wisdom ordered that purifying baths be taken, apparently by We-ila, on the 1st, 7th and 15th days of the month. A parallel repetition of this chronological statement states that the purifying baths were taken on those days. In the middle of the story are some regulations given by the birth-goddess for women bearing children, including the instruction that a woman should remain in confinement for 7 days after giving birth.

The birth-goddess gave birth to mankind, as stated twice in a parallel bicolon, in the 10th month of her gestation. Parallel statements inform us that 9 days were assigned for her confinement and the rejoicing connected with the creation. But the noisy population of the earth prevented the gods from sleeping, and before mankind had existed for 1200 years, the decision was made to decimate their ranks with a plague. This plot was foiled when the god of wisdom told Atra-hasis — the human hero of the story — to avert the plague by making offerings to the plague god.

After a second period of 1200 noisy years, the gods decided to decimate mankind by drought and famine. This time the storm god resupplied mankind with water after they built him a temple. The difficulties experienced during this famine are described as becoming progressively more severe through its 1st, 2nd, and 3rd years. The point was expanded in the later Assyrian version of this text.

Because the plague and famine had failed to solve the problem posed by mankind, the gods decided to send a flood as the final solution. Obeying instructions from the god of wisdom, Atra-hasis built an ark and was able to escape, along with his family and the birds and animals, from the flood. Only two chronological references occur in this portion of the story. As with Noah in the Bible, Atra-hasis was warned 7 days before the onset of

the flood: "he (the god of wisdom) announced to him (Atra-hasis) the coming of the flood on the seventh night."[23] The flood lasted seven days and seven nights.[24] The Sumerian version also indicates that the flood lasted seven days and seven nights, but about 40 lines are missing from the portion where one might have found reference to the length of time before the flood.[25]

Utnapishtim is the name of the hero in the flood story told in the Gilgamesh Epic. Utnapishtim built the ark in two days, starting five days after the god informed him that a flood was coming and finishing it on the seventh day.[26] In contrast to the Atra-hasis Epic, this source gives a rather detailed description of the size and shape of the ark. A biblical literary critic would attribute these details, along with the chronological statements, to P. Utnapishtim's flood also lasted 7 days, and he waited another 7 days after landing before sending out his birds at intervals of unspecified lengths of time. Thus three main periods of time are present in this version of the flood: 7 days before the flood, 7 days of the flood, and 7 days after the flood. These periods of 7 days are broken down in the text, however, so that a dozen chronological references occur in the story.

In terms of chronology the biblical account of the flood is considerably more complex than either of the Mesopotamian flood stories. It contains five specific dates whereas they contain none. It also contains references to six different periods of 7, 40, and 150 days duration, while the Babylonian stories refer only to 2 or 3 periods of 7 days each. The broken Sumerian version refers to the 7 days of the flood, the Atra-hasis Epic refers to the 7 days before and during the flood, and the Gilgamesh Epic refers to the 7 days before, during, and after the flood. There are 17 chronological data in the entire Atra-hasis Epic, 16 in the biblical flood account, and 12 in Gilgamesh's version.

From this summary the question can now be asked, how should the chronological data in these two Babylonian flood stories be handled from the standpoint of literary criticism? If one were to follow the techniques of biblical source critics, most of these should be attributed to a P (C?) source, whereas much of the body of the story should be attributed to a J (Ah and G?) source. But no Assyriologist has ever suggested that these chronological details should be sorted out from these stories and attributed to another source other than that through which the main body of the narrative was received. I suspect that if such an approach to this narrative were proposed at a professional meeting of orientalists, it would meet with a very cool reception.

On April 12,1978, I attended a symposium on Sumerian literature at the annual meeting of the American Oriental Society in Toronto, Canada. Sumerologists are now able to analyze as literature the Sumerian myths

and epics that have been recovered from cuneiform texts. At this symposium it was suggested that Sumerologists could learn from the techniques of literary criticism that have been practiced by biblical scholars for a century. One observer responded that the field of documentary analysis in biblical criticism was in chaos and disarray, and he recommended that Sumerology avoid getting bogged down in a similar morass.

This observation emphasizes the dichotomy in methodology between biblical and ancient Near Eastern studies. Instead of evaluating biblical literature according to the dead-reckoning canons drawn from Homeric studies of the last century, attention should first be given to the writing of the ancient Semites who lived in the same world as the biblical Hebrews. This has never been done thoroughly and consistently in biblical studies.

A further illustration of this problem is seen in a reaction to *Ancient Orient and Old Testament* (Inter-Varsity Press, 1966), by K.A. Kitchen, an English Egyptologist and conservative Christian who strongly rejects the documentary hypothesis. In a book review which appeared in 1970, E.F. Campbell, Jr., of McCormack Theological Seminary in Chicago, objected that "comparison of ancient Near Eastern law to the materials in Leviticus could lead a Speiser to suggest how old some of the Leviticus is, but the same Speiser could work very effectively with the J and E strands and with P in writing his Genesis commentary."[27] But Campbell failed to realize that Speiser — a professional Assyriologist — never applied the methodology employed in his commentary on Genesis to the corpus of ancient Near Eastern extrabiblical literature. It is particularly important to note that Speiser followed a rather standard documentary approach to Genesis 6-9, but never deigned to analyze the Mesopotamian flood stories along similar lines.

IV. CONCLUSION

Even if my analysis of the literary structure of the biblical flood narrative is only approximately correct, the documentary analysis postulated by source critics in the past century cannot be correct. As it stands, the structure could only have come from the hand of one author. Its precise design far transcends any modifications that might have been introduced to mold such sources together by a later editor. Each section delimited above is a building block which contributes a very precise part to the elaborate crescendo:decrescendo design of the narrative. To remove any or to attribute them to separate sources differing in date by several centuries would require a total rejection of any literary structure in the flood account. In other words, the study of the literary structure of this narrative stands in direct opposition and tension to the previous documentary analyses that have been performed upon it.

On those rare occasions when this point is emphasized, source critics have suggested that P used J extensively and actively in writing up his account.[28] So extensive has been this supposed reuse of J that the two sources are essentially indistinguishable at present. But if J and P are no longer distinguishable from each other, then there is also no reason to maintain that such separate sources were ever involved. The author of the biblical flood account, as it currently stands, could have employed sources to compose his work, but in whatever form those sources may have come to him, they are not really recognizable beyond the current literary unity of the flood narrative. This re-examination of its structure has borne out Cassuto's comment on it in relationship to source criticism, and the point he makes is just as valid as when he penned it three decades ago:

> *If we examine the section of the Flood without bias and pay heed to its finished structure ... it becomes apparent that the section in its present form cannot possibly be the outcome of the synthesis of fragments culled from various sources; for from such a process there could not have emerged a work so beautiful and harmonious in all its parts and details. If it should be argued that the artistic qualities of the section are the result of the redactor's work, then one can easily reply that in that case he was no ordinary compiler, who joined excerpt to excerpt in mechanical fashion, but a writer in the true sense of the word, the creator of a work of art by his own efforts. Thus the entire hypothesis, which presupposes that the different fragments were already in existence previously in their present form as parts of certain compositions, collapses completely.*[29]

ENDNOTES

1. Speiser assigns the following sections to J: 6:1-8; 7:1-5; 7:7-10; 7:12; 7:16b; 7:17b; 7:22-23; 8:2b-3a; 8:6-12; 8:13b; 8:20-22; and 9:18-27. He assigns the following sections to P: 6:9-22; 7:6; 7:11; 7:13-16a; 7:17a; 7:18-21; 7:24 - 8:2a; 8:3b-5; 8:13a; 8:14-19; 9:1-17; and 9:28-29. Speiser EA. 1964. Genesis, Anchor Bible, Vol. 1. Garden City, NY: Doubleday, *passim*.
2. Ibid., p 54.
3. Cassuto U. 1964. A commentary on the book of Genesis, Vol. II. Jerusalem: Hebrew University, p 30ff.
4. Anderson BW. 1978. From analysis to synthesis: the interpretation of Genesis 1-11. Journal of Biblical Literature 97:23-29.
5. See also: McEvenue SE. 1971. The narrative style of the Priestly writer. Analecta Biblica, vol. 50. Rome: Pontifical Biblical Institute, p 35ff. McEvenue has also studied the structure of the flood narrative to some extent, but his study is complicated by the fact that he examined only those passages which he attributed to P; hence his study is incomplete for the purposes of the analysis presented here. Another similar study has been done by: Wenham GJ. 1978. The coherence of the flood narrative. Vetus Testamentum 28:336-348. Wenham and I concur that the climax of the narrative in 8:1 stands alone and the parallels begin on either side of it; he also places more emphasis upon the parallelisms between the chronological elements in the two halves of the narrative. In contrast to my study, however, Wenham divides the narrative into 31 smaller units, and his does not include the

prologue or epilogue, which he did not analyze. His conclusion is that Genesis 6-9 forms one complete literary unit that cannot be divided into different sources without disruption of the structural integrity of this account.

6. Cassuto, p 30-31.
7. Ibid., p 31.
8. Anderson, p 33.
9. Cassuto, p 3ff.
10. Anderson, p 33.
11. Speiser, p 46.
12. Vawter B. 1977. On Genesis: a new reading. Garden City, NY: Doubleday, p 118.
13. For a discussion of the theme of the remnant, see: Hasel G. 1972. The remnant: the history and theology of the remnant idea from Genesis to Isaiah. Berrien Springs, MI: Andrews University Press.
14. Anderson, p 36.
15. Speiser, p 49.
16. Vawter, p 129.
17. Horn SH. 1960. Seventh-day Adventist Bible dictionary. Washington DC: Review and Herald Publishing Association, p 355. For a more detailed discussion of the calendar involved here, see: Wood LH. 1953. The chronology of Ezra 7. Washington DC: Review and Herald Publishing Association, p 49-53.
18. As translated by M. Civil. In: Lambert WG, Millard AR, editors. 1969. Atra-hasis: the Babylonian story of the flood. Oxford: Oxford University Press, p 138-145.
19. Lambert & Millard, p 31-32.
20. As translated by E.A. Speiser. In: Pritchard JB, editor. 1955. Ancient Near Eastern texts relating to the Old Testament. Princeton, NJ: Princeton University Press, p 93-96, hereinafter referred to as ANET.
21. Lambert & Millard, p 134-137.
22. Ibid., p 45. The other chronological data mentioned from this text follow in this work *passim*.
23. Ibid., p 91.
24. Ibid., p 97.
25. Ibid., p 143.
26. ANET, p 93-94. The other chronological data mentioned from this text follow in this work *passim*.
27. Campbell EF, Jr. 1970. Book review of K.A. Kitchen's Ancient Orient and Old Testament. Journal of Near Eastern Studies 29:137.
28. This is Anderson's solution to the problem he has posed in his own study. See Anderson, p 31.
29. Cassuto, p 34.

ARTICLES

THE INTERPRETATION OF C-14 DATES

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WHAT THIS ARTICLE IS ABOUT

This article discusses the basic principles and assumptions of radiocarbon age dating. The author points out the difference between real time and radiocarbon age determinations which have to be adjusted to agree with Bristlecone Pine chronology or biblical chronology. Also, a variety of models for the past history of the earth that might affect the accuracy of radiocarbon ages is evaluated. Variation in the intensity of cosmic rays which produce C-14 is not considered by the author to be a significant source of discrepancy, since evidence indicates that in the past there has not been a significant change in the cosmic ray intensity. Changes in the geomagnetic field which diverts cosmic rays might make C-14 dates appear as much as 11,000 years too old. The influence of changes in the magnetic field of the sun on cosmic rays produces a negligible effect. Higher upper atmosphere water vapor content in the past would produce little effect, since a model based on our present knowledge of molecular relationships would allow for only limited changes. The author suggests that the most significant change in the relationship of C-14 dates to real time could come from a dilution of the C-14 by a significantly larger biosphere in the past. An increase of more than two orders of magnitude in this biosphere could make C-14 dates appear 51,000 years too old.

THE RADIOCARBON AGE CONCEPT

The radiocarbon "date" or age for a specimen is a statement of the length of time that would be required for a specimen from an idealized contemporary environment to lose by spontaneous radioactive transformation sufficient carbon-14 (C-14) to have the same C-14 concentration as found in the test specimen. Radiocarbon age is a convenient and useful way to express the concentration of C-14 in natural organic and sedimentary material. The idealized contemporary environment reference level is 1.18×10^{-12} C-14 atom per C-12 atom (one C-14 for 848 billion C-12 atoms), which is equivalent to an average of 13.6 disintegrations of C-14 per minute per gram of carbon.

The better-equipped radiocarbon dating laboratories using the conventional gas or scintillation counting technique are capable of detecting concentrations of C-14 as low as 1.4×10^{-15} (one atom of C-14 per 700 thousand billion C-12 atoms). To reach a concentration this low by

radioactive decay from the contemporary reference level would require in the order of 55,000 years at the rate C-14 now spontaneously converts to nitrogen-14 (N-14). Accordingly, the maximum age range of radiocarbon dating by conventional disintegration rate techniques is said to be approximately 55,000 years. Techniques under development for directly counting C-14 atoms by means of nuclear accelerators hold promise of extending this range to the vicinity of 70,000 years (Bennett 1979). "Infinite age" is commonly assigned to a specimen that has a C-14 concentration below the detection threshold of the procedures by which it was analyzed. In practice radiocarbon laboratories are reluctant to specify a radiocarbon age greater than 40,000 due to uncertainties with respect to contamination from younger C-14.

A radiocarbon age can have meaning in terms of real time only over time periods during which there has been no introduction of C-14 into the specimen and no loss of C-14 other than by spontaneous radioactive decay. Another way of stating the same restriction is to say that there has been no chemical contamination, that the specimen has been chemically isolated. Under this restriction a radiocarbon age will be directly equivalent to a real-time age if the C-14 concentration in the specimen was initially at the contemporary reference level, and if C-14 radioactive decay has not varied from its present rate. There are no theoretical considerations or experimental data that suggest there has been a significant variation in the decay rate (half-life) (Brown 1974). The initial C-14 concentration must be assumed on a speculative basis, unless calibration by a reliable independent dating technique is available.

CONVERSION OF RADIOCARBON AGE INTO CORRESPONDING REAL TIME

Work that has been done to determine the initial C-14 concentration in the past and make possible a conversion of radiocarbon age into real-time age has been reviewed in *Origins*, Vol 2, No 1 (Brown 1975a). Evidence is given there which strongly suggests that in the more remote ancient times the initial C-14 concentration was much lower than has been the case over the past three or four thousand years. Additional evidence of this nature has been presented in the *Creation Research Society Quarterly* (Brown 1975b).

Since this material was published additional analysis has been made of accumulation rates for over 280 peat and sediment features described in *Radiocarbon*, volumes 8-17 (1966-1975). For the time range represented by C-14 ages 0-4000 the worldwide average accumulation rate for the

sedimentary features was determined to be 1.295±0.317 mm per C-14 year. For peat bogs the corresponding average accumulation rate was determined to be 0.726±0.125 mm per C-14 year. For the time range represented by C-14 ages 15,000 - "infinite," the corresponding accumulation rates were found to be 0.333±0.166 mm per C-14 year and 0.203±0.091 mm per C-14 year, respectively. When comparing the 0-4000 with the 15,000 - "infinite" C-14 age, these results specify a sediment accumulation rate ratio of 3.89±2.14 and a peat accumulation rate ratio of 3.58±1.72. The magnitude of these ratios, particularly that for sediments, rules out compaction as a satisfactory explanation for the apparently lower accumulation rates in time greater than that which is associated with a C-14 age of 15,000. One must account for the apparent lower accumulation rates as an indication of less favorable conditions for erosion, sedimentation, and peat growth or as an indication of a lower C-14 concentration in the early biosphere.

