Genesis One and the Origin of the Earth

Second Edition

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and
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William Henry Green (1825-1900), a graduate of Lafayette College and Princeton Theological Seminary, spent his entire teaching career at the latter institution, where he was Professor of Oriental and Old Testament Literature from 1859 until his death. Professor Green was President of the Faculty for seventeen years, declined the presidency of Princeton University, and served as chairman of the Old Testament section of the American Bible Revision Committee. He wrote a number of books, including *Grammar of the Hebrew Language* (1861), *The Hebrew Feasts* (1865), *General Introduction to the Old Testament* (1898), as well as several works responding to critical theories of the Pentateuch.

Daniel E. Wonderly was a graduate of Wheaton College (A.B., anthropology), Central Baptist Seminary (B.D., Th.M.) and Ohio University (M.S., biological science). He had done graduate work at various universities in embryology, paleontology and several areas of geology, including studies of sedimentology in Bermuda. Professor Wonderly taught Bible and anthropology at Southeastern Bible College (1952-55), zoology at Wingate Junior College (1961-66) and biology at Grace College (1966-73). He was a member of several scientific societies and the author of *God's Time Records in Ancient Sediments* (1977) and *Neglect of Geologic Data: Sedimentary Strata compared with Young-Earth Creationist Writings* (1987). Daniel passed away in 2004.

Finally, we gratefully acknowledge **Jewel Kennington** for her very excellent editorial help. Any errors in this work, however, remain totally with the authors.

Preface to first edition

Since the present book is a proposal rather than a survey, no attempt has been made to note more than a small fraction of the voluminous literature that has been published on this subject. Instead, a few works which are easily obtainable have been cited to indicate a particular viewpoint or to note a datum of science or of the Biblical text. Because this work is written to be read by some who know science but not exegesis, and vice versa, technical words and terminology from both fields have been avoided as much as possible. Special acknowledgment is due to Herman J. Eckelmann, Jr., who, though not responsible for the final form of this work, has been so instrumental in certain aspects of the model proposed that any recognition less than co-authorship would he unfair. For valuable discussions I thank Prof. Robert J. Dunzweiler, Dr. Perry G. Phillips and Dr. Robert W. Manweiler. My thanks also to Daniel E. Wonderly and R. John Snow for permission to include their papers as appendices of this work.

Most of all I thank the Lord God Almighty, Maker of heaven and earth, and Jesus Christ, his only Son. May this work be used to magnify God's name in the hearts of men.

Preface to Second Edition

The pace of solar system research is accelerating. At this writing, Mars rovers Spirit and Opportunity are roaming and examining the Martian surface; Cassini—the largest probe ever—is in orbit around the ringed planet Saturn; Huygens, which "piggybacked" on Cassini, has landed on Saturn's moon Titan and has transmitted intriguing pictures of its surface; the Deep Impact probe has fired an 800-pound copper projectile into the heart of Comet Tempel 1 to examine the comet's makeup; and the Stardust probe has collected dust from Comet 81P/ Wild 2 and has returned to earth with its prize. Extraterrestrial robots; orbiting telescopes such as Hubble, Chandra, and Spitzer; and intricate earth-based telescopic investigations have revolutionized our understanding of the solar system and its origin.

This book combines the latest scientific evidence on the creation of the solar system with our understanding of Genesis chapter one. It is a revision of the 1977 edition, incorporating new data not available at that time. Though some sections have been extensively revised, the flow of the book remains the same, except that chapters 5 and 6 have been combined.

The plan of the book is as follows: In chapter 1 we present data for why we believe the ages of the universe and of the earth are about 14 billion and 4.6 billion years, respectively. We discuss astronomical and geological evidence pointing to such great ages. We have expanded our treatment of the Big Bang theory, incorporating recent results on the cosmic background radiation. These results confirm inflationary Big Bang cosmology for all but the most determined opponents. We have also expanded our discussion of radiometric dating. We describe how radiometric ages are measured and how researchers in this field guard against false age determinations. We conclude that astronomic and geologic dates are accurate and that arguments to the contrary are unjustified.

Chapter 2 deals with the overall "personality" of the solar system. This includes the bulk makeup of the planets and the sun, the orbital regularities of the planets, and the "angular momentum problem," the solving of which is crucial to any theory of the formation of the solar system.

In chapter 3 we choose the best model of the origin of the solar system that fits the data presented in chapter 2. We discuss failed attempts to explain the formation of the solar system and then focus on the nebular theory as the best explanation to date.

Chapter 4 begins our theological discussion of Genesis chapter one. Here we advance Biblical reasons for thinking the creation of the solar system took far longer than six, contiguous 24-hour days.

Chapter 5 examines the events of the Biblical creation account and correlates them to the nebular theory of chapter 3. We end with a summary of our results.