A specimen that began its existence with a C-14 concentration lower than the standard contemporary reference level would reach the C-14 concentration it has at present in less time than is suggested by its conventional radiocarbon age.

Figure 1 depicts a first-approximation for the initial C-14 concentration, according to three models for converting radiocarbon age into a real-time age. The contemporary reference level is specified as "100%" in this figure. Curve A represents the situation as it would have been if the initial C-14 concentration had been essentially the same as the contemporary reference level throughout the full range of radiocarbon dating. Curve B represents the initial C-14 concentration required by the currently accepted Bristlecone Pine dendrochronology (Ralph et al. 1973). Curve C depicts a situation that would be compatible with the chronological implications of the first eleven chapters of Genesis, taking into account the demonstrated approximate equivalence between radiocarbon ages and real-time at least as far back as 3500 B.P. and the absence of detectable concentrations of C-14 in material that can confidently be considered to have been buried at the time of the flood (anthracite coal, deep-well oil, most natural gas, e.g.). The horizontal bars designated "Flood" and "Creation" span the time range between the dates for these events as estimated by a straightforward application of the data in the Masoretic text (left end) and the Septuagint text (right end).

Figure 2 is a chart for first-approximation conversion of conventional radiocarbon ages into real time according to each of the models represented in Figure 1. This chart makes no distinction between the "B" model and

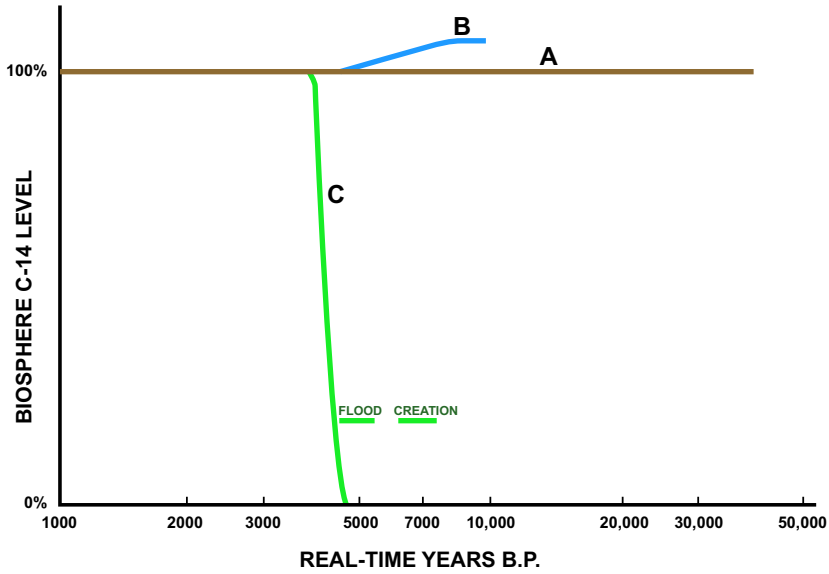

FIGURE 1. Models for Biosphere C-14 Level. The idealized contemporary reference level is specified as "100%." A: Strictly uniform conditions model. B: First approximation for current Bristlecone Pine dendrochronology model. C: First approximation for biblical chronology model requirements.

the "C" model over the range for which dendrochronological calibration is indisputable. The B curve is a smoothed trend line for the MASCA (Museum Applied Science Center for Archaeology) radiocarbon age conversion data. For greater detail the MASCA charts and tabulations should be consulted (Ralph et al. 1973).

Possibly the first intensive effort to provide a scientific base for interpretations of radiocarbon ages as suggested by the C curves in Figures 1 and 2 was made in the early 1960s by Henry F. Pearl (1963). Other efforts include Whitelaw (1968) and Clementson (1974).

VARIABILITY OF INITIAL C-14 CONCENTRATION

The model depicted by line C in Figures 1 and 2 translates conventional radiocarbon ages from "infinity" to approximately 3500 into a real-time age range no more than about 1800 years. Some support for this model has already been cited (Brown 1975a, 1975b, and above). Are there reasonable factors that could account for so great a compression of the radiocarbon age range? The reasonableness of the following effort to

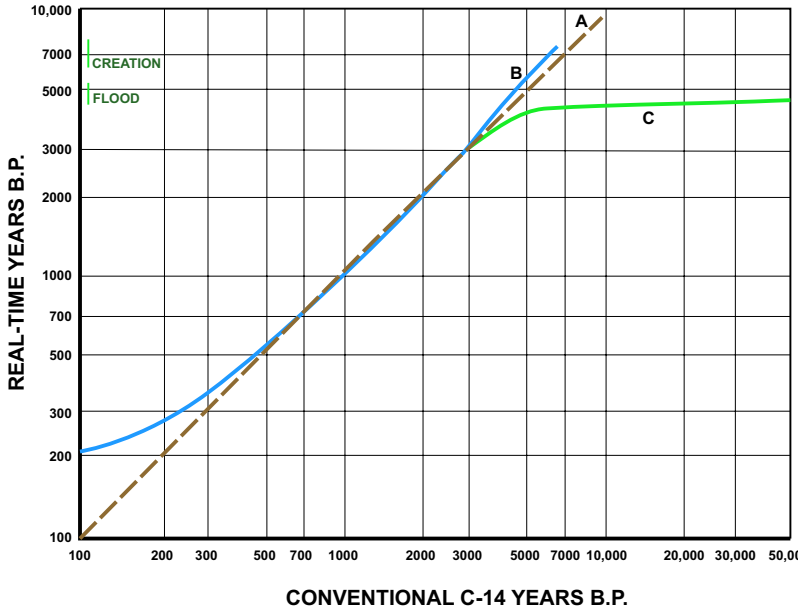

FIGURE 2. Radiocarbon Age Conversion. First-approximation conversion of conventional C-14 age into real-time age for the models depicted in Figure 1.

answer this question may depend in part on the confidence of the reader in the historical authenticity of the first eleven chapters of Genesis.

INFLUENCE OF COSMIC RAY INTENSITY VARIATION ON C-14 AGES

Since C-14 is cosmogenic, i.e., formed by interaction with primary cosmic radiation, there is a possibility that changes in the cosmic ray intensity have brought changes in the biosphere C-14 concentration, as has been the case with nuclear weapon tests. An encounter between a primary cosmic ray particle and an atom often results in the atom being broken up into smaller atoms. Some of these smaller atoms are unstable, i.e., radioactive. Cosmogenic radioactivity in meteorites and rocks from the moon provides a measure of cosmic ray intensity in the past. After exposure of a meteoroid or moon rock to a constant cosmic ray intensity for a time equal to about four half-lives, a cosmogenic radioactive nuclide formed therein reaches an equilibrium concentration at which the number of new atoms formed within a given period of time is equal to the number

that experience radioactive decay during the same time. The half-lives for the more than 20 cosmogenic radionuclides found in meteorites and moon rocks cover the range from 5.7 days to 3.7 million years (Shedlovsky et al. 1967; Trivedi & Goel 1973). Within the uncertainty of experimental determinations, these nuclides (manganese-52, aluminum-26, beryllium-10, manganese-53, e.g.) are found to be in equilibrium with the present intensity of cosmic radiation. From these observations it is apparent that the present cosmic ray intensity is essentially the same as the average that has been maintained for longer than any period that can be covered by radiocarbon dating. The experimental data also indicate that any short-time variation of the galactic cosmic ray intensity about the average that may have occurred during this time has been within a factor of two (Forman & Schaeffer 1979).

A change in the C-14 concentration by a factor of two would shift the radiocarbon time scale by only 5730 years — one half-life. Therefore fluctuations that may have occurred in the cosmic ray intensity cannot be expected to have produced a discrepancy of more than about 5700 years between any radiocarbon age and equivalent real time. In my judgment there is not a sound basis for assigning any C-14 age discrepancy to the cosmic ray intensity factor.

INFLUENCE OF GEOMAGNETIC FIELD ON C-14 AGES

Only the cosmic ray particles that reach Earth's atmosphere are effective in producing C-14 in the biosphere. The magnetic field of the Earth deflects a large proportion of the incoming cosmic ray particles so that they do not interact with the atmosphere. It has been reliably estimated that if the present geomagnetic field were to completely disappear the C-14 production rate would double (Kigoshi & Hasegawa 1966; Lingenfelter & Ramaty 1970). An eleven-fold increase in the geomagnetic field would reduce the C-14 production rate to one-fourth its present value. An increase in the order of 100-fold would be required to bring the production rate near zero.

Since ionizing radiation is harmful to organisms it is to be expected that when life was originally placed on this planet a mechanism for protection from radiation damage was provided. This protection could have been afforded by a capability for healing radiation damage to tissue, a capability that has largely diminished by the present time. It seems more reasonable to presume that such protection was provided, at least in a large measure, by a radiation shield that isolated the biosphere from cosmic radiation.

One can postulate that prior to a catastrophic event such as the Genesis flood the geomagnetic field was strong enough to hold the production of

C-14 in the atmosphere to a negligible level. Since the mechanism by which the geomagnetic field is maintained is not understood, there is little restraint against postulating that this field may have been 100-fold greater in the world that was destroyed during the flood episode. But there is no evidence (paleomagnetism of sediments and intrusives in Cambrian and Precambrian formations) that the geomagnetic field strength has ever been so great. With the evidence presently available, it seems to me wisest to suggest that the geomagnetic field was probably greater before the flood than it is at present, but possibly no greater than sufficient to hold the worldwide C-14 production rate to in the order of one-fourth its present value. A factor of one-fourth would reduce the real-time equivalence of the radiocarbon time scale range by two half-lives — 11,460 years. Magnetic field effects produced by the sun also influence the rate at which cosmic ray particles interact with Earth's atmosphere. Solar magnetic effects are considered to be a primary cause of the observed fluctuations of radiocarbon age about the average trend that is indicated by the B curve in Figure 2 (Lingenfelter & Ramaty 1970; compare the curves in Ralph et al. 1973). There does not appear to be any need to consider solar magnetic effects in seeking an explanation for order-of-magnitude discrepancies.

INFLUENCE OF UPPER ATMOSPHERE WATER VAPOR CONTENT ON C-14 AGES

A magnetic field is not the only means by which the biosphere could have been shielded from the harmful effects of cosmic radiation. The destruction of the original surface features of our planet in the flood experience could have been accompanied by a reduction in the water content of the atmosphere that resulted in conditions more favorable to C-14 production. From Genesis 2:5, 6 it has appeared to many Bible students that in the preflood world moisture requirements of plants were met by a subsoil water supply and heavy dew. Heavy dew implies an atmosphere nearly saturated with water vapor (near 100% relative humidity) during most of a typical 24-hour cycle. Such a condition would provide a comfortable climate if the temperature remained cool.

Over the region in which most biosphere C-14 is presently produced — 20 km to 75 km above sea level — the barometric pressure varies from approximately 55 mm Hg to 0.025 mm Hg, and the temperature varies from -56ºC to -75ºC, respectively, with a temperature maximum of about +10ºC at the 47-53 km level (Handbook of Chemistry and Physics 1970). At these temperatures the saturated vapor pressure of water (or ice) ranges from 0.0138 mm Hg up to 9.2 mm Hg and then down to 0.00105 mm Hg.

At the 47-53 km level the ratio of water molecules at +10ºC saturation to nitrogen and oxygen molecules would range between 7.5/1 and 15/1. At the 20 and 75 km levels the corresponding ratio is 0.0025/1 and 0.042/1 respectively. At sea level only 3.6% (ratio of 1/28) of the atmosphere molecules are H_2O under conditions of complete water vapor saturation (100% relative humidity) at 27ºC (81ºF).

To estimate C-14 production in a hypothetical preflood atmosphere, let us assume relative humidity near 100% at *all* levels and a temperature profile similar to that which is now characteristic of the atmosphere in the 20-75 km region. We do not have enough information to construct an atmosphere model that meets the specifications of Genesis 1:6, 7, and are confident that the present temperature profile would be incorrect for such a model, but offer the following as an indication of the limited influence atmospheric water vapor can have on C-14 production. Let us compare an atmosphere with a *maximum* ratio of H_2O molecules to $N_2 + O_2$ molecules of 1/28 with an atmosphere for which this ratio ranges between 0.0025/1 and 7.5/1, 7.5/1 and 15/1, and 15/1 and 0.042/1. For a rough estimate the latter can be assumed to have a weighted average of 6/1, giving a comparison between atmospheres with water molecule ratios of 1/28 at sea level and 6/1 higher up in the biosphere.

Neutrons released by the breakup of nitrogen and oxygen atoms as a result of an encounter with a primary cosmic ray particle may convert nitrogen-14 into carbon-14, hydrogen-1 into hydrogen-2, nitrogen-14 into nitrogen-15, or oxygen-16 into oxygen-17. The probabilities for these reactions, expressed in the standard nuclear reaction probability units, are respectively: 1.82, 0.332, 0.075, and 0.000,18 barns. The reactions with other isotopes of nitrogen, hydrogen and oxygen are too infrequent to be of concern in this discussion. Given an equal number of encounters of neutrons (thermal) with nitrogen and hydrogen, the ratio of C-14 to H-2 production will be 1.82/0.332 = 5.5/1.

Since standard air contains 78% nitrogen molecules, the ratio of water molecules in the atmosphere mixtures we are comparing become 1/22 and 6/0.78, rather than 1/28 and 6/1. For a rough estimate it will suffice to use 1/22 and 8/1. In order to compare the nitrogen molecules with hydrogen molecules equivalent we should use the ratios 22/1 and 1/8, since each water molecule contains two hydrogen atoms, and each nitrogen molecule is composed of two nitrogen atoms.

With the foregoing stipulations we have a C-14 to H-2 production ratio of 5.5/1 × 22/1 = 121/1 in an atmosphere that has the same composition as 100% moisture-saturated sea-level air. Of the C-14 and H-2 atoms

produced under these circumstances 99.2% would be C-14.[1] In 100% moisture-saturated air for the average conditions hypothesized at 20-75 km altitude this ratio is $5.5/1 \times 1/8 \cong 0.7/1$. Under such circumstances approximately 40% of the combined C-14 and H-2 production would be C-14. The reader should be cautioned again that the atmospheric model presented here is *extremely* crude; it requires impossible values of total gas pressure in the 47-53 km region, and unreasonably large $H_2O/(N_2 + O_2)$ ratios. A reduction from 99.2% to 40% is in the ratio $1/2.5 = 1/2^{1.3}$, which would correspond with a 1.3 half-life compression of the real-time range of the C-14 age scale, only about 7500 years. A more realistic model for a water vapor saturated preflood atmosphere would prescribe a smaller C-14 age correction.

INFLUENCE OF BIOSPHERE CARBON INVENTORY ON C-14 AGES

The most significant line of reasoning concerning possible mechanisms for a compression of the C-14 age scale is based on estimates of the amounts of non-radioactive carbon in which C-14 has been distributed. C-14 can be compared with red coloring used to make white cake into pink cake. The larger the amount of cake batter into which a given amount of coloring is placed, the less pink the cake will be. It has already been pointed out that the ratio between C-14 and C-12 in the contemporary reference atmosphere is 1/(848 billion). Since the beginning of the industrial revolution this ratio has progressively reduced as a result of burning fossil fuels (Wilson 1978; Nozaki et al. 1978). The combustion of fossil fuel introduces into the atmosphere CO_2 that does not contain C-14 and restores to the biosphere carbon from a more luxuriant period in the past.

Estimates that have been made of the world carbon inventory are in general agreement (Borchert 1951; Rubey 1951; Revelle & Suess 1957; Bolin 1970; Fairhall & Young 1970; Reiners 1973; Woodwell et al. 1978; Hall 1979). The estimate that developed out of the 24th Brookhaven Symposium in Biology in 1972 (Reiners 1973) is utilized in Table 1. The estimate for the total "fossil" organic carbon inventory given in Table 1 is taken from William Rubey (1951). The term fossil is here used within quotation marks to indicate that some of the buried organic carbon may be primordial rather than associated with organisms. According to the data given by Reiners, the total carbon inventory in the present biosphere is less than one five-hundredth of the total "fossil" carbon inventory. On the basis of the estimate given by Rubey, the ratio of total carbon inventory

in the present biosphere to the total "fossil" organic carbon inventory is 1/176.

Presuming that the fossil carbon was removed from the biosphere by the flood, one can postulate that the preflood biosphere contained in the order of 500 times more carbon than does the contemporary biosphere. If the same world inventory of C-14 as is now maintained were distributed in this preflood biosphere the level of C-14 activity would have been about 1/500 the contemporary reference level. Since $500 = 2^{8.97}$ approximately nine C-14 half-lives or 51,000 years of the radiocarbon time scale can be accounted for in this way.

Even if one assumes that *no* sedimentary carbonates were formed during and after the flood and that all present "fossil" organic carbon was buried by the flood, the reduction in the active biosphere carbon inventory resulting from flood burials is 176-fold, according to Table 1. On this basis the apparent C-14 age of plant and animal material at the time of the

TABLE 1
World Carbon Inventory

Primary data as given by Reiners (1973), excepting that for total "fossil" organic carbon inventory which is taken from Rubey (1951). Estimates are presented in units of 10^{12} metric tons.

1.	Atmosphere	0.670
2.	Freshwater	0.330
3.	Living organisms on land	0.833
4.	Dead organic material on land	0.700
5.	Living organisms in the ocean	0.0015
6.	Dead organic material in the ocean	1.000
7.	Atmosphere, freshwater, and organic material (Sum of Items 1-6)	3.53
8.	Dissolved in the ocean surface layer	0.500
9.	Primary contemporary biosphere (Sum of Items 7 and 8)	4.03
10.	Dissolved in deep ocean	35.000
11.	Total contemporary biosphere (Sum of Items 9 and 10)	39.03
12.	Available coal and oil	10.000
13.	Total "fossil" organic	6,820
14.	Sedimentary carbonates	13,180
15.	Total "fossil" carbon (Sum. of Items 13 and 14)	20,000
*16.	Ratio (20,000 + 39.03)/39.03	$513 = 2^{9.00}$
*17.	Ratio (6820 + 39.03)/39.03	$176 = 2^{7.46}$

*Uncertainties in the inventory estimates make the exponents of 2 uncertain by as much as possibly ±2 (9.00±2, 7.46±2).

TABLE 2
C-14 Time-Scale Adjustment Factors

Cause	Probable Maximum Adjustment in C-14 Years
Variation in cosmic ray intensity	±<1,000
Variation in geomagnetic field	-~11,000
Variation in solar influence on magnetic field	±<500
Loss of water vapor "canopy"	- ?
Loss of carbon from the biosphere	-~51,000†*
Total possible scale reduction	~62,000†

* The adjustment for loss of carbon from the biosphere on the basis of "fossil" organic carbon alone is approximately 43,000† years.

† Uncertainties in the inventory estimates given in Table 1 may produce uncertainties as great as ±10,000 in these time estimates.

flood would be 42,730 (7.46 × 5730), assuming that the world C-14 inventory at that time was the same as has been characteristic of contemporary times. Since the chronological data in the Bible places the flood approximately 5000 years ago, at the present time this material would have a C-14 age in the order of 48,000. The remaining difference between 48,000 and "infinite" (50,000 - 55,000 in practice) C-14 age can be accounted for by assuming that some sedimentary carbonates were formed during and following the flood. One only has to postulate that about 1/6 of the sedimentary carbonates were formed during and after the flood to account for a 45,000 reduction totally on the basis of carbonate precipitation and organism burial.[2]

SUMMARY OF C-14 TIME-SCALE ADJUSTMENT FACTORS

The physical possibilities for an adjustment of the radiocarbon time scale to chronological requirements implied in the Bible, as discussed in this paper, are summarized in Table 2. Since a scale reduction of only 45,000 C-14 years is required by the C Model depicted in Figures 1 and 2, it is apparent that this model does have a reasonable physical science base. Although the estimates summarized in Table 2 are at best only rough approximations, they seem to clearly establish that geomagnetic field reduction, upper atmosphere water vapor depletion, and biosphere carbon loss that are likely to have been associated with the flood can account for changes in the C-14 concentration that would be adequate for a conversion of radiocarbon ages into real time in a manner that is in agreement with the chronological boundary conditions given in the Bible. Table 3 suggests

TABLE 3
Suggested Tentative Model for a C-14 Age Scale Compatible with Biblical Chronology

Real time since the flood	5,000
Reduction in geomagnetic field (present intensity ~1/4 the preflood intensity)	6,000
Burial of organic material (preflood carbon exchange system contained ~1/3 the present "fossil" organic carbon)	34,000
Formation of sedimentary carbonates during and following the flood (~1/5 present sedimentary carbonates)	6,000
Total C-14 age range	51,000

one way in which these factors might be combined to account for the total C-14 age range.

The model suggested in Table 3 requires a preflood biosphere carbon inventory nearly 130× greater than that of the contemporary biosphere. Many individuals do not consider so great a biosphere carbon inventory to be reasonable. It is unquestionable that a world with a biosphere containing this much carbon would be distinctly different from our present world. It is reasonable to presume that in the preflood world organisms were larger and more abundant and that the portion of the planetary surface capable of supporting luxurious growth was possibly two orders of magnitude greater than at present (e.g., see Table 4-2 of Whittaker 1970), but it should be recognized that if the 130× increase is to be accounted for entirely by carbon in organic compounds, an increase of much more than 1000× is required. I do not believe that sufficient certain knowledge concerning the preflood world is available to either eliminate or adequately model this possibility.

In selecting the last two items of Table 3, 39.03×10^{12} metric tons of carbon was used for the contemporary biosphere reference, as for items 16 and 17 of Table 1. For the purpose of estimating C-14 concentrations this procedure probably places excessive emphasis on the deep ocean (Table 1, Item 10). With the presently available data on C-14 concentration the deep ocean should probably be assigned a weight factor of approximately 85% in comparison with the upper biosphere as a C-14 reservoir (Broecker 1974, p 66). Accordingly the denominator in items 16 and 17 of Table 1 would be $0.85 \times 35{,}000 + 4.03 = 33.8$ rather than 39.03. This adjustment would permit use of slightly smaller fractions of "fossil" carbon and/or sedimentary carbonate for the last two items of Table 3.

CONCLUSION

From the foregoing considerations it appears that data now available for the concentration of C-14 in the biosphere together with reasonable estimates for the active and fossil carbon inventory provide justification for confidence that C-14 age data for time prior to approximately 3500 B.P. are associated with a transition between the pre-biblical-flood biosphere and the contemporary biosphere.

ENDNOTES

1. High altitude rocket soundings have provided data which indicate that the present water vapor concentration at altitudes above 10 km is less than 20 parts per million (Harries et al. 1976; Scholz et al. 1970), more typically less than 5 parts per million (Evans 1974). The production of H-2 by neutron capture is negligible in comparison with the production of C-14 under these circumstances.
2. $39.03/(39.03 + 6820 + 13{,}180/6) = 1/232.\ 232 = 2^{7.86}.\ 7.86 + 5730$ years = 45,027 years.

LITERATURE CITED

Bennett CL. 1979. Radiocarbon dating with accelerators. American Scientist 67:450-457.

Bolin B. 1970. The carbon cycle. Scientific American 233:124-132.

Borchert H. 1951. Zur Geochemie des Kohlenstoffs. Geochimica et Cosmochimica Acta 2:62-75.

Broecker WS. 1974. Chemical oceanography. NY: Harcourt, Brace, Jovanovich.

Brown RH. 1974. Non-Poisson distributions observed during counting of certain carbon-14-labeled organic (sub)monolayers. Review of a paper by John L. Anderson. Origins 1(2):99-100.

Brown RH. 1975a. C-14 age profiles for ancient sediments and peat bogs. Origins 2(1):6-18.

Brown RH. 1975b. Can we believe radiocarbon dates? Creation Research Society Quarterly 12(1):66-68.

Clementson SP. 1974. A critical examination of radiocarbon dating in the light of dendrochronological data. Creation Research Society Quarterly 10(4):229-236.

Evans WFJ. 1974. Rocket measurements of water vapor in the stratosphere. Proceedings of the International Conference on Structure, Composition and General Circulation of the Upper and Lower Atmospheres and Possible Anthropogenic Perturbations. The University of Melbourne, Melbourne, Australia. January 14-25, 1974. Vol. 1, p 244-256.

Fairhall AW, Young JA. 1970. Radiocarbon in the environment. In: Gould RF, editor. Radionuclides in the Environment, p 401-418. Washington DC: American Chemical Society.

Forman MA, Schaeffer OA. 1979. Cosmic ray intensity over long time scales. Reviews of Geophysics and Space Physics 17:552-560.

Hall DO. 1979. Plants as an energy source. Nature 278:114-117.

Handbook of Chemistry and Physics. 1970. 51st ed. Standard atmosphere, p F-146 — F-151. Cleveland: The Chemical Rubber Company.

Harries JE, Moss DG, Swann HRW, Neill GF, Gildwarg P. 1976. Simultaneous measurements of H_20, $N0_2$ and HNO_3 in the daytime stratosphere from 15 to 35 km. Nature 259:300-302.

Kigoshi K, Hasegawa H. 1966. Secular variation of atmospheric radiocarbon concentration and its dependence on geomagnetism. Journal of Geophysical Research 71:1065-1071.

Lingenfelter RE, Ramaty R. 1970. Astrophysical and geophysical variations in C-14 production. In: Olsson IU, editor. Radiocarbon Variations and Absolute Chronology, p 513-537. NY: John Wiley and Sons.

Nozaki Y, Rye DM, Turekian KK, Dodge RE. 1978. A 200 year record of carbon-13 and carbon-14 variations in Bermuda coral. Geophysical Research Letters 5:825-828.

Pearl HF. 1963. A re-evaluation of time-variations in two geochemical parameters of importance in the accuracy of radiocarbon ages greater than four millenia. Unpublished Master's thesis. Pacific Union College, Angwin, California.

Ralph EK, Michael HN, Han MC. 1973. Radiocarbon dates and reality. MASCA Newsletter 9(1). Applied Science Center for Archaeology, University of Pennsylvania, Philadelphia.

Reiners WA. 1973. A summary of the world carbon cycle and recommendations for critical research. In: Carbon and the Biosphere, p 369. CONF - 720510, National Technical Information Service. Springfield, VA: U.S. Department of Commerce.

Revelle R, Suess HH. 1957. Carbon dioxide exchange between atmosphere and ocean and the question of an increase of atmospheric CO_2 during the past decades. Tellus 9:18-27.

Rubey WW. 1951. Geologic history of sea water: an attempt to state the problem. Geological Society of America Bulletin 62:1111-1148.

Scholz TG, Ehhalt DH, Heidt LE, Martell EA. 1970. Water vapor, molecular hydrogen, methane, and tritium concentrations near the stratopause. Journal of Geophysical Research 75:3049-3054.

Shedlovsky JP, Cressy PJ, Jr., Kohman T. 1967. Cosmogenic radioactivities in the Peace River and Harleton chondrites, Journal of Geophysical Research 72:5051-5058.

Trivedi BMP, Goel DS. 1973. Nuclide production rates in stone meteorites and lunar samples by galactic cosmic radiation. Journal of Geophysical Research 78:4885-4900.

Whitelaw RL. 1968. Radiocarbon confirms Biblical creation (and so does potassium-argon). Creation Research Society Quarterly 5(2):78-83.

Whittaker RH. 1970. Communities and ecosystems. NY: The Macmillan Company.

Wilson AT. 1978. Pioneer agriculture explosion and CO_2 levels in the atmosphere. Nature 273:40-41.

Woodwell GM, Whittaker RH, Reiners WA, Likens GE, Delwiche CC, Botkin DB. 1978. The biota and the world carbon budget. Science 199:141-146.

NEWS AND COMMENTS

CREATION IN THE COURTS

Creationists are continuing the legal battle over the teaching of creation. State legislatures have been presented with bills requesting that creation be included as a valid theory of origins in the science classes of public schools.

In California, the conflict has been centered around the State Board of Education's science framework, which contains the guidelines for textbook selection, teacher training, and curriculum development. Whereas the 1970 framework required science textbooks to present a less biased view of origins, the 1977 framework treats evolution as the accepted theory about the development of life forms. Furthermore, it states that religious and philosophical theories about the origin of life "are not within the realm of science," because they can be neither proved nor disproved. After futile attempts to have the State Board of Education revise the guidelines to allow equal treatment of alternative views of origins, the Creation-Science Research Center (CSRC) of San Diego sought a preliminary injunction to block the guidelines from going into effect as planned in the fall of 1981. Joining the CSRC in this legal action against the State Board of Education and State Superintendent Wilson Riles were Congressman William Dannemeyer and former Assemblyman Mike Antonovich.

At the court hearing on 6 August 1979, there were no witnesses; instead, lawyers produced signed statements and presented oral arguments. Richard Turner, representing the CSRC, maintained that the new guidelines presented evolution as a fact. For example, one passage states that some evidence "indicates that all living organisms on earth have a common ancestor from which they have diverged by evolution during about three billion years." Turner further contended that "when you're talking about origins, you're talking about religion," and that by excluding all other theories except evolution, the State is promoting the religion of secular humanism — an infringement on the constitutional rights of freedom of speech and freedom of religion.

Representing the State Board of Education, Deputy Attorney General Robert Tyler accused the CSRC of "attempting to ... have a religious doctrine taught on an equal footing with science." He defended the guidelines, saying that evolution "says nothing about whether there is a God or there is not a God," because it is merely presented as a theory of development, not origins.

On the following day, Superior Court Judge W.A. White ruled in favor of the State Board of Education, saying that the teaching of evolution "contains no disparagement of the creationists' view." Though Judge White's decision was disappointing to the plaintiffs, they do not plan to give up their efforts to have creation presented in the science classes. The next step will be an appeal to the State Supreme Court.

Unfortunately, even if a favorable ruling is eventually granted, the struggle over the theories of evolution and creation will continue. Legal support for the teaching of creation does not guarantee its receiving fair and equal treatment in the science classrooms of the public schools. While legal action might provide one way of ensuring the inclusion of alternative theories of origins, other methods should be pursued with equal, if not greater, vigor. Perhaps those who desire creation to be accepted as a valid scientific theory should make more effort to become known as practicing scientists. Also needed are adequately prepared, pedagogically acceptable science textbooks that present objective evaluations of different theories of origins.

Katherine Ching

LITERATURE REVIEWS

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

A REFERENCE ON RADIOMETRIC DATING

PRINCIPLES OF ISOTOPE GEOLOGY. Gunter Faure. 1977. NY: John Wiley & Sons. 464 p.

Reviewed by R. H. Brown, Geoscience Research Institute

Radiometric age data must be taken into account in the development of a suitable model for the history of Earth or the solar system. A survey of creationist literature reveals that many of its authors have not understood radiometric techniques well enough to satisfactorily relate radiometric age data to their premises. Examples that bring discredit to efforts toward Earth history modeling from a creationist viewpoint are not difficult to find. Because of the extraordinary difficulty of obtaining adequate information for an understanding of radiometric techniques, these authors should not be criticized unsympathetically. The availability of *Principles of Isotope Geology* now makes it possible for a competent writer to readily obtain an adequate understanding of radiometric techniques.

Principles of Isotope Geology was designed for use as a textbook and is written with extraordinary clarity. The author is Professor of Geology at Ohio State University and is one of the world's best-recognized authorities on isotope geology and radiometric dating.