We have kept the three original appendices. Their content is just as valid today as when they were written, so except for minor editorial changes, we have not reworked them.

As with the original edition, no attempt has been made to note more than a small fraction of the voluminous literature that has been published on this subject. Instead, a few works that are easily accessible have been cited to indicate a particular viewpoint or to note a datum of science or of the Biblical text.

We have included numerous footnotes. One can understand our work without constantly referring to the footnotes, but we encourage readers to make use of them if they require more help in understanding the concepts under discussion or if they wish to see other works relating to the matter at hand. We especially encourage using the footnotes in chapter 3 where we discuss the formation of planets from a collapsing interstellar cloud. In our view, this is the most difficult chapter in the book, so we provide numerous footnotes to aid comprehension.

No humans were present at the origin of the solar system to record what happened. We are dependent upon evidence from nature and from Scripture, both from times long past, and this has given rise to divergent interpretations. This is obvious when we see the number of disparate scientific and theological works that have been advanced to explain the creation of the sun and the planets.

Theories for the origin of the solar system, therefore, are somewhat like trials where one does not have eye-witnesses to cross-examine, but is dependent upon circumstantial evidence relating to the crime. The jury may not be able to tie together all the individual details, but if the evidence is sufficiently strong, they can reach a reasonable, logical verdict. Likewise, no theory of origins has tied together every last observable facet of the solar system. Any theory, therefore, is tentative; evidence may crop up tomorrow that disqualifies either its scientific or its theological foundations. Even so, we believe that the evidence so far is handled best by what we propose, and to this end we present our work.

Introduction

Only two centuries ago, the horse and the sailing ship were the fastest ways to travel. To go a hundred miles in one day was a major feat. Today, thousands cross the continents and the oceans in a matter of hours; astronauts circle the globe in ninety minutes; and space craft traverse our solar system at dizzying speeds.

Modern science, joined with technology, has transformed everyday life and revolutionized our view of the cosmos. Atomic force and tunneling microscopes image the structure of atoms; the Hubble Space Telescope pours out pictures of the outermost parts of the universe. People once saw the earth as the physical center of the universe around which the sun, moon, stars, and planets moved in a complex dance. Now we realize that our home is a small satellite of an average star, in a moderately sized galaxy, surrounded by innumerable other galaxies in a vast, unfathomable universe.

One of the results of our new knowledge and power has been to claim that modern science has eliminated any need for the concept of God. In spite of good evidence that Christianity played a significant role in the rise of modern science,[1] some argue that as man originally made God to explain the mysteries of nature, he can now dispense with Him.[2]

Eliminating God from the discussion of science does not sit well with Christians, especially in the area of origins. On the one side, non-theists believe that science points to a universe that, solely by natural means, produced the earth and life upon it billions of years ago. Subsequent evolutionary processes have culminated (so far) in the origin of humans, a few million years ago, from higher forms of animal life. Against this, numerous Christians believe God miraculously created the earth and everything on it a few thousand years ago in six, contiguous, twenty-four hour days.

Popular opinion sees these differences as part of an irreconcilable clash between science and Christian theology.[3] But is this conflict real, or is it just an artifact of narrow views of science and of theology? After all, given the range of scientific theories and of Biblical interpretations, one cannot rule out that an overlap—which remains true to accepted beliefs in both fields—might exist between some scientific and some Biblical understandings.

Ideally, science seeks a true description of physical reality through study of the observable data of nature. Science can explain the "how" of nature, but not necessarily the "why," and certainly not the "who." Theology seeks a true description of physical and spiritual reality by examining the revealed data of

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1 R. Hooykaas, *Religion and the Rise of Modern Science* (Grand Rapids: William B. Eerdmanns Publishing Co., 1972).

2 Herbert Butterfield, *The Origins of Modern Science: 1300-1800*, revised ed. (New York: Free Press, 1965), pp. 177-78. Also see Steven Weinberg, *Dreams of a Final Theory* (New York: Pantheon Books, 1992) chapter XI "What about God," pp. 241 – 261.

3 Unfortunately, it has become common to discuss the conflict between "science" and "the Bible." These, however, are not parallel categories. Science is a method of studying the data from nature, and theology is a method of studying the data of the Bible. Parallel comparisons, therefore, are "science and theology," or "nature and the Bible," or "scientific data and Biblical data." We will use parallel categories in the rest of this work.

Scripture. Theology concentrates on the "why" and the "who," thereby enhancing our appreciation of the "how."

In spite of these differences, both scientific and theological explanations are based upon similar methodologies.[4] Researchers in each field construct models (hypotheses, theories)[5] that, in competition with other models, run a gauntlet of critical scrutiny and argument. In the end—all things being equal—the model that best explains the data is to be believed until a second model, deemed better at explaining both old and new data, replaces the first.[6] Thus, when accepting a model of reality, one must be concerned with the *process*, as well as the facts, used to reach scientific and theological conclusions.