The theoretical foundation and practical techniques for each of the various radiometric dating methods, excepting the recently developed Samarium-Neodymium method, are explained with care. Although Samarium-Neodymium dating is not discussed, references to this method are provided into 1976. The assumptions and restrictive conditions that must be satisfied to interpret radiometric age in terms of real calendric time are fully explained for each method. The discussion of each dating method concludes with an illustrative application to a set of data from the original research literature.

The book also traces the historical development of the scientific principles on which radiometric dating is based. Approximately one-third of the text is given to the geologic significance of variations in the stable

isotope composition of hydrogen, carbon, oxygen, sulphur, strontium and lead. Since stable isotope geochemistry is closely related to radiometric dating, there is great advantage in having both topics treated in the same volume.

Each chapter provides an extensive list of references that can enable the reader to readily find access to the authoritative literature on any topic he may wish to pursue further. The text of all but two chapters concludes with a few problem exercises that enable the reader to test his comprehension of the preceding material. Data for these problems are frequently taken from investigations reported in the research literature. Answers are given for most of the problems. Chapters that treat specific techniques are summarized.

Two minor comments may be of assistance to users of this book. The presentation on p 217 would have been improved by specifying the slope age of the thorium-lead isochron shown in Fig. 12:10(a). An appropriate value is 2.64×10^9 years. On p 306-307 it is stated that steady-state equilibrium of carbon-14 is maintained in the atmosphere and hydrosphere, and in living green plants, by "continuous decay" of carbon-14 balanced by continuous production of carbon-14 in the atmosphere and continuous absorption from the atmosphere. Radioactive decay of carbon-14 is a negligible factor in these equilibrating processes. In living plants uniform or equilibrium concentration of carbon-14 is maintained by continuous exchange with the atmosphere. In the atmosphere and upper hydrosphere essentially uniform concentration of carbon-14 is maintained by continuous transfer of carbon-14 to the deep ocean and sediments.

An individual who is seeking for an interpretation of radiometric age data that is compatible with a short history of Earth's present geologic features or of the solar system will not find it in this book. But he will find unsurpassed convenience of access to an understanding of radiometric age data that is essential for the development of credible models for Earth and solar system history, whatever the premises of these models may be.

GENERAL SCIENCE NOTES

PRECAMBRIAN AND PALEOZOIC GLACIATION?

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The slow but powerful action of glaciers has fascinated man for centuries. The work of glaciers and the characteristic landscape features left by the movement of these huge quantities of ice has been the subject of considerable investigation. As a glacier retreats it often leaves a number of tell-tale signs of its past presence. These include hanging valleys perched high above other large carved U-shaped valleys, till (pieces of unsorted ground rock) deposited below or along the sides of a glacier in the form of ground or lateral moraines (Figure 1), striations (scratches) and polish left by the grinding action of ice and rock and a host of other features. Some of these characteristics are used to tell where a glacier may have been in the past, even though no ice is present now.

Numerous deposits of reported glacial origin are observed throughout the geologic column. Their presence can significantly affect one's interpretation of the amount of time involved in deposition. Most familiar are glacial deposits associated with the more recent and surficial "Pleistocene ice age"; however, of special interest are very ancient Precambrian and Paleozoic deposits which are attributed to previous glacial activity. Presumed very ancient glacial deposits are reported from every continent. Two examples are the Precambrian Kingston Peak formation near Death Valley, California, and "Reusch's moraine" in Norway. Glacial features such as tills, glacial pavement with striations, and faceted and striated boulders are generally presented as evidence. Are other interpretations (non-glacial) of the data justified? Some researchers say "yes."

Dunbar (1940) questioned the glacial origin of the Carboniferous tillites (cemented till), striated boulders, and glacial pavement of San Juan, western Argentina. He concluded that the regional geology indicates that the striated pavements were slickensided fault surfaces, and the striated pebbles and tillites were the result of landslides and mudflows.

It has been suggested (see Lakshmanan 1969) that the Precambrian (Vindhyan) deposits in central India are of glacial origin. However, Lakshmanan states that "the evidence offered for Vindhyan glaciation are disputable and wholly unconvincing." He concludes that: 1) the tillites

FIGURE 1. View of Athabasca Glacier located in the Canadian Rockies. The glacier originates from the Columbia Ice Field located beneath the clouds in the background. The glacier flows down over several bedrock steps giving a staircase appearance to its upper flow. Thickness of the glacier is up to 300 m. At present the glacier is moving at an average rate of about 6 cm per day, but since it melts faster than that, its toe is retreating at the rate of approximately 12 m per year. This retreat exposes some typical glacial till deposits such as ground and terminal moraines in the foreground in front of the toe of the glacier and lateral moraines along the sides. In this photograph the darker debris at the sides of the glacier is rock material covering up the ice at the edge of the glacier. A good lateral moraine can be seen at the left of the glacier. It is steeper than the rock debris described above and lighter in color, with small buildings on top.

could be mudflow deposits and, 2) the mudcracks, ripple marks, rain-print impressions, stromatolites and limestones are generally associated with warm climates.

Newell (1957), after examining reported Permian tillites in northern Mexico, concludes that the "Mexican boulders and volcanic rocks most probably are submarine slide deposits...."

The presence of striated pavement may at first seem to be solid evidence for glacial activity. Crowell (1963) proposed that the striations present in the quartzite underlying Reusch's moraine in Norway may have formed when the pebbles in subaqueous mudflows or slumps were

impressed into soft sand. The presence of a pebble at the end of a striae impressed into the quartzite was noted.

Not all glacier-like features can be attributed to geologic causes. Berkland & Raymond (1973) reported Pleistocene glaciation in the southern Appalachian mountains, North Carolina. However, their evidence was disputed by Hack & Newell (1974), who commented that the "grooves" were "made by moving cables used in logging operations." McKeon (1974) also agrees that they are man-made rather than glacial.

These examples indicate that geologic features which resemble those associated with modern glaciers may be formed by mechanisms other than ice. Crowell (1963) examined the geologic processes that could account for such similarity; his list includes slumping, mud-flows, turbidity currents, giant slide blocks, volcanic lahars, talus debris, and weathering of conglomerates. Presently, much controversy still exists over the glacial origin of some ancient deposits. Alternative geologic processes are numerous and at times not completely understood. The mechanism, whether it invokes unusual events such as giant tides or persistent freezing weather, is of significance to our understanding of earth history.

LITERATURE CITED

Berkland JO, Raymond LA. 1973. Pleistocene glaciation in the Blue Ridge Province, southern Appalachian mountains, North Carolina. Science 181:651-653.

Crowell JC. 1963. Climatic significance of sedimentary deposits containing dispersed megaclasts. In: Nairn AEM, editor. Problems in Paleoclimatology, p 86-99. NY: Interscience Publishers, John Wiley & Sons.

Dunbar CO. 1940. Validity of the criteria for Lower Carboniferous glaciation in Western Argentina. American Journal of Science 238:673-675.

Hack JT, Newell WL. 1974. North Carolina Glacier: evidence disputed. Science 181:89.

Lakshmanan S. 1969. Vindhyan glaciation in India. Vikram University Institute of Geology Journal 2:57-67.

McKeon JB. 1974. North Carolina Glacier: evidence disputed. Science 184:88-89.

Newell ND. 1957. Supposed Permian tillites in Northern Mexico are submarine slide deposits. Geological Society of American Bulletin 68:1569-1575.

EDITORIAL

BEYOND SCIENCE

Science has performed many wonders. One only has to mention such expressions as "genetic code" or "moon rock" to evoke a significant degree of admiration. On the other hand, the general decline in respect for science and the increasing demand on the part of the general public for alternative explanations to the general theory of evolution suggest a general dissatisfaction with purely "scientific" explanations. This dissatisfaction may lie more with purely naturalistic explanations, which exclude the supernatural, than with the scientific process itself which, at least in the past, did not necessarily exclude the supernatural. The recent increase in literature emphasizing supernatural explanations further reflects this concern. Many individuals object to being reduced to simple machines and to having their origin explained as being the result of mere accidents of naturalistic phenomena.

Although millions of dollars have been spent developing and improving textbooks that promote evolution, many evolutionists attribute the lack of support for their theory of origins to poor salesmanship. The problem is probably not poor salesmanship but the poor explanatory value of a purely naturalistic approach. Many are loath to reject a reality beyond naturalism, and many feel that the solution to the major problems of society lie beyond the simple approach of a naturalistic technocracy.

The philosopher Alfred North Whitehead touched on the issue when he pointed out that scientists whose purpose is to show that they are purposeless form an interesting subject for study. Naturalism poses some serious questions. Can we reduce all of reality to that which we can understand? Can we with confidence say that there is nothing beyond naturalistic explanations? Normal caution would preclude such conclusions.

Without question, science is the best system devised by man for obtaining truth about nature, and in this area it has been eminently successful. Science often deals with very tangible aspects of reality. Because they are tangible, we have significant confidence in what is observed; but this confidence does not negate the existence of that which can be less easily known. We cannot use the readily demonstrable as an excuse for denying the existence of the less demonstrable.

Many areas of experience point to a reality beyond the purely naturalistic. The mention of words such as love, purpose, duty, concern, loyalty, morality, beauty, or religion suggests the inadequacies of pure naturalism. Free will, which most admit they possess to some degree, has

no place in naturalistic explanations that are based on simple cause and effect instead of free choice.

Educational institutions play a significant part in establishing the pattern of thought in society. The philosophy of most citizens is molded by these institutions; hence, what is taught in the classroom has broad consequences for humanity. As we look about, few can doubt that our morally sick society needs much improvement. Educational institutions would be of greater help if they would pay much more attention to those important values that are above the mundane. Instead of concentrating so much on naturalistic explanations, immediate economic advantages, or the preparation of super technicians, we should encourage the preparation of men and women with moral qualities that will contribute to the enhancement of integrity, concern for others, religion, and those characteristics that have broader and more enduring value. Such an approach need not compromise the excellence sought in academic pursuits. There need be no conflict between excellence and morality or between intellectual integrity and concern for our fellow man. However, such an approach will demand that we elevate our sights above the purely naturalistic.

Ariel A. Roth

REACTIONS

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

RE: ANDERSON: REACTIONS (ORIGINS 6:7)

Professor Anderson's query illustrates the usefulness of consulting the original language of the biblical text, for a direct reading of Genesis 2 in the English translation he has quoted could indeed convey the impression that animals were created after man. The Hebrew verbal system differs from that of English by hav ing only two tenses, the imperfect and the perfect, and the word "tense" in the temporal sense does not fit them very well. The imperfect verb *yiser* in Genesis 2:19 is preceded by the conjunctional letter *waw* which in Hebrew has the standard grammatical effect of converting it into a perfect. In the simplest cases Hebrew perfects are translated with the English past tense; so this verb commonly has been translated "formed." The spectrum of English translations for perfect verbs in Hebrew is broader than just the simple past, however, and in this verse an English past perfect fits the context best. One reason for preferring a past perfect translation here is the parenthetical nature of this verse. The preceding verse quotes God as stating that He would make (*'e'eṣê*) a helper (singular) for Adam. This intent was fulfilled in verse 22 which states that God built (*yiben*) woman from the rib which He had taken (note the past perfect translation of this Hebrew perfect in the RSV which Anderson has quoted) from man. That God did not intend one of the animals to be Adam's helper is evident from the singular versus plural contrast here and probably also from the different verbs that were juxtaposed in verses 18 and 19. The reference to the animals in verse 19 is parenthetical, therefore, and the conjunction with which this verse begins should be translated in a disjunctive manner to bring out this point. This fits the past perfect translation proposed for the verb which follows it. Thus the opening of Genesis 2:19 is best translated, "Now Yahweh God had formed every beast...." The preferable past perfect translation of this verb refers back to the creation of the beasts and birds on the 6th and 5th days of the preceding narrative respectively (note that both are mentioned here in an inverted order), and the verb at the beginning of Genesis 2:19 does not need to imply they were created again after man.

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ARTICLES

THE ATTITUDE OF UNIVERSITY STUDENTS TOWARD THE TEACHING OF CREATION AND EVOLUTION IN THE SCHOOLS

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WHAT THIS ARTICLE IS ABOUT

The recent increase of activity in the evolution-creation controversy has emphasized the significant dichotomy that exists in public education between the wishes of the taxpayers that support the schools and the evolutionists who would have only their views presented. A number of public opinion polls have been taken, showing that about ¾ or more of the general public would prefer that both creation and evolution be taught. A study of secondary-school biology teachers also showed that about half thought that evolution was a theory and not a fact and that alternative theories should be presented. The study reported in detail here deals with the opinions of prospective teachers in a teacher-training program.

An opinionnaire was designed to assess the attitudes of undergraduate students about the creation-evolution question. In addition, a sample of biology graduate students was utilized to compare graduate and undergraduate opinions. From a total of 516 undergraduates, 91.0% felt that both creation and evolution should be taught. In addition, 43.0% of the undergraduate students classified themselves as "pure creationists," 46.0% as "theistic evolutionists," and 8.0% as "atheistic evolutionists." Of the sample of 74 natural-science graduate students, 72.0% felt that both evolution and creation should be taught in the schools. Also, 36.0% classified themselves as "pure creationists," 46.0% as "theistic evolutionists," and 14.0% as "atheistic evolutionists."

Since the beginning of his existence, man has sought an answer to the question, "Where have I come from?" Children commonly ask their parents this question and usually receive some type of explanation about sexual reproduction and the process of pregnancy and birth. The realization that one "comes from" one's parents may temporarily satisfy the need to explain one's existence, but sooner or later children begin to wonder, "Where did mankind as a race, and indeed all things, come from?"

Some parents explain that God created man, but this answer sooner or later elicits the response, "Who created God?" Other parents explain to the child that man came from the monkeys, and monkeys came from reptiles which came from fish, which evolved from one-celled animals which formed naturally in a primordial soup. A child's next question then might be, "Where did the primordial soup come from?" No matter which

explanation a parent uses (and we have oversimplified and dichotomized the two basic explanations, i.e., creation and evolution), *neither is fully satisfactory*.

Because the subject of origins deals with the things that have happened in the past, as does history itself, much speculation is involved. In addition, one's beliefs regarding the "purpose" of man influences his or her beliefs regarding origins. As the question of origins is connected with belief structures, it would be expected to be an emotional issue; and indeed it has been such since the popular acceptance of the theory of evolution in the late 1800s.

As evolution gained acceptance, opposition to teaching it in the schools surfaced almost immediately. For decades, only a few schools taught the subject (Laba & Gross 1950). Even many colleges did not include evolution in their biology courses until the 1930s. Within the last 70 to 80 years evolution has been highly accepted, and though it is still not universally taught in American schools, it is clearly the most widely taught theory of origins. Now that the shoe is on the other foot, for the past 30 years or so, evolutionists have opposed the teaching of competing theories of origins in the schools. When creation held sway in the people's minds, the teaching of evolution was resisted by various means, and when evolution became the accepted theory of origins, the teaching of the previously accepted theory — creation — was resisted.

THE SCOPES TRIAL

The most famous confrontation relative to the question of teaching origins in the schools is the Scopes Trial of 1925. Essentially, Clarence Darrow for the defense argued that teachers, being knowledgeable about the subject area, should teach what they feel is correct. Parents are not the "experts" and thus should defer to the teacher's judgment as to what is to be taught. On the other hand the prosecution, headed by William Jennings Bryan, felt that the *parents*, who provide financial support for the schools, should make the final decision on what is taught. In essence, the prosecution felt that "if I hire a painter to paint my house, the painter should use the color I choose, because I am paying the costs and have to live in the house; the painter is my employee." Because parents are essentially hiring the teachers to educate their children for them, Bryan felt they should be allowed to determine how the teachers do the job. Bryan further argued that since the majority of people at that time in Dayton, Tennessee, were creationists, the creationist position should be favored. Unfortunately, the common perception of the Scopes Trial, such as expressed in the play and movie "Inherit the Wind," is grossly distorted, as anyone who has read the original trial transcript can easily discern.

REVIEW OF THE LITERATURE

At this point, most of the literature concerning people's attitudes toward evolution consists of "random phone surveys" usually done by individuals who favor the creationist position. For example, the *ICR Midwest Center Newsletter* of 1976 stated that "a 1976 random phone survey in the Midwest, a random home survey in California and a newspaper survey in the Chicago area all yield similar results in the public opinion regarding the teaching of origins in our public schools." The Midwest survey utilized volunteers to first pick a phone number from the phone book at random, and then to call the number and read the following:

> *I am helping conduct a random telephone survey. We are attempting to determine the community opinion about how our public school system should handle the subject of origins, or how things began. I will suggest three choices, and you may state your preference.*
>
> 1. *I prefer that only the evolution model be taught as the explanation of how things began.*
> 2. *I prefer that only the creation model be taught.*
> 3. *I prefer that both creation and evolution be taught as alternative explanations of how things began.*
>
> *QUESTION: Which do you prefer to be taught; only evolution, only creation or both the evolution and creation models? (record if they vote "no opinion").*

The researchers called individuals in five states, but did not report the number of responses obtained. The percentage distribution of responses is given in Table 1, Survey I. A second ICR Midwest Center survey that sampled 989 is broken down in Table 1, Survey II. A more recent survey that polled 4506 individuals found "the percentages remain basically the same."

TABLE 1

	Midwestern Survey I	Midwestern Survey II	
	%	No.	%
Creation and Evolution	68	719	72.6
Creation only	16	125	12.6
Evolution only	5	53	5.0
No opinion	11	92	9.0
Total creation only or creation and evolution	84	844	85.3
Total	100	989	100.0

In two other polls, "a representative sample of homes were contacted in two California school districts with 89% (1346 homes) in the Del Norte and 84% (1995 homes) in the Cupertino area district preferring that both creation and evolution be taught in the public school system."

A survey of secondary-school biology teachers in Indiana (Troost 1966) showed that 173 out of 325 felt that evolution was a theory and not a fact, and 163 out of 330 thought that evolution should be presented as one of several alternative theories.

The only longitudinal studies of which the author is aware indicate that the creationistic explanation is growing in acceptance among college-age students. The percentage of students at Brigham Young University accepting the creationist alternative to evolution was surveyed by Christensen and Cannon (1978). They found that in 1935, 36% of the students agreed with the statement: "Man's creation did not involve biological evolution," compared to 81% in 1973. The affirmative response to the statement: "The world's creation did not take millions of years" was 5% in 1935, compared to 27% for 1973. This is one of the most significant changes Christensen and Cannon found. The sample size was 1159 for the 1936 study and 1056 for the 1973 sample.

PRESENT STUDY

According to all recent studies, the vast majority of the public favors teaching *both* creation and evolution in the schools (Bliss 1978, Bergman 1979). It is usually assumed, though, that while the public may favor teaching both theories, the teaching profession favors teaching only the theory of evolution. To further answer this question, the writer developed the following opinionnaire which was administered to 442 undergraduates (most of whom were in their last year of a teacher-training program) and 74 graduate students taking courses in the area of biology.

OPINIONNAIRE

Instructions*: We are attempting to determine community opinion about how our public school system should handle the subject of origins (the origin of plants, animals, man, etc.). Please circle the number by the response which most closely represents your opinion.*

1. Circle the statement which you agree most with:

- *a. Only the evolution model should be taught as the explanation of how things began.*
- *b. Only the creation model should be taught.*
- *c. Both the evolution model and the creation model should be taught as alternative explanations of origins.*

2. Which of the following describes your present position?

- *a. Atheistic evolution (there is no God — the origin of all things is natural evolution).*
- *b. Theistic evolution (God used evolution to bring about man and all things).*
- *c. Theistic creationism (God created in some way man and the basic forms of animals).*
- *d. Other — please elucidate.*

It is commonly assumed that the vast majority of teachers would opt for teaching only evolution. This assumption is constantly presented in articles discussing the creation-evolution issue. It is this assumption we are testing.

Teachers in teacher-training programs were utilized as opposed to using teachers in the field because of the availability of the sample and because a wide variety of teachers would be polled, i.e., special education, high school, elementary, speech and hearing, and other areas. There were not enough biology majors (5 out of 516 students) to make meaningful comparisons; therefore, the total sample was used. Further research should include a larger sample of biology majors and contrast their attitudes with other teachers. We were able to assess graduate students taking biological classes (mostly biology majors or minors) and presumably graduate students taking classes in biology would reflect the attitudes of biology majors.

THE BACKGROUND OF THE SCHOOL

Bowling Green State University (BGSU) is a state-supported university which was established in 1910 in Bowling Green, Ohio, a lower middle-class suburb of Toledo, Ohio. Bowling Green is 23 miles south of Toledo proper. The University has about 16,000 students in undergraduate, master's and doctoral programs in a wide variety of areas. Originally the school was founded to train teachers and thus was called Bowling Green Normal School. It later expanded its program offerings but is still well known as a teacher-training institution. A high percentage of the faculty have Ph.D.'s, and, although teaching tends to be stressed, a number of faculty have published extensively in scholarly journals. The University has a reputation of being conservative and tends to attract students from the middle and upper-middle classes.

RESULTS

The results of the survey found that the clear majority of both undergraduate students and graduate students taking biology classes favored the teaching of both theories of origins in the schools (see Table 2).

Of the undergraduate students, a total of *91% felt that both the evolution and creation models should be taught in the schools*. Of the graduate students, *71.8% felt that both models should be taught in the schools*. Of the graduate sample, 21.1% felt that only evolution should be taught, compared to 6.1% of the undergraduate sample. This is a difference of almost 3.5 times. On the other hand, a small number of both samples felt that *only* creation should be taught; 2.9% of the undergraduate sample, compared to 7.0% of the graduate sample.

TABLE 2

Results of Evolution-Creation Attitude Survey

	Males				Females				Total			
	U. Grad.		Grad.		U. Grad		Grad.		U. Grad.		Grad.	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Only the evolution model should be taught	10	11.0	11	33.3	17	4.8	4	9.8	27	6.1	15	21.1
Only the creation model should be taught	4	4.4	22	6.1	9	2.6	3	7.3	13	2.9	5	7.0
Both the evolution and creation models should be taught	77	84.6	17	51.5	325	92.6	34	82.9	402	91.0	51	71.8
TOTAL	91	17.6	33	6.4	351	68.0	41	7.9	442	86.8	74	14.3

Which of the following describes your present position?

	Males				Females				Total			
	U. Grad.		Grad.		U. Grad		Grad.		U. Grad.		Grad.	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Atheistic evolution	13	14.3	4	12.1	22	6.3	6	14.6	35	7.9	10	13.5
Theistic evolution	36	39.6	17	51.5	169	48.2	17	41.5	205	46.4	34	45.9
Theistic creation	39	39.6	11	33.3	154	43.9	16	39.0	190	43.0	27	36.5
Other	6	6.6	1	3.0	6	1.7	2	4.9	12	2.7	3	4.1
TOTAL	91	17.6	33	6.4	351	68.0	41	7.9	442	86.8	74	14.3

According to most studies, females are more “religious” than males. If religiosity is an indication of one’s orientation towards the acceptance of evolution or creation, our sample likewise indicates that females are more religious than males. The undergraduate males were 2.5 times *more likely* to feel that only evolution should be taught, compared to females (11.0%, compared to 4.8%). On the other hand, interestingly, the undergraduate males were slightly *more* likely to want only creation to be taught: 4.4%, compared to 2.6%. As to wanting both models taught, again the percentage of females was higher (92.6%, compared to 85.6% for males).

Relative to the respondents' belief structure, 7.9% of the undergraduates classified themselves as "atheistic evolutionists," compared to 13.5% of the graduate students. This seems to indicate that the more education one has in a secular school, the more likely one is to reject the concept of God, a relationship which is commonly believed to be true (see Hites 1965; Pilkington, Poppleton & Robertshaw 1965). On the other hand, approximately half of both the graduate and undergraduate students (there was only 0.6% difference) classified themselves as theistic evolutionists. In addition, 43.0% of the undergraduates classified themselves as either theistic creationists or pure creationists, compared to 35.2% of the graduate students. Thus, according to this survey, 89.4% of the undergraduates believed some form of creation, compared to 79.9% of the graduate students. Essentially, 80% of both the graduate and undergraduate students could be classified as "creationists"; the only difference would be in their understanding of how much of the present order is attributed to chance, and how much is explained by the activity of an outside agent. The beliefs of most of the students who selected either theistic evolution or theistic creation likely ranged from the view that an outside force did "nothing more than begin the process of evolution which continues today," to the idea, as several students stated, that "God created Adam and Eve and all living things within a literal seven day week, just as the Bible says He did."

COMMENTS BY STUDENTS

Several students mentioned the belief that God had "unlimited knowledge and wisdom, but [He was] not...the one who created heaven and earth." Others stated the opposite, i.e., "someone created the heavens and the earth, but not necessarily God." Others felt there is "some creator," but felt it could be a God, Gods or someone else, but that *someone* created the world.

Nineteen students who checked "other" said that they were not convinced either way — the evolutionary explanation did not convince them, but neither did the creationist view. Several students said they believed in "both" evolution and creation. One student stated, "Sometimes one comforts me more than the other and thus I believe it when it does."

Several of the students indicated a belief in the existence of a God, but they felt that the *origin* of all things is natural. Another common response is that man evolved from the basics that God put here. A variation of this as stated by several students is that they believed in both "Adam and Eve and evolution." A number of students mentioned that their science courses caused them to believe in evolution, whereas before they were creationists.

Students who circled "other," but gave reasons such as belief that "God created the heavens and the earth within a literal six day, 24 hour

period," or "Adam and Eve were the first man and woman directly created by God," were coded as theistic creationists instead of "other." The fact that several answered this way indicates that choice "c" was not as clear as it could have been.

One student commented, "I haven't decided yet on how man evolved. Maybe it was by atheistic evolution." Another student selected "other" and stated, "God created everything the way He said He did and not 'in some way.'" And, lastly, several students circled "other" and expressed thoughts similar to the student who said, "Maybe man came about through evolution, maybe God did it, maybe it was natural laws; how am I supposed to know? Let me know when you find out."

Other comments written on the opinionnaire are as follows:

1. There was a God or superior being at one time (there still may be), but the earth and all in it came about through evolution.
2. There was something yet unexplained that controls and causes us to evolve. I believe there must be something to both creation and evolution. Everything must have started somewhere. Science has only shown evolution to be true after a certain point.
3. Man may have evolved, but God had to start everything in the beginning.
4. I believe in both as there is no proof one way or the other. Thus I must hold them as simply alternate theories.
5. There may be a God, but whether there is, is for each individual to decide.
6. I doubt the existence of a God (it has yet to be proven) yet it is unknown and may be possible. Evolution is a proven *fact* and I accept only those theories that can be proven, and employ them until a contradiction is found.
7. Man created himself; and God is in man.
8. God brought about the conditions to bring life into being.

DISCUSSION

This research raises several important questions. Foremost is: Why is there so much opposition in some professional journals (e.g., see the index of the *American Biology Teacher*) to teaching both theories of origins, when according to the above surveys, a clear majority of both parents and teachers are in favor of the two-model approach to origins? A second concern is, why, when most parents and teachers are evidently in favor of a dual-model approach, does a single-model approach tend to predominate in the schools? Further research should include exact determination of the extent to which the single model does predominate, and the manner

and extent to which biology teachers cover the creationist or other positions. Once this can be determined, there is the need to assess the reasons for the discrepancy, if indeed such is the case.

Informal surveys by the writer found that the vast majority of students were not exposed, in their biology classes, to any model other than the evolutionary one. The writer's experience in both his graduate and undergraduate biology courses was that when creation was brought up, it was generally ridiculed and held as untenable and accepted by very few scientists. Such examples as ontogeny recapitulates phylogeny, the gill slits, the peppered moth in Britain, the os coccygis (coccys), adenoids, tonsils, appendix and wisdom teeth were generally used as examples to support the evolutionary position.

Possibly, evolution predominates because in most textbooks, evolution is the only position which is discussed. In those rare instances where the creationist position is mentioned, it is usually accompanied with counter-arguments in very much of an apologetic fashion.

As the writer has discussed elsewhere (Bergman 1979), from both an educational and pedagogical standpoint, a two-model position is much more tenable, regardless of the validity of each position. Teaching by contrasts and understanding the source of knowledge and ideas aids in understanding almost any information.

In the past few years there has been an increasing pressure from a wide variety of groups to present a less one-sided view in teaching the subject of origins in the schools. Unfortunately, there has been a great deal of intolerance and emotionality on both sides, making it difficult to accurately understand the real world. No matter which side one opts for, it still tends to be an emotional issue bound up with one's basic belief structure concerning the purpose of man and subsequent questions of right and wrong. Resolving this question requires not only objective, empirical research on the theories of origins, but research relative to the opinions and attitudes of both parents and teachers. In view of the above research, it would seem that some type of dual approach to the teaching of origins should be explored. In addition, there should be concern that each view be accurately and appropriately presented, and it would seem appropriate that other theories such as the exobiological theory proposed by Carl Sagan be discussed in an intellectually acceptable manner.

LIMITATIONS OF THE SURVEY

In a survey such as this there is always the difficulty that some of the terms used (i.e., the trichotomy of "atheistic evolution, theistic evolution, and theistic creation") were not clear. Even with the definitions printed on the form, probably the meaning was not clear for every student. Although

this problem was likely minor, some evidence for the validity of this assumption can be found in the comments written by the students on the opinionnaire. From our total of graduate students, a much larger number than we would expect classified themselves as theistic creationists. Quite possibly the respondents did not fully understand the creationist position in contrast to the theistic evolutionist position. Ideally, more than three categories could be used, including acceptance of microevolution and macroevolution.

A limitation of our sample is that it was administered at BGSU which has traditionally been labeled a "conservative" school. Possibly a large number of students come from religious backgrounds as compared to, for example, Ohio State or other Ohio universities. If a student body is more conservative, it will probably be less oriented towards choosing a response which indicates evolution. Possibly this skewed our sample somewhat, at least in comparison to the general college student population.

Another handicap of this study is that, unfortunately, only 20.6% of the undergraduate respondents were males. Most of the respondents (79.4%) were females. Most of the classes in which this survey was administered were part of teacher-training programs which typically consist of primarily female students. In spite of this, though, there were 91 males, which is a fairly good sample and should accurately assess the position of males, at least for schools comparable to BGSU.

FUTURE RESEARCH

Future research should probably correlate hours in biology, hours in evolution, and hours in the natural sciences (such as physics and chemistry) with one's position on origins. Presumably, as the number of hours in biology increases, a person would be more disposed to hold an evolutionary position.

Another important area for further research is a comparative evaluation of the attitude of active biology teachers, active teachers in other sciences, and the opinions reported here.

CONCLUSIONS

This study has shown that the majority of both graduate and undergraduate students favor the two-model approach for the teaching of origins. It would seem that some direction should be taken by educators to implement a two-model approach which can be agreed upon by most individuals involved in the educational process. A serious concern in any implementation of the two-model approach would relate to the problems of "indoctrinating" students in a particular belief that is based primarily on tradition as opposed to empirical data.

Obviously the students should be exposed to a wide variety of beliefs regarding the theories of origins, including even the myths of Babylon, Sumeria, and other ancient civilizations. Which theory the student accepts will likely depend upon his/her own value-belief structure, which is more a function of the home and church than the school. The school's objective, most people believe, is to provide information to help students be better aware of various alternatives available to them. If the school is able to stimulate discussion in this manner, regardless of the view the child or the child's parents hold, the school will, to some degree, have served its function.