Scientific and theological rigor, however, is not enough to eliminate controversies between model-makers. Among those who consider the Bible an authoritative revelation from God, the tension between science and theology has resulted in the appearance of a wide spectrum of views on the question of origins.[7] At one end of this spectrum are certain theistic evolutionists who accept whatever consensus on origins there is among scientists, adding only that the God revealed in the Bible is behind it all.[8] At the other end of the spectrum are a few proponents of recent creationism (also called "young-earth creationism") who maintain that the earth is no older than about 10,000 years. In order to rule out any data that seem to point to an older earth or universe, they are ready to make extensive use of the idea that either God created with the appearance of age, or that Noah's Flood—not long-term processes—reworked the earth to its present appearance.[9]

The views of theistic evolution and recent creationism cover a wide spectrum. Not all are so extreme as those above; there are many varieties within these views. Nevertheless, we the authors of this book find that our view falls neither in the theistic evolution nor in the recent creation camp. Rather, we advocate a third, intermediate outlook usually labeled "progressive creationism"[10] or "old-earth creationism." This view differs from theistic evolution by accepting a more active role for God in the creation and maintenance of the world. It differs from recent creationism in accepting the very old ages for the earth

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4 John Warwick Montgomery, "The Theologian's Craft: A Discussion of Theory Formation and Theory Testing in Theology" in his *The Suicide of Christian Theology* (Minneapolis: Bethany Fellowship, Inc., 1970), pp. 267-313. J.P. Moreland, *Christianity and the Nature of Science: A Philosophical Investigation* (Grand Rapids: Baker Book House, 1989).

5 By "model," we mean a theoretical construct whose validity can be tested by observations.

6 Thomas Kuhn, *The Structure of Scientific Revolution*, 3rd ed. (Chicago: University of Chicago Press, 1996).

7 See *Portraits of Creation: Biblical and Scientific Perspectives on the World's Formation*, by Howard J. Van Till, Robert E. Snow, John H. Stek, and Davis A. Young (Grand Rapids: Eerdmanns, 1990). *Three Views on Creation and Evolution*, J.P. Moreland and John Mark Reynolds, gen. eds. (Grand Rapids: Zondervan, 1999).

8 We believe Howard Van Till's view of a "fully gifted creation" falls into this category. See his "Fully Gifted Creation" in *Three Views on Creation and Evolution*, J.P. Moreland and John Mark Reynolds, eds. (Grand Rapids: Zondervan Publishing House), pp. 161 – 247. Responses to Van Till are included in this section of *Three Views*.

9 The classics for this formulation are Alfred M. Rehwinkel, *The Flood*, Revised ed. (St. Louis: Concordia Publishing House, 1957) and John C. Whitcomb, Jr. and Henry M. Morris, *The Genesis Flood: The Biblical Record and its Scientific implications* (Grand Rapids: Baker Book House, 1961).

10 This term was apparently coined by Bernard Ramm. See his *The Christian View of Science and Scripture* (Grand Rapids: William B. Eerdmanns Publishing Co., 1954), pp. 112ff. Also see Moreland, *et al*, *Three Views on Creation*.

and of the universe. We *do affirm* that the Bible is the authoritative, inerrant revelation of God. We *deny* that (l) the scientific models regarding the age of the earth and the of universe must be overthrown to maintain the scientific authority of Scripture, or that (2) the scientific authority of Scripture should be reduced to a few propositions like "God is behind it all," thereby ignoring the Biblical details or considering them unimportant in understanding the process of earth's creation.

In this work we limit ourselves to the origin of the universe and of the earth as narrated in the first four "days" of Genesis. We do not discuss biological evolution, which would be a proper topic for "days" five and six.[11] We first direct the reader's attention to the physical data that form the "old earth" framework for our discussion. We then consider the Biblical data, noting especially the points at which traditional interpretations may or may not be required by the Hebrew text. In the process, we will suggest a model that synthesizes the scientific and the Biblical data into a unified theory of the origin of earth.

We base our synthesis on the assumption that the data of Scripture and of nature are both true. We suggest, however, that the simplest interpretation of either set of data, taken alone, does not give the complete picture, or even a correct picture, of the origin of earth. Leaving out scientific or Biblical evidence is, in our view, an example of applying Ockham's Razor too quickly to an incomplete set of the relevant data. For a complete picture that answers the "how," "why," and "who," we must use data from both nature and the Bible.

Our quest to combine scientific and Scriptural data is similar to that used in solving the problem of the chronology of the Hebrew kings. For many years, secular and Biblical dates for the rulers of Israel and of Judah appeared to be in conflict. Edwin Thiele, however, believed that both archeological and other extra-Biblical data would agree with the Bible's statements on the rule of these kings if all sets of data were interpreted correctly. [12] After much study he proposed a scheme to unify the Biblical and the extra-Biblical data that most accept to this day.