LITERATURE CITED

Bergman J. 1979. Teaching about the creation-evolution controversy. Bloomington, IN: Phi Delta Kappa Educational Foundation.

Bliss R. 1978. A comparison of two approaches to the teaching of origins of living things to high school biology students in Racine, Wisconsin. Ed.D. thesis, University of Sarasota, Florida.

Christensen HT, Cannon KL. 1978. The fundamentalist emphasis at Brigham Young University: 1935-1973. Journal for the Scientific Study of Religion 17(1):53-58.

Hites RW. 1965. Change in religious attitudes during four years of college. Journal of Social Psychology 66:77-87.

Hunsberger B. 1978. Stability and change during college. Journal of the Scientific Study of Religion 17(2):159-164.

ICR Midwest Center Newsletter. 1976. University students hear scientific evidence against evolution.

Laba E, Gross E. 1950. Evolution slighted in high-school biology. Clearing House 24:396-399.

Pilkington GW, Poppleton PK, Robertshaw G. 1965. Changes in religious attitudes and practices among students during university degree courses. British Journal of Educational Psychology 35:150-157.

Troost CJ. 1966. An analysis of factors influencing the teaching of evolution in the secondary schools of Indiana. Ed.D. thesis, Indiana University.

ARTICLES

THE ORGANIC LEVELS OF THE YELLOWSTONE PETRIFIED FORESTS

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WHAT THIS ARTICLE IS ABOUT

In the fossil forests of Yellowstone one sees scores of layers of petrified trees (many of them upright) that have been interpreted as successive forests preserved in growth position. Many thousands of years would be required to grow these successive forests; hence, they have significant time implications for the creation and evolutionary models of origins. At the base of many of the tree layers, one finds finer sediments that contain organic material and that have been interpreted as soils. One may assume either the trees grew in their present position or that trees and soil were transported and deposited about the same time. A sequence of successive forests could be accommodated within a short period of time by the transport model which is favored by the author who presents evidence indicating that the organic zones do not show normal soil features.

The main points in support of this view are: 1) The organic zones are often thin or absent despite the presence of abundant or large petrified trees. 2) The organic profile may be reversed to that expected in normal soils, and there is no evidence of differential decay from top to bottom. 3) There is no evidence of the presence of animals or animal activity as would be expected on a normal forest floor. 4) Several areas show complex multiple and branching organic levels which suggest transport rather than in situ development. 5) Vertical microscopic sections through the organic layers show the type of sedimentary features and sorting of organic material expected from transport. 6) Clay is usually absent or, when present, does not appear to be related to the organic zones. 7) Unweathered feldspar crystals which are expected from rapid burial and not from slow soil development are abundant.

INTRODUCTION

The Yellowstone petrified forests of Wyoming and Montana consist of scores of superimposed sequences of petrified trees. Because many of these trees are preserved in an upright position, the sequence gives the appearance of one forest having grown above another. Many thousands of years would be involved in the growth of these successive forests; hence, this topic is of considerable interest to various time-related interpretations of earth history.

Much of the recent discussion (Ritland & Ritland 1974, Coffin 1979) of these forests centers on the question of their origin — autochthonous or allochthonous *in situ* growth or transport. The latter proposal would

tend to negate the thousands of years that would be required for the growth of successive forests. One aspect of this question relates to the nature of the fine sediment layers containing organic material often found at the base of the trees. Do these layers show time-dependent maturing characteristics as expected in true soil development, or do they show evidences of rapid transport, thus not implying much time for formation?

Much of the research on the Yellowstone petrified forests since the first report by Holmes (1878) has been taxonomic. Knowlton's monograph (1899) was the first and most extensive. Read (1933) and Dorf (1960) have examined and revised the work of Knowlton. Dorf also discussed the paleoecology and interpreted the organic zones as growth surfaces or pockets and lenses of organic debris deposited by small streams. Ritland & Ritland (1974) and Coffin (1979) have discussed basic models of formation, and Fritz (1979) discusses various depositional features. Beyond this, little attention has been given to the organic zones except as sites for the collecting of specimens for taxonomic study.

The fossil forest areas most frequented lie along the slopes and cliffs of Specimen Ridge which flank the Lamar Valley on the south. Two classic areas generally referred to as Specimen Ridge and the Fossil Forest lie several miles apart opposite Slough Creek and Soda Butte Creek respectively. However, fossil forests also exist in and beyond the northwest corner of the Park, on both sides of Soda Butte Creek, and on the east side of Cache Creek. Other less significant sites are known in the northern and eastern parts of the Park. In addition, an extensive area exists in the Stratified Primitive Area south of Yellowstone Park. The research reported in this paper has been undertaken in all the sites mentioned above except the Stratified Primitive Area. All these petrified forests are in Eocene volcanic breccia and ash beds.

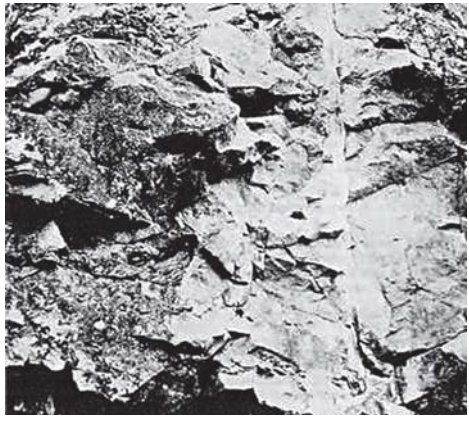


FIGURE 1. Vertical broomstick-size petrified tree in volcanic breccia, Mt. Norris, Yellowstone National Park. The tree is to the right of the picture and is about 1.5 m high.

GENERAL DESCRIPTION

The upright trees (Figure 1), which sometimes reach as high as 6.7 m and occasionally even higher, have a diameter up to 4.5 by 3.8 m and are often seen to arise from layers or zones which are composed of needles, leaves

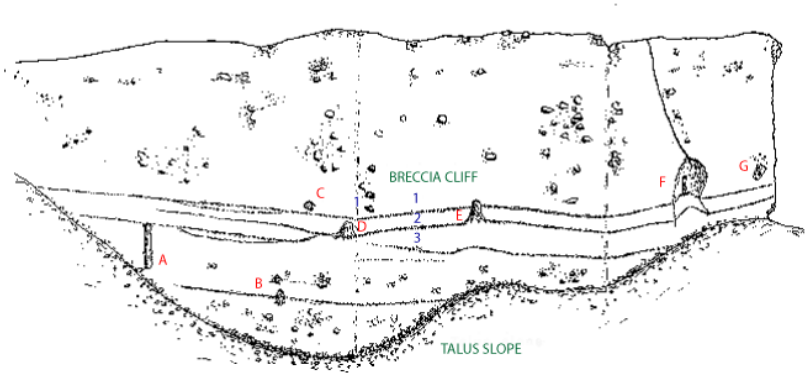


FIGURE 2. Sketch of a breccia cliff in the Cache Creek petrified forest showing a complex arrangement of organic levels and trees.

and organic debris. These levels lie in positions in relation to the roots of the upright petrified trees that correspond to growing surfaces upon which humus and soil have accumulated (Figure 2). They have been interpreted as soil levels — a natural and obvious interpretation.

However, many of the organic levels of the Yellowstone petrified forests are thin and contain only a small fraction of the organic material that would be expected, based on the sizes of the trees arising from the levels. Sixty-three levels on the slopes above Specimen Creek range from a trace of organic matter to 15 cm thick. The average is close to 3 cm. These dimensions are for the total depth of "soil" or organic matter. A distinction between forest floor litter and underlying soil is not visible. Of the 130 levels with upright trees included for the four petrified forests listed in Table 1, 24% contain no organic matter; however, the situation appears highly variable. Sixteen of the 37 levels of Mt. Hornaday have no forest debris whereas only two of the 48 levels of Specimen Creek are exceptions.

TABLE 1

Tree and organic levels for four Yellowstone petrified forests

Area	Number of Upright Tree Levels	Number* of Upright Tree Levels Without Organic Zones	Number of Organic Levels Without Upright Trees	Total Number of Levels
Cache Creek	13	3	12	25
Fossil Forest	32	10	9	41
Mt. Hornaday	37	16	5	42
Specimen Creek	48	2	17	65

*Numbers in this column are included in the previous column.

FIGURE 3. Photomicrograph of petrified deciduous leaf in volcanic ash from Mt. Hornaday, Yellowstone National Park.

FIGURE 4. Photomicrograph of the cross-section of a petrified coniferous needle from Cache Creek petrified forest.

Preservation of the organic matter is excellent. This good condition has, of course, facilitated the identification of the plants. Occasionally even the detailed cellular structure of specific tissues of leaves and needles can be seen in thin-section slides (Figures 3 and 4).

EVIDENCES OF REWORKING BY WATER

Cross-sections through true soils reveal a typical profile of organic density resulting from increased blackness or richness of humus toward the surface of the ground. Eighty-six (71.6%) of 120 vertical thin sections of organic levels studied have the organic matter mixed into the sediments with no prevailing order of density. Twelve of the sections (10%) have a reverse organic profile with the greatest accumulation of organic matter at the bottom.

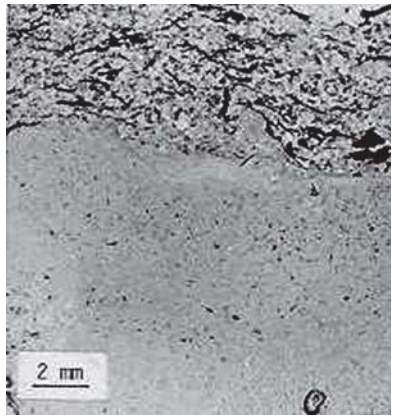


FIGURE 5. A vertical thin section of an organic level from Mt. Norris. Note the sorting of both organic and inorganic matter. The dark streaks and spots are vegetable matter.

There is also sorting of organic material in 20% of the sections from 19 levels in the Specimen Creek Fossil Forest, Mt. Norris and Miller Creek petrified forests. Figure 5 shows a relationship between the size of the ash sediment and the size of the organic material — fine sediment, fine organic matter; coarse sediment, coarse organic matter. Similar to this example is size sorting of the inorganic particles among or between leaves. Figure 6 is from an Oregon site, but also illustrates the Yellowstone situation. The leaves are seen in cross-section as long, somewhat undulating lines. Between the lines the sediments show normal grading (also see Coffin 1979, Figure 8).

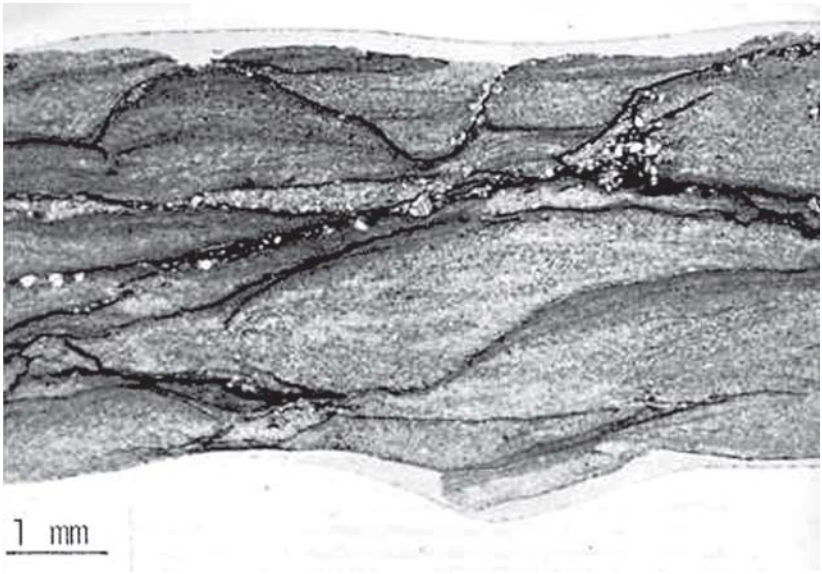


FIGURE 6. Enlargement of a vertical thin section from an organic level near Cascade Locks, Oregon. The petrified tree-volcanic breccia relationships here are similar to those of Yellowstone. Note the normal grading of sediments between the deciduous leaves, seen here in cross-section.

In a normal soil, undecayed leaves and needles are confined mostly to the surface. Material more than a few seasons old disintegrates into humus, and identification becomes difficult or impossible. Differential decay with depth is absent in the organic levels of Yellowstone. Throughout the petrified forests of the region, vegetable debris at the bottom of a layer is as well preserved as that at the top.

A feature known for many years is the absence of animal remains. Volcanic activity could have caused larger forest animals to flee elsewhere. This explanation is not satisfactory, however, because many animals could not or would not leave their forest habitats. Land snails, some amphibians and reptiles, many insects, arachnids and worms would not escape burial. Eggs and young of many types would be unable to flee. In addition, bones, teeth, scales, exuviae, castings, droppings, burrows, etc., would qualify as evidence of animal life. None of these have been found in the organic levels during a century of research. Considering the excellent preservation of the delicate plant parts, diagenetic destruction of animal remains appears unlikely.

COMPLEXITY OF ORGANIC LEVELS

The complexity of the organic levels is apparent especially in the Cache Creek and Specimen Creek petrified forests. In Figure 2, the sketch of a section of cliff in the Cache Creek area, notice how some of the organic levels split and recombine. Levels one and two are less than a meter apart. Note the penetration of trees b and e through overlying organic zones. Even more complex are the Specimen Creek organic levels (see Coffin 1979, Figure 6).

Could the upper organic bands of multiple levels represent the leaf-fall zones associated with air-drop ash in volcanic eruptions? In such cases the lowest band would represent the true soil level, whereas the upper one(s) would result from physical and chemical stripping of leaves and needles from the trees by explosive volcanic activity. These upper bands should not be growth surfaces unless no further ash accumulation occurred for many years and a new forest established itself on this level. The study accompanying the survey of the complex Specimen Creek levels failed to distinguish any significant differences between surfaces from which visible trees arise and adjacent bands containing no visible upright trees. Growth levels with trees and also bands within levels were sampled and examine in the thin section studies described earlier. If leaf-drop zones are present, they are not readily apparent and cannot be distinguished from the other levels. Until some quantitative feature for separating leaf-drop from growth levels is found, evaluation of this possibility is difficult.

TAXONOMIC CHARACTERISTICS

In this research gross identification of the plant specimens in the organic levels was undertaken. Trees were classified as Pine-type (resin ducts present), Sequoia-type (no resin ducts), and deciduous (vessels present). Leaves and needles in the organic levels were identified to the same categories.

Taxonomic sorting of the constituents in the organic bands were noticed early in the research. It resulted in a sequence of broad leaves at the top of the organic zone, mixed broad leaves and needles just below, and only needles at the bottom. Under normal conditions leaves, needles, cones, limbs, bark, etc., fall as a well-mixed litter onto the forest floor year by year as the seasons pass and the trees grow. A flotation experiment involving aspen and poplar leaves and fir needles in a tank of water showed that the needles became saturated and sank to the bottom first. Thus flotation in water is a possible explanation for this kind of taxonomic sorting.

Three transects 90 m long and $^{2}/_{3}$ m wide in a central California mature redwood forest showed Sequoia and other cones on the surface of the forest floor (Table 2). Although Sequoia cones are small and fragile, they do remain intact and visible for several months after failing. No petrified Sequoia cones have been found in Yellowstone despite the dominance of Sequoia trees. Cones of any type are rare in the petrified forests.

TABLE 2

Abundance of cones, acorns, and animal evidences on the surface of a Central California redwood forest floor (Each transect 90 m long and 60 cm wide.)

Transect	Sequoia Cones	Other Cones	Acorns	Animal Evidences*
1	59	57	17	3
2	19	1	5	5
3	52	21	34	1

*Snails, worm casts, bones and insects.

In a mixed forest of redwood and deciduous trees such as exists in California, the redwood needles greatly predominate in the forest floor litter. For the area overshadowed by a tree, conifers appear to drop proportionately many more needles than do deciduous trees their broad leaves. Knowlton (1899, p 757) remarked about the absence of needles in the organic levels associated with the fenced petrified tree near Roosevelt Lodge in Yellowstone National Park. Our studies there have been summarized in Table 3. There is a lack of taxonomic agreement between the dominant trees in the area and the leaf and needles in the organic layers. One would expect to find great numbers of Sequoia needles and some cones, since most of the upright trees are Sequoia. However, large numbers of broad leaves and only a few pine needles are seen in the organic levels. Sequoia needles were entirely absent.

TABLE 3

Taxonomic breakdown of the petrified forest 2 km west of Roosevelt Lodge, Yellowstone National Park

	Sequoia-type	Deciduous	Pine-type	Undetermined	Totals
Petrified Trees	28	5	4	3	40*
Leaf & Needle Evidences	0	75	27	0	102

*30 erect.

Many genera are represented only by pollen, but this might be expected, since the wood samples have not received thorough taxonomic study. More difficult to explain, if the trees are in position of growth, are the cases represented by wood or leaves only. Trees with wind-transported pollen such as walnut and sycamore should have left a pollen record in the forest floor, but little or no pollen for these two has been found. DeBord (1977) worked in the petrified forest in the northwest corner of the Park (Specimen Creek). Four levels especially were given careful analysis. Pollen obtained from samples taken from 100 meter sections for each of the four levels were compared within levels, between levels, and between micro- and megaflora. Modern forest floors contain pollen in abundance inversely proportional to the distance from the source trees — especially for trees using wind as the pollen-transporting force (Tauber 1965,1976; Anderson 1970, 1973). No positive correlation exists between Yellowstone fossil pollen abundance and the proximity of possible source trees. The differences between individual samples on the same level are such that single sample analysis cannot be used to adequately describe the level.

The taxonomic composition of any particular forest of trees should influence the composition of the next higher forest of the area (if the trees are in growth position) because in most cases only the lower trunks of the standing trees would be covered by the advancing breccia-mud slide. The cones, seeds, nuts, and fruits would fall from the upper parts of the partially buried trees and repopulate the new surface with a similar forest. In DeBord's study (1977) no positive correlation exists between the taxonomic composition of pollen of the organic levels of one forest with that of forests directly above or below. Pine pollen was under-represented in three of the four forests analyzed. One of these three levels showed a severe under-representation of pine pollen and a severe over-representation of deciduous pollen.

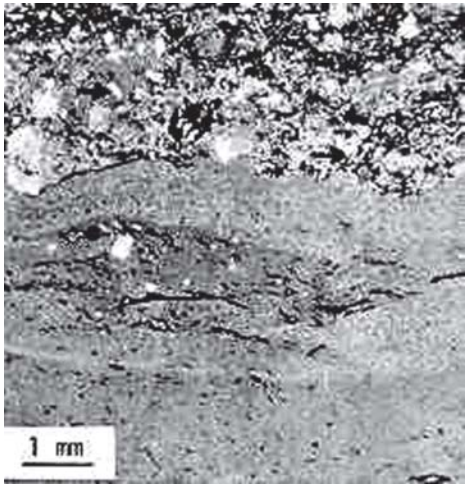
OTHER RELATED EVIDENCE

The presence of a clay profile formed by the slow breakdown of minerals is related to normal soil maturity processes. An analysis by x-ray diffraction and infrared scans on over 350 samples has been done for the Specimen Creek Area. Of nine horizontal bands of clay (montmorillonite) found distributed through the Specimen Creek petrified forest, three were limited to the breccias between organic levels. Five included one organic level and portions of the breccia beds immediately above and below and one included two organic levels and associated breccia beds. Clay content was up to 60% but no profile was detected on any of the seven organic zones included in the clay bands. Horizontal sampling of two clay bands at 5 to 10 feet intervals for 100 feet showed a constant mineral makeup. Abundant unweathered feldspar is scattered throughout the Yellowstone organic levels (Figure 7), suggesting rapid burial.

None of the other organic zones contained detectable amounts of clay. Clay detection limits were at the 1-2% level. The apparent absence of clay in the majority of levels raises temporal questions concerning the so-called soil zones. Furthermore the sudden abundant appearance of clay in a few horizontal bands that include both organic levels and breccia beds suggests transport rather than *in situ* formation.

The rate of clay formation is variable, depending on climate and the parent rock. A sequence of mud slides on Mt. Shasta ranging in ages from 27 to 1200+ years showed little increase in clay content with age (Dickson & Crocker 1953). In contrast, clay formed on the volcanic ash soils of the West Indian island of St. Vincent at the rate of 1½ to 2 ft./1000 years (Hay 1960). Some levels in Yellowstone with large trees (up to 15 feet in diameter) would represent soil development well over 1000 years duration if the trees are in growth position. The mixed flora of the Yellowstone fossil forests makes it difficult to determine what the past climate of the region would have been.

FIGURE 7. Unweathered crystals of plagioclase from an organic level on Mt. Hornaday. Note arrows.



The tentative results from the study of clay appear to

suggest that no significant passage of time has been involved in the formation of the organic levels of Yellowstone. Spark source mass spectrometry research (in progress) appears to give the same results. The lack of significant difference between organic levels points toward these levels (and associated breccia beds) as being the result of one rapid volcanic episode.

COMPARISONS WITH OTHER BRECCIAS

Fiske (1963, p 391-406) has described volcanic lahars of the extensive Ohanapecosh formation in Mt. Rainier National Park, Washington. In these breccias we found some organic levels, although they are less strongly developed than those of Yellowstone. Horizontal petrified trees also are noted. Fiske interprets these breccias as being subaqueous deposits. Obviously these organic levels cannot be growth surfaces if the deposits slid into position under water.

A road cut for Interstate 80 in the Miocene Eagle Creek formation near Cascade Locks, Oregon, exposed several levels of petrified trees and organic debris in volcanic breccia — a situation closely similar to that of Yellowstone. Whatever interpretation is achieved for the Yellowstone breccias will probably apply to the breccias of this Oregon location and vice versa. Figure 6 is an unusual section of the organic level of the one remaining vertical tree still visible in the road cut. The pronounced normal gradation of sediments between the deciduous leaves (seen in cross-sections) is unique. Such grading hardly could be produced in normal undisturbed soil and suggests transport.

CONCLUSION AND IMPLICATIONS

The normal accumulation of organic debris and the subsequent formation of humus and true soil which proceeds relentlessly on modern growth surfaces does not readily account for several of the phenomena seen in the organic levels of Yellowstone. Specifically these are:

1. The thinness or absence of organic matter on levels with abundant and large trees.
2. Good preservation — no differential decay from top to bottom.
3. The absence of evidences of animals expected in typical forest plant-animal associations.
4. The multiplicity and complexity of the organic levels.
5. Lack of agreement between organic components and the dominant tree types as seen by studies of leaf types and pollen.
6. The evidences of contemporaneous water deposition of sediments and organic matter seen in the thin sections of the organic levels.

7. The vertical sorting of organic matter and atypical soil profiles.
8. The absence of weathering of feldspar crystals in many organic levels.
9. The absence of anomalous arrangement of clay in the organic levels.

The movements of volcanic lahars over the ground could eliminate a normal soil profile but they would not be expected to produce a reverse profile or sort the organic matter. These phenomena might be produced by small streams sorting and redepositing humus and forest litter as suggested by Dorf (1960, p 257). However, these organic levels are often widespread and uniform in thickness. This feature and the absence of scouring or erosion would appear to eliminate small streams as agents for sorting and redepositing organic matter. Widespread flooding associated with volcanic activity and preceding each breccia-mud slide might be responsible for some of the anomalies seen in the organic levels. Such water activity could be responsible for features described in items 1, 2, 4, 6, 7, 8, and 9 above. The absence of animal remains and the lack of agreement between micro- and macroflora (items 3 and 5) suggest transport and sorting in a sea or large lake.

The unusual problems posed by the Yellowstone Petrified Forests and their surrounding sediments challenge research from multiple disciplines. I wish to acknowledge the work in palynology (Lanny H. Fisk and Phillip L. DeBord), surveying and plotting (Donald G. Jones), and geochemistry (Ivan G. Holmes and Clyde Webster, Jr.) that I have cited in this paper.

REFERENCES

Anderson ST. 1970. The relative pollen productivity and pollen representation of North European trees, and the correction factors for the pollen spectra. Geological Survey of Denmark, Series No. 96.

Anderson ST. 1973. The differential pollen productivity of trees and its significance for the interpretation of a pollen diagram from a forested region. In: Birks HJB, West RE, editors. Quaternary Plant Ecology, p 108-114. Oxford: Blackwell Scientific Publications.

Coffin HG. 1979. The Yellowstone petrified forests. Spectrum 9(4):42-53.

DeBord PL. 1977. Gallatin Mountain "petrified forest": A palynological investigation of the *in situ* model. Ph.D. dissertation, Loma Linda University.

Dickson BA, Crocker RL. 1953-1954. A chronosequence of soils and vegetation near Mt. Shasta, California. I, II, III. Journal of Soil Science 4:123-154; 5:173-191.

Dorf E. 1960. Tertiary fossil forests of Yellowstone National Park, Wyoming. Billings Geological Society, 11th Annual Field Conference Guidebook, p 253-259.

Fiske RS. 1963. Subaqueous pyroclastic flows in the Ohanapecosh formation, Washington. Geological Society of America Bulletin 74:391-406.

Fritz W. 1979. Depositional environment of the Yellowstone fossil forests as related to Eocene plant diversity. Geological Society of America Abstracts 11(7):428.

Hay RL. 1960. Rate of clay formation and mineral alteration in a 4000-year-old volcanic ash soil on St. Vincent, B.W.I. American Journal of Science 258:354-368.

Holmes WH. 1878. Fossil forests of the volcanic Tertiary formations of the Yellowstone National Park. U.S. Geological and Geographical Survey Territorial Bulletin 5:125-132.

Knowlton FH. 1899. The Tertiary floras of the Yellowstone National Park. U.S. Geological Survey Monograph 32:651-691, Plates 77-121.

Read CB. 1933. Fossil floras of Yellowstone National Park, Part 1, Coniferous woods of Lamar River flora. Carnegie Institution of Washington Publication 416:1-19.

Ritland RM, Ritland SL. 1974. The fossil forests of the Yellowstone region. Spectrum 6(1-2):19-66.

Tauber H. 1965. Differential pollen dispersion and the interpretation of pollen diagrams. Geological Survey of Denmark 11, Series No. 89.

Tauber H. 1967. Investigations of the model of pollen transfer in forested areas. Review of Paleobotany and Palynology 3:277-286.

NEWS AND COMMENTS

PUBLICITY FOR CREATION

Reactions to a legislative bill in Iowa indicate that academic freedom is not being practiced. The bill required the inclusion of scientific evidence for creation "whenever the origin of human kind or the origin of the earth is taught in the educational program of the public schools of this state."

On April 5, 1979, at a public hearing before the Iowa State Senate, students from Iowa State University contended that academic freedom is being suppressed in their science classes. Several testified that attempts to either question the theory of evolution or discuss evidence for creation were countered with hostility and/or ridicule. While some of the faculty members dismissed creation as religious and unscientific, three other science professors at the hearing maintained that all of the scientific evidence should be presented — whether or not it supports evolution. They recommended the use of a two-model approach to the study of origins.

Although the bill did not come to a vote (further action is expected in 1980), additional indications of discrimination against creation were seen in subsequent actions on the Iowa State campus. Upon his return, one of the students who testified at the senate hearing was dismissed from his biology class. Publicity from his dismissal (and subsequent reinstatement by the school administration) caused other students to cite more examples of suppression of ideas, i.e., the cancellation of a popular seminar on creation. Another professor suggested that, for future biology classes, prospective students be screened and admitted only on the basis of their acceptance of evolution.

Students at Iowa State University have not been the only creationists to receive publicity for their activities. A news item in *Science* (June 1, 1979) focused attention on the Smithsonian lawsuit (see *Origins* 5:99-100). In the June 15 issue of the *Wall Street Journal*, a front-page article stated that creationists were, to the dismay of Darwinians, somewhat successful in winning equal time in the classrooms for the teaching of creation.

The following month, *Scientific American* discussed recent legal cases sponsored by creationists. Entitled "Creationism Evolves," the article described the new creationist approach. First, the legislative bills do not require that the teaching of evolution be abolished and replaced by the teaching of creation as described in Genesis. Second, the two-model approach to origins is not led by theologians and church leaders, as might

be expected; instead, it is being promoted and supported by creationists who hold advanced degrees in science.

The September issue of *BioScience* contained a similar article describing legislative efforts to gain equal treatment for alternative theories of origins. Though creationists have been defeated in the courts, they are influencing both professors and textbook publishers, and the article seems to suggest that it is only a matter of time before they would also win a court decision in their favor.

In the middle of this century, evolution dominated in the classroom, and the issue between creation and evolution was relatively calm. This is no longer the case. It appears that a persistent controversy may be developing between scientists who hold differing views on origins, i.e., evolution or creation.

Katherine Ching

LITERATURE REVIEWS

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

QUESTIONS ON THE METHODOLOGY OF GEOLOGY

THE STRUCTURE OF GEOLOGY. David B. Kitts. Dallas, TX: Southern Methodist University Press. 180 p.

Reviewed by Albert E. Smith, Department of Physics, Loma Linda University

"The goal of geology is the derivation and testing of singular descriptive statements about the past" (p 39).

At least this is true for historical geology, and it is the structure of the science of historical geology that is studied in this book. It consists of a series of eight essays originally published in the technical literature over a period of eleven years.

To paraphrase the author's words: There has been a failure to produce a coherent account of the structure of geological knowledge in the two centuries since Hutton as a result of a confusion between metaphysical questions and epistemological concerns. Geological tradition is radically empirical and notably untheoretical, and although geology is recognized as a historical science dependent upon physics and chemistry for its theoretical foundations, little reflective attention has been given to the unique methodology required. When geologists discuss their science, they are likely to compare it to physics. The comparison is not apt, however, for geology is in a sense physics turned upside down. Geology takes the universals of physics and chemistry for granted and is mainly interested in finding and testing singular statements. Instead of prediction, it is concerned with "retrodiction."

The common thread that ties the eight essays together is the attempt to examine various areas of the science for epistemological clarity. The relation of geology to physical-chemical theory, the methodological differences that distinguish geology as a historical science from conventional history, indeterminism in geology, the paradigm shift associated with continental drift as a Kuhnian revolution, the relation between evolutionary theory and the fossil record are all in one way or another used to illuminate some aspect of Kitts' primary assumption.

This assumption is that the goal of geology is to develop an earth history consistent with the understood laws of physics and chemistry. "Modern geology assumes *all* of contemporary physical-chemistry theory and presents on the basis of this assumption a high degree of logical integration" (p 62).

It is not an easy book to read. The author's style is diffuse and wordy; the organization of any one essay is seldom clear, and it is inevitable that a group of essays written over such a long period are not going to appear particularly coherent when presented in book form. The reader is left with a desire for seeing a systematic treatment of the subject that would critically enlighten both geologists and non-geologists on the unique methods of geological science and the reasons for them in a comprehensive way. It is, however, an important book because of its content and one that I believe is well worth the attention of *Origins*' readers.

In thinking about applications for Kitts' concern with methodology, this reviewer was reminded of Barnes' (1979) challenge to the activities of those working in flood geology, a series of questions about the success possibility of any attempt at a "flood model." It appears that his questions cannot be answered without an analysis of the epistemological-methodological problems associated with the science of flood geology. Do the flood geologists hold with Kitts the laws of physics and chemistry as their basic assumption? This to Kitts is the uniformitarian principle and limits as a methodological device the generalizations used in geological explanation. Barnes' challenge appears to claim that one simply cannot get at the evidence of a "miraculous" event by this means. Is it possible to frame a reasonable set of assumptions that define the methodology of "flood scientists" or for any model that allows for divine intervention in nature?