Our model follows in Thiele's footsteps. We are using scientific data rather than archeological and historical records, but the methodology is the same—investigate both sets of data to seek a model that explains the earth's origin better than current models. If such a model is found, then we have a correlation between interpretations of nature and of the Bible that avoids the contradictions commonly imagined between these two. Such a correlation, if valid, will have far-reaching implications for the reliability of the scientific method for investigating prehistory and for the scientific reliability and divine inspiration of Scripture.

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[11] Pattle P. T. Pun, *Evolution: Nature and Scripture in Conflict?* 1982. Revised edition 2002. Available online at: http://www.ibri.org/DVD-1/Books/Pun_Evolution/Pun_Contents.htm. (Accessed 12 September 2007)

[12] Edwin R. Thiele, *The Mysterious Numbers of the Hebrew Kings*, 2nd ed. (Grand Rapids: William B. Eerdmanns Publishing Co., 1965).

PART 1: SCIENCE

Chapter 1: Chronological Evidence from Scientific Data

One of the main points of disagreement between science and Christian theology is when humans, the earth, and the universe came into existence. Thus, our discussion of the scientific data begins with chronology. (We discuss the chronological data of the Bible in chapter four.) As the origin of humans is not relevant to our concern in this book, we shall look only at the scientific data concerning the age of the earth and of the universe. We divide this material into two headings: astronomical evidence and geological evidence.

Astronomical Evidence

Light Travel-Time[13]

One of the simplest arguments for a universe far older than a few thousand years comes from starlight. Light travels outward from its source at a large but finite speed, 186,000 miles per second—or six trillion miles per year. In fact, astronomers use this distance as a unit of measurement, the *light-year*.

The argument

If the universe were only a few thousand years old, we would expect to see no objects more than a few thousand light-years away. But in fact we see objects much farther away. Some stars in our Milky Way galaxy are more than 100,000 light-years away. The nearest large galaxy beyond ours, the Andromeda Galaxy, is about two million light-years off. The farthest galaxies we see using the Hubble Space Telescope are eight to ten billion light-years away. Since the universe is at least as old as the time it takes light to travel from the farthest objects we can see, the universe must be at least eight to ten billion years old.

This argument depends on three assumptions. We need to consider each of these in order to have some feeling for how compelling the argument is. Each assumption is quite natural, and no physical evidence has arisen to doubt any one of them. We examine each in turn.

Assumption #1: constant speed of light

The first assumption is that *the speed of light is constant (or nearly so) throughout space over the history of the universe*. Notice that this supposition does not require that the speed of light be exactly constant, but only that it not be drastically different elsewhere or at a different time in the past. If light travels much faster in other places than it does near us, or if it traveled much faster in the past than it does now, then to be able to see objects 10 billion light-years away in a 10,000 year old universe requires that the speed of light *average* more than a million times faster elsewhere than it does here, or

[13] Adapted, with permission, from "Light-Travel Time: Evidence for an Old Universe" by Robert C. Newman, which is available at http://ibri.org/DVD-4/Tracts/lttmetct.htm. (Accessed 16 June 2007)

that its speed was similarly larger 10,000 years ago. There is no observational evidence for anything of this sort.[14]

Those who suggest the speed of light was faster in the past propose that it was about one thousand times faster early in human history than it is now.[15] But this leads to disaster. According to Einstein's famous equation linking energy to mass, $E = mc^2$ (where m is the mass of an object and c is the speed of light), each quantity of mass produced a million times more energy back then than it does now. (If c is 1000 times greater, then c^2 is one million times greater.) That means that the sun, which depends on Einstein's relationship to generate energy, was one million times brighter early in human history than at present, which, of course, is nonsense since this would have burned up the entire solar system!

To counter this excess energy, those advocating the "fast light speed" scenario propose that the sun's energy output really remained the same as today. Then, however, according to Einstein's equation, the mass of the sun must have been one million times *less* than what it is now in order to counteract the increase in energy output from the alleged higher light speed. But then the sun's gravitational attraction would have decreased by a million times,[16] and all the planets would have escaped the solar system. As for earth, its own gravity would have been reduced to the point that neither humans nor air would have been able to keep from floating into space, and life would have been impossible. This obviously was not the case, so it does not appear that the speed of light has changed in such a way as to avoid an old universe.[17]

Assumption #2: large distances

The second assumption is that *distance measurements to objects that are millions or billions of light-years away are accurate.*

Distances to relatively close astronomical objects are measured by *parallax*. One observes the object from two different locations, and the difference in apparent position of a nearby object with respect to distant objects allows us to calculate its distance. The effect can be illustrated by holding up a finger and looking at it against a wall as background, first with the left eye and then with the right. The finger will appear to jump back and forth against the wall. The apparent shift of the finger against the distant wall illustrates parallax. For stars, the two different locations used are the positions of the earth six months

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[14] In fact, all speed of light measurements show consistency through the age of the universe. See Perry G. Phillips, "A History and Analysis of the 15.7 Light-Year Universe," *Perspectives on Science and Christian Faith* 40 (March, 1988):19-23. Available online at: http://www.asa3.org/asa/PSCF/1988/PSCF3-88Phillips.html. (Accessed 5 May 2007)

[15] T. Norman and B. Setterfield, *The Atomic Constants, Light, and Time*, 1987. Flinders University of South Australia, School of Mathematical Sciences, Technical Report. Available online at: http://www.ldolphin.org/setterfield/report.html. (Accessed 12 September 2007)

[16] Gravitational attraction depends directly on the mass.

[17] Robert C. Newman discusses the changing light speed proposal in "An Ancient Historical Test of the Setterfield- Norman Hypothesis," *Creation Research Society Quarterly* 28 (Sept 91): 77-78.

apart (on opposite sides of its orbit). Parallaxes even for close stars are very small, a few ten thousandths of a degree. The distances of stars out to about 300 light-years can be measured by this technique.[18]

Distances to stars farther away are estimated by using the physical characteristics of stars within 300 light-years of earth. Most nearby stars belong to a grouping called the "main sequence." Main sequence stars shine by fusing hydrogen into helium in such a way that there is a simple relationship between surface temperature (star color) and brightness. All things being equal, blue stars—which are hotter—are more luminous than red stars, which are cooler. Suppose now that a very distant star is observed to have exactly the same color as a nearby star. If the distant star is a main sequence star, which an astronomer can easily determine, we can assume that its luminosity is the same as that of the nearby star. Comparing the brightness of the distant star to that of the nearby star allows one to calculate its distance.[19]

Main sequence stars can be used to measure distances from less than 300 light-years out to a few hundred thousand light-years.[20] Our galaxy contains millions of stars that are hundreds of thousands of light years away, thereby indicating that the galaxy is at least a few hundred thousand years old.

For greater distances, variable stars are ready-made distance indicators. Cepheid variables—one class of these stars—vary in brightness with regular periods. They have a peculiar property: Cepheids that vary their brightness slowly are more luminous than those that change brightness quickly. Thus, by observing the period of a distant Cepheid, one can determine its luminosity. As with main sequence stars, one can compare the actual brightness of a Cepheid to its apparent brightness to determine the star's distance. Cepheid variables can be used to measure distances out to some 10 million light-years.

Astronomers use other methods, which we will not discuss here, to measure distances out to hundreds of millions and even to billions of light years.[21] Since the universe is at least as old as the time it takes light to reach us, we find that the universe is billions of years old.

Assumption #3: real sources

The third assumption is that *the light we see when we observe objects in the heavens actually came from those objects*. That is, the universe is not the trick of a cosmic magician using smoke and mirrors to fool us into seeing something that is not really there. When we look at a galaxy, which appears to be hundreds of millions of light years away, we are gazing upon a real object. The galaxy is not just an

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18 The Hipparcos satellite, not hindered from the blurring of the earth's atmosphere, gave parallax measurements accurate to about 800 light years.

19 For the curious, an inverse-square relationship exists between brightness and distance. Suppose star A and star B are exactly alike, which means they have the same color and luminosity. Suppose further that star B is twice as far away as star A. Then star B will appear *four times* dimmer. If star B is three times farther away, it will appear *nine times* dimmer, and so on.

20 The Hubble Space Telescope has increased this distance to a couple million light-years.

21 Any introductory astronomy text discusses how distances are measured in the universe. Also see chapter three, "Observational Cosmology," in Joseph Silk, *The Big Bang*, 3rd ed. (New York: W. H. Freeman, 2001). For those well-versed in physics and mathematics, we refer the interested reader to the classic by Michael Rowan-Robinson, *The Cosmological Distance Ladder* (New York: W. H. Freeman Co., 1985) and to Stephen Webb's *Measuring the Universe: The Cosmological Distance Ladder* (Berlin, Heidelberg, New York: Springer Praxis Books/Space Exploration [Paperback], 1999).

illusory image of (say) our own Milky Way whose light has bounced from one celestial mirror to another to dupe us into thinking that we are observing another galaxy.

These, then, are the three basic assumptions with which astronomers have been able to measure the span of the heavens. That so much useful information arises from such simple propositions is truly breathtaking.

Young-earth responses

The commonest attempt to avoid these arguments is to claim that the light detected from very distant objects did not originate from them. These objects do exist at the measured distances, and God wants us to know of their presence to show us his glory. But if the light originated from them, it would take much more than 10,000 years to reach us. Since we observe these objects now and don't have to wait billions of years, it must be that God, when he created the objects, simultaneously created their light spanning the intervening space.

This suggestion, however, raises a serious problem—is God's revelation through nature true? Let us assume that the cosmos is only 10,000 years old. Now consider this: when we look at our sun, we see what was happening (surface appearance, rotation rate, sunspots, flares, etc.) about 8 minutes ago when the light left the sun.[22] When we look at the next nearest star, Alpha Proxima, we see what was happening about four years ago when the light left that star. For a star 8,000 light-years away, we see what it was doing 8,000 years ago. But when we observe a star (say) 12,000 light-years away, we do not see what it was doing 12,000 years ago because the star did not exist. Instead we see what it *would* have been doing *if* it had existed. As such, we are being given fictitious history! (We are not just dealing with "appearance of age"; rather, we are viewing a full, complex history of events that never occurred.)

And false history is not what we deduce for just a few objects. On the contrary, we must conclude that the overwhelming majority of stars and star-clusters in our galaxy, and galaxies and galaxy-clusters in the universe, are displaying false history. To such extremes are we led if we are determined to interpret the Bible as teaching a young earth in spite of evidence to the contrary that God has provided us in nature!

In harmonizing the revelation God has provided us in his word and his universe, it seems much preferable to expend our effort on models that avoid fictitious history!

Expansion of the Universe

Another line of evidence for a very old universe comes from the rapid movement of distant galaxies away from us. In the 1920s, Edwin Hubble extended earlier work by Vesto M. Slipher, who was the first to observe the recession of galaxies. Hubble—for whom the Hubble Space Telescope was named—turned the newly-built telescope at Mt. Wilson (and later, that at Mt. Palomar) toward the so-called "island universes," which today we call galaxies.

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[22] The sun is about 93 million miles away, so it takes its light a little over eight minutes to reach us. We say that the sun's distance is about eight light-minutes from us.

Hubble confirmed Slipher's observation that light emitted by various elements in distant galaxies appeared redder than light emitted from the same elements in an earthbound laboratory.[23] Hubble also determined that the redshift is progressive: the greater the distance, the greater the redshift. In fact, the relationship is linear. That is, doubling the distance doubles the redshift; tripling the distance triples the redshift, etc. This relationship between a galaxy's distance and its redshift is now known as "Hubble's Law."[24]

The simplest explanation for Hubble's Law is that the universe is expanding. As such, the space between the galaxies is increasing, thereby "stretching" the light emitted by the galaxies towards longer wavelengths to produce the redshift. But why, in an expanding universe, should more distant galaxies move away from us at faster speeds?

The time-honored analogy to explain this effect is the "raisin-cake" model. Suppose we bake a raisin cake and that the dough—for simplicity—forms a cube six inches on a side.[25] Let the dough contain randomly dispersed raisins. Just before baking we measure the distance between one pair of raisins, say A & B, as two inches, and the distance between raisin-pair C & D as eight inches. We now bake the cake and watch the rate at which the raisins in each pair separate.

The baking, of course, increases the size of the cake, and for this analogy we assume that the cake rises by a factor of two. After an hour the baking is complete, and the raisin cake is now 12 inches on a side. Since the cake has expanded by a factor of two, so has the distance between our raisin pairs. Raisins A & B increased their separation from two to four inches, and raisins C & D went from an eight to a 16-inch separation. To calculate the speed at which each raisin in a pair receded from its partner, all we need to do is find the distance through which the raisins traveled and divide by the time of travel, which is one hour. The distance between raisins A & B increased by two inches, so their recession speed was two inches per hour. Raisins C & D, on the other hand, increased their separation by eight inches in the same time, so their recession speed was eight inches per hour.

To connect our analogy with the universe, think of the raisins as galaxies and of the dough as the space between them. As the intervening space expands, it carries the galaxies along with it, just as the expanding dough carries the raisins. Further, just as the more distant raisins separate faster than the

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[23] A spectrum of the light from a galaxy can be analyzed by an instrument called a *spectrograph*. A spectrograph breaks down the light into its component colors, much the same way that raindrops (or prisms) break up sunlight into the colors of the rainbow. Since red light has a longer wavelength than blue light, astronomers refer to the shifting of the galaxy's light towards longer wavelengths as a "redshift."

[24] Hubble's Law gives rise to Hubble's Constant, which is a measure of how fast distant galaxies are receding. Astronomers calculate Hubble's Constant to be about 72 kilometers/second/megaparsec, which to lay persons means nothing. Mathematically, this value is roughly 16 miles/second/million light years. That is, on average, each increase in distance from earth by one million light years increases the recession speed by 16 miles/second. Note, however, that Hubble's Law comes into effect for distances greater than 250 million light years.

[25] We realize that bakers do not bake cakes that are cubical, but bear with us. After all, this is only an analogy to explain Hubble's Law. (This is what happens when you let astronomers in the kitchen!)

closer ones, so in our universe the more distant galaxies separate more quickly. In fact, some galaxies are so far away that they are receding from us at nearly the speed of light![26]

Our analogy explains Hubble's Law, but how does this help us derive an age for the universe? If one takes the simplest explanation—that the universe is expanding at pretty much a steady rate—then running the expansion backward in time places all of the galaxies (and everything else) together at some time in the past. Astronomers consider this time as the "creation" of the universe. Using the most accurate figures available for the expansion rate of the universe, we find that the elapsed time since its creation, at the so-called "Big Bang," is about 14 billion years. [27]

Proponents of a young universe, naturally, reject this scenario. Their responses include: (1) the expansion never started from the Big Bang but rather from some more expanded configuration only a few thousand years ago; (2) the redshift is not related to the expansion of the universe; (3) a cosmic slowdown in time allows for creation of the universe some 10,000 years ago, though on earth it will appear as though billions of years have gone by.[28]

All these alternatives lack evidence, amounting to no more than *ad hoc* explanations for the redshift feature of Big Bang cosmology. But the observed redshift is not the only evidence for the Big Bang. Additional evidence includes the following *predicted* and *observed* phenomena: (1) the cosmic background radiation; (2) the abundances of deuterium and helium compared to regular hydrogen; (3) the existence of only three different kinds of neutrinos; (4) the acoustic waves in the cosmic background

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[26] It is common knowledge that nothing can travel faster than the speed of light, so some might question this statement. Keep in mind, however, that the restriction of travel to speeds slower than the speed of light holds for objects traveling *through space*, not for *space itself* expanding faster than the speed of light and carrying galaxies along with it. There is no contradiction here.

[27] Hubble's constant gives the so-called Hubble age of the universe. We realize that other factors besides the present value of Hubble's constant have to be taken into account to determine a more accurate age for the universe. These factors include the universe's density and curvature, and the presence of dark matter and dark energy. Including these factors still gives a universe that is billions of years old. See Barbara Ryden, *Introduction to Cosmology* (San Francisco: Addison Wesley, 2003), pp. 82 – 99.

[28] The hypothesis for a cosmic time slowdown has been advanced by D. Russell Humphreys, *Starlight and Time: Solving the Puzzle of distant Starlight in a Young Universe* (Colorado Springs: Master Books, 1994). His arguments have been thoroughly refuted, albeit he refuses to acknowledge this. Readers can follow the exchange between Humphreys and his critics and decide for themselves: Phillips, P. G., "D. Russell Humphreys's Cosmology and the 'Timothy Test'." *Creation Ex Nihilo Technical Journal*, 11 (part 2, 1997):189 - 194. Sarfati, J. D., "D. Russell Humphreys's Cosmology and the 'Timothy Test' A Reply." *Creation Ex Nihilo Technical Journal*, 11 (part 2, 1997):195 - 198. D. R. Humphreys, "Timothy Tests Theistic Evolutionism," *Creation Ex Nihilo Technical Journal*, 11 (part 2, 1997):199 - 201. For a rejoinder to the last two articles, see P. G. Phillips, "Rejoinder to Humphreys and Sarfati Responses," at http://www.ibri.org/DVD-1/Papers/Timothy_Test/Timtest_Rejoinder.htm. (Accessed 16 June 2007) Conner, S.R. and Page, D. N., 1998 "Starlight and time is the Big Bang." *Creation Ex Nihilo Technical Journal*, 12(2):174-194. Also see the rebuttal by Samuel R. Conner and Hugh Ross, "The Unraveling of Starlight and Time," http://www.reasons.org/resources/apologetics/unraveling.shtml. (Accessed 16 June 2007) Humphreys has a list of articles that challenge his thesis, along with some gratuitous responses, at http://www.trueorigin.org/ca_rh_03.asp. (Accessed 16 June 2007)

radiation arising from inflation of the cosmos; and (5) the polarization of the cosmic background microwave radiation.[29]

The Big Bang explanation for the creation of the universe has enormous observational support. Moreover, it points to a universe with a beginning, which of all world religions, Christianity alone claims as an essential feature of the cosmos.[30] The parallel between Big Bang cosmology and Genesis 1.1 could not be more striking!

Stellar Structure

So far, our estimates of age based on astronomical data have involved simple calculations in which the major factor is the speed of light and the expansion rate of the universe. Now, however, we turn to more complex details involving physical processes inside stars. The structure and the lifespan of stars serve as clear indicators of an old cosmos. But first we must describe the physical makeup and life-cycle of stars to see how they serve as age indicators. This is somewhat involved, so we ask the reader to be patient.

What is a star?

Stars are far simpler in structure than planets. They have no solid core, no rocks, no mountains, and no seas. A star is basically an enormous ball of very hot, dense gas held together by its own gravity. The outward pressure from the hot gas counterbalances the inward pull of gravity. The outward pressure depends strongly on heat sources within the star. This heat is generated primarily from energy liberated as hydrogen fuses into helium within the star's core.

This sounds simple enough, but calculations as to what exactly is happening are complicated by the fact that stars also contain small quantities of elements heavier than their main constituents—hydrogen and helium. These other elements influence the star's rate of fusion and energy transport from the core to the surface. Further, the structure of a star depends drastically on other factors, such as what nuclear processes are occurring within its core, whether the heat is carried to the surface by radiation or by gas flow (convection), the degree of transparency of various layers within the star (opacity), and whether stellar rotation and magnetism are significant.

In spite of such complications, high-speed computers allow detailed calculations of both the structure and the changes in stars under a wide variety of circumstances. We now know that stars —like people— are born, spend most of their lives as adults, and eventually die. Mathematically and observationally, we can trace the life-cycles of stars from birth through adulthood, and finally to their death as white dwarfs, neutron stars, or black holes.

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[29] Expanding on each of these items is beyond the scope of this book. We strongly contend that *only* the inflationary Big Bang theory gives rise to all of these phenomena as natural outcomes. We encourage the interested reader to examine the evidence presented by Perry G. Phillips in "The Thrice Supported Big Bang," *Perspectives on Science and Christian Faith*, vol. 57, no. 2 (June, 2005), pp. 82 – 96. The annotated bibliography in this article will point the reader to further discussions of the Big Bang. Available online at: http://www.asa3.org/aSA/PSCF/2005/PSCF6-05Phillips.pdf. (Accessed 12 September 2007)

[30] "Genesis 1:1 & Big Bang Cosmology" in *The Frontiers of Science & Faith: Examining Questions from the Big Bang to the End of the Universe*, by John Jefferson Davis (Downers Grove, IL: InterVarsity Press, 2002), pp. 11-36.

Stellar birth

It appears that stars are born in the large gas and dust clouds common in our galaxy, since newly formed stars are invariably associated with such clouds.[31] A star's birth is initiated when a cloud begins to contract because of gravitational attraction within the cloud. A cloud about one light-year across with a very low temperature (- 370 ^{o}F) gradually contracts to a sun-sized star (about a million miles in diameter) with a surface temperature of a few thousand degrees (several million degrees at the center). During this phase, the main heat source of the star is the gravitational energy provided by the contraction itself. This phase lasts a few millions years. (We will have more to say about star-birth and the formation of planets in chapter 3.)

Stellar adulthood

Next, when the temperature at the center of the star reaches several tens of millions of degrees, a fusion reaction—similar to what happens in an exploding hydrogen bomb—begins in the core. Fusion changes hydrogen into helium. This reaction is a powerful source of heat, and the hot gases in the core quickly build up enough pressure to stop the gravitational contraction. This outward pressure will continue to oppose gravity so long as the core contains enough hydrogen to sustain fusion. Once fusion has begun, the star enters its so-called *main sequence* phase, where it will spend most of its lifetime in a perfect balance between the inward pull of gravity and the outward push of gas pressure.

At the rate our sun uses up hydrogen, it should last about 10 billion years as a main sequence star. But stars differ in mass. Some are 50 times more massive than the sun; others are only a few percent as massive.[32] Surprisingly, massive stars, though they have far more fuel, don't last nearly as long as less massive ones. The reason? The stronger gravity of massive stars increases the interior temperature, and hydrogen will fuse into helium at a prodigious rate with just a slight increase in temperature. The result is that a massive star consumes its hydrogen in just a few million years. Less massive stars, on the other hand, have cooler core temperatures, so their hydrogen burns much more slowly. Some of these "light-weight" stars can remain on the main sequence for a hundred billion years.

Advanced adulthood

In time, a star exhausts the hydrogen in its core. This hydrogen has been converted into helium. Since helium requires a far greater temperature than hydrogen to fuse into heavier elements, nuclear reactions cease, and the outward pressure within the star diminishes.[33] Since internal pressure can no longer counterbalance the gravitational force, the star begins to contract.

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[31] Just as we conclude that babies are born primarily in hospitals by observing the association between a great number of newborns and hospitals, so we conclude stars are born in large gas and dust clouds by observing a similar association between a great number of newly-formed stars and the clouds.

[32] There are upper and lower limits to the mass of a star. Stars greater than 100 solar masses produce so much energy that they blow themselves apart. Stars less massive than about 2% of the sun's mass are too cool to fuse hydrogen to helium. These stars are called "brown dwarfs."

[33] Hydrogen has a positive charge in its nucleus. Like charges repel, so it takes