Young (1979) makes the claim that flood geology is of necessity methodologically uniformitarian; that flood catastrophists may be less than consistent, but cannot escape being uniformitarians, as he and Kitts define the term. He, with Barnes, is asking for an examination of the foundations of flood geology in order to make it intelligible. Progressive creationists and theistic evolutionists also need to address themselves to the same basic questions.

In the most comprehensive essay in the book, "The Theory of Geology," Kitts raises several questions about the theoretical structure of the science and in an introductory remark places the questions in a context of the most appropriate educational curriculum for geology. According to him, scientific explanation has been regarded as a deductive operation and geology is different because it is of necessity inductive.

This leads to an examination of the credibility status of geological generalizations; he points out that the words "probably," "frequently," and "tends to" are common occurrences in geological "laws." Following Scriven (1959) generalizations of this type are called "normic statements" to distinguish them from the universal laws of physics. It is not necessarily a weakness for the science to rely on less-than-universal statements, since its goal is to "frame *general* statements, universal or not, on the basis of which explanation can be justified."

Following this discussion the author identifies with the curious (in this context) hope that "normic statements might become universal" and then says: "Certainly no consistent, economical, complete deductive system of geology exists, but I think that we can detect the suggestion of such a system." The reader is left with the impression that Kitts is unfairly comparing geology with physics, with an overemphasis on the deductive systems that exist in physics. Since no complete deductive system exists for physics either, it is an ideal apparently not realizable in fact.

Kitts does not pursue the question of the ideal curriculum; but it is one that cannot be answered without consideration for the structure of the science. A safe conclusion is that geological education that neglects concern for the study of the structure of the science will continue the confusions of the past.

In summary, the book is well worth reading for anyone interested in the foundations of geological science or the philosophy of science. Kitts' literary style makes it a difficult book to read, but the book is effective in that it deals with significant issues.

LITERATURE CITED

Barnes RO. 1979. Biblical creationism after a century of scientific investigation. Spectrum 10(1):2-11.

Scriven M. 1959. Truisms as the grounds for historical explanations. In: Gardiner P, editor. Theories of History, p 443-475. Glencoe, IL: The Free Press.

Young DA. 1979. Flood geology is uniformitarian! Journal of the American Scientific Affiliation 31:146-152.

GENERAL SCIENCE NOTES

CORAL REEF GROWTH

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On a quiet moonlight night in the year 1890, the British-Indian liner *Quetta* was traveling through the Torres Strait near Thursday Island in northern Australia. This strait is located at the northern end of the Great Barrier Reef, the world's largest coral reef complex. Suddenly the ship hit a reef pinnacle that ripped through two-thirds of its bottom and sank within three minutes. Nearly half of the ship's 293 passengers perished as a result of this unexpected encounter. The strait had been carefully charted between 1802 and 1860, and no reef was expected where the ship foundered. Some have wondered (e.g., Ladd 1961) if possibly a reef could have grown fast enough between the time of sounding and 1890 to cause this tragedy.

FIGURE 1. Portion of Enewetak Atoll, Marshall Island. To the right of center is Perry Islet. It is the largest islet visible in the picture and has a length of 2.3 km. The shallow atoll lagoon is to the left of the reef while the deep ocean is to the right.

FIGURE 2. Closeup view of part of a coral tip of *Acropora formosa* from the lagoon of Enewetak Atoll. Each one of the "cups" on the tip harbors a single coral organism. The tip is about 25 mm long.

The question of the rate of coral reef growth is of considerable interest not only because reefs are incipient navigational hazards, but also because of the time required to build these large structures. A number of unsolved questions related to slow rates of subsidence or sea level rise and rapid rates needed to drown a reef (e.g., Schlager 1979) are of considerable academic interest. Some also wonder if the few thousand years proposed for life on earth in a biblical context can account for the growth of these huge structures. The Great Barrier Reef of Australia does not appear to pose a problem here. While it is over 2000 km long and up to 320 km offshore, drilling operations down through this structure have run into quartz sand (a non-reef type of sediment) at less than 200 meters (Stoddart 1969), indicating that it is a very shallow structure that does not necessarily require a vast amount of time for development. On the other hand, drilling operations on Enewetak (Eniwetok) Atoll (Figure 1) in the Western Pacific have gone through 1405 m of apparent reef material before reaching a basalt rock base (Ladd & Schlanger 1960). The rates of growth assumed by most investigators would dictate that at least scores of thousands of years would be required to grow a reef this thick. We shall evaluate the basis for these rates but will first consider a few of the peculiarities of the organisms involved.

Coral reefs are produced by a variety of organisms that precipitate carbonates (lime) from seawater. Molluscs, foraminifera, and bryozoa can provide substantial amounts of carbonate for reef growth; however, coral and coralline algae are considered to be the most important contributors. Warm temperature appears to be essential for coral reef growth which is limited to the warmer waters of the tropical and western portions of the world oceans. Light is also important for coral reef growth. Coral are colonial animals (Figure 2), many of which harbor symbiotic algal plants that require light. One will not get the luxuriant type of growth necessary for live reef survival without light. This is illustrated by a number of "drowned" (essentially dead) reefs that are found from a few meters to over a kilometer down in the ocean (Macintyre 1972; Shepard 1973, p 354; Ladd, Newman & Sohl 1974; Purdy 1974).

I have noted that significant coral growth stops below a depth of 50 m at Enewetak. If light is so essential to reef growth, one may wonder how reefs such as Enewetak extend to a depth of 1405 m in the sea where virtually complete darkness prevails. The present explanation is that in the past, that portion of the floor of the Pacific Ocean on which Enewetak grew was at sea level and has gradually subsided as reef growth proceeded at or near the surface of the ocean.

Coral reefs present an interesting array of other fascinating enigmas related to their morphology, nutrition and survival which are, unfortunately, beyond the scope of this brief note.

Rates of coral and coral reef growth have been studied by a number of investigators. Chave, Smith & Roy (1972) have analyzed some of the findings of other investigators and suggest net rates of growth of 0.8 to 26 mm/year. The net growth rate of a reef is the combination of total carbonate production less carbonate losses by biological, chemical and physical factors. Odum & Odum (1955) suggest a growth rate of 80 mm/year. Smith & Kinsey (1976), using an analysis of the CO_2 system in seawater, suggest growth of 2-5 mm/year. Adey (1978) feels that this figure is too low for Atlantic reefs that must grow 2-3 times faster.

The figures given above contrast sharply with some figures based on actual soundings of reefs. Sewell (1935) reported 280 mm/year in the Andaman Islands in the Bay of Bengal, and Verstelle (1932) reported a maximum rate of growth of 414 mm/year in the Celebes. This latter figure would allow for the development of the 1405 m of the Enewetak reef in less than 3400 years.

One wonders why there should be a difference of one to two orders of magnitude between the estimates usually based on rates of coral growth and on soundings. A few suggestions follow.

FIGURE 3. Stand of *Acropora formosa* at Enewetak Atoll. The individual branches are approximately 10 mm in diameter.

1) Most of the estimates of coral reef growth are based on growth rates at the surface of a reef. Experiments which I have conducted indicate that at the surface of the sea, natural ultraviolet light inhibits coral growth; however, the effects do not seem to be sufficient to account for the two orders of magnitude difference obtained between surface measurements and soundings conducted at greater depth.
2) The reef surface where most studies are conducted may be a poor place to evaluate potential reef growth. Reef-building organisms are occasionally killed by exposure to air during very low tides, and further upward growth results in increased harmful exposure. For example, a slowly sinking ocean floor would tend to lower the reef below the ocean surface, where more rapid growth would be possible and, in fact, necessary to keep it from dropping too far below the surface. In contrast, reefs that are already at the ocean surface are inhibited from growing into the air.
3) An additional factor is that the rate of growth of coral and other organisms on the reef may not be the only source of carbonate with which to build a reef. Schroeder & Zankl (1974)

FIGURE 4. Isolated colony of *Acropora cervicornis* near the Florida Keys. This species has been reported to grow as fast as 260 mm/year. The colony is about 40 cm high. A large number of soft coral surround this colony.

point out that the reef can act as a filter, trapping some of the suspended carbonate load from the seawater passing through. Apparently, sediments on or near the bottom of the ocean could also contribute to reef growth, since Lonsdale, Normark & Newman (1972) found that the net movement of sand along the sides of Horizon Guyot (a submerged flat-topped mountain reaching up 3 km from the Pacific Ocean floor) is *upslope*, being moved up by tidal currents. Under similar circumstances, some of the rapidly growing coral near the surface of a reef (Figure 3) would facilitate more rapid carbonate deposition by trapping sediments brought upslope along the reef. In this situation the live coral would not have to build the entire mass of the reef, but only build a framework to hold the sediments.

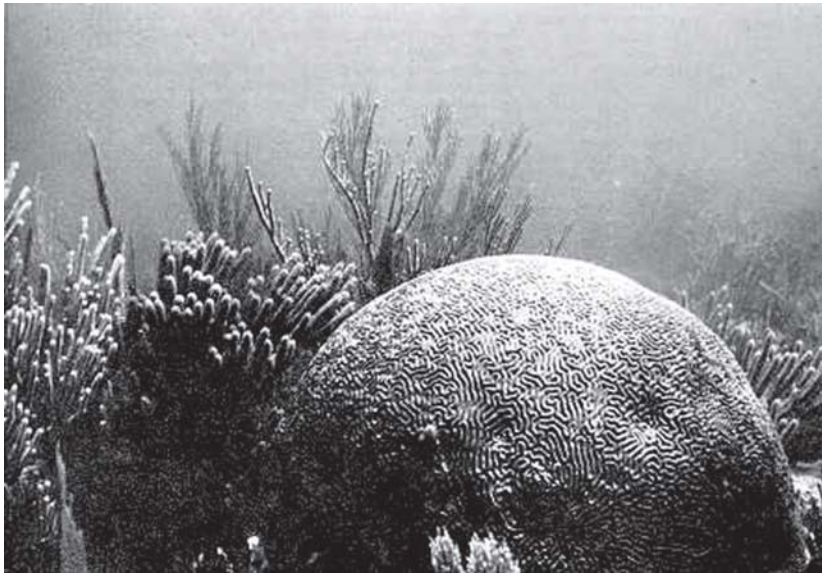
The fastest growth rate reported for any coral is the staghorn species *Acropora cervicornis* (Figure 4). Lewis et al. (1968) found in Jamaica a maximum rate of 264 mm/year. Shinn (1976) studied the growth of this species following destruction in a hurricane near Florida. He estimated linear growth rates of 100 mm/year. He also found that because of the branching habit (several new branches added to a single previous one)

much more than the linear growth of a single branch is involved in establishing a dense stand of this coral (see Figure 3 for an example). Under these branching growth conditions, carbonate production would be more geometric than linear and could contribute further to the carbonate mass of the reef. Gladfelter, Monahan & Gladfelter (1978) report rates of 99 mm/year for *Acropora palmata* in the Virgin Islands. Some massive corals (Figure 5) grow much more slowly.

The upslope movement of sediment along reefs may be enhanced near the surface by the occasional action of typhoons. Maragos, Baines & Beveridge (1973) reported that in 1972 a rampart of coral rubble 3.5 m high, 37 m wide, and 18 km long was brought up from below the surface at Funafuti Atoll in a few hours during Cyclone Bebe. Blocks of coral 2 m high were brought up on Jaluit Atoll (another Pacific reef) during another typhoon in 1958. A new rampart was also formed there (Wiens 1962, Plates 19 and 35).

The three main factors mentioned above indicate that reef growth can be much faster than surficial measurements would indicate. They may explain the major discrepancies between reported rates of reef growth. However, before any final conclusions can be arrived at, one must also take into consideration those factors that contribute to the attrition of

FIGURE 5. A massive but slow-growing coral near the Florida Keys. The hemisphere is about 1 m in diameter.



reefs. These include: 1) destruction by corallivores (boring organisms) (Macintyre 1972), 2) possible chemical breakdown, and 3) mechanical destruction by waves and downslope movement along the edge of the reef.

Experiments that my graduate students and I have conducted indicate that one can, at least temporarily, nearly double the rate of coral growth by raising the temperature 5ºC or by increasing the carbonate ion content of seawater. What relationship this might have to past rates of coral reef growth remains to be investigated. Nevertheless a number of facts indicate that coral reef growth rates may be much faster than some of the slower estimates reported in the literature. Our present knowledge does not preclude rapid rates of development; some factors definitely facilitate it.

LITERATURE CITED

Adey WH. 1978. Coral reef morphogenesis: a multidimensional model. Science 202:831-837.

Chave KE, Smith SV, Roy KJ. 1972. Carbonate production by coral reefs. Marine Geology 12:123-140.

Gladfelter EH, Monahan RK, Gladfelter WB. 1978. Growth rates of five reef-building corals in the northeastern Caribbean. Bulletin of Marine Science 28:728-734.

Ladd HS. 1961. Reef building. Science 134:703-715.

Ladd HS, Newman WA, Sohl NF. 1974. Darwin Guyot, the Pacific's oldest atoll. Proceedings of the Second International Coral Reef Symposium 2:513-522.

Ladd HS, Schlanger SO. 1960. Drilling operations on Eniwetok Atoll, Bikini and nearby atolls, Marshall Islands. U.S. Geological Survey Professional Paper 260Y:863-905.

Lewis JB, Axelsen F, Goodbody I, Page C, Chislett G. 1968. Comparative growth rates of some reef corals in the Caribbean. Marine Sciences Manuscript Report 10. McGill University.

Lonsdale P, Normark WR, Newman WA. 1972. Sedimentation and erosion on Horizon Guyot. Geological Society of America Bulletin 83:289-316.

Macintyre IG. 1972. Submerged reefs of eastern Caribbean. American Association of Petroleum Geologists 56:720-738.

Maragos JE, Baines GBK, Beveridge PJ. 1973. Tropical cyclone Bebe creates a new land formation on Funafuti Atoll. Science 181:1161-1164.

Odum HT, Odum EP. 1955. Trophic structure and productivity of a windward coral reef community on Eniwetok Atoll. Ecological Monographs 25(3):291-320.

Purdy EG. 1974. Reef configurations: cause and effect. In: Laporte LF, editor. Reefs in Time and Space, p 9-76. Society of Economic Paleontologists and Mineralogists Special Publication 18.

Schlager W. 1979. Drowning of carbonate platforms. Geological Society of America Abstracts 11(7):511-512.

Schroeder JH, Zankl H. 1974. Dynamic reef formation: a sedimentological concept based on studies of Recent Bermuda and Bahama reefs. Proceedings of the Second International Coral Reef Symposium 2:413-428.

Sewell RBS. 1935. Studies on coral and coral-formations in Indian waters. Geographic and Oceanographic Research in Indian Waters No. 8. Memoirs of the Asiatic Society of Bengal 9:461-539.

Shepard FP. 1973. Submarine geology. 3rd ed. NY: Harper & Row.

Shinn EA. 1976. Coral reef recovery in Florida and the Persian Gulf. Environmental Geology 1:241-254.

Smith SV, Kinsey DW. 1976. Calcium carbonate production, coral reef growth, and sea level change. Science 194:937-939.

Stoddart DR. 1969. Ecology and morphology of Recent coral reefs. Biological Reviews 44:433-498.

Verstelle JT. 1932. The growth rate at various depths of coral reefs in the Dutch East Indian Archipelago. Treubia 14:117-126.

Wiens HJ. 1962. Atoll environment and ecology. New Haven and London: Yale University Press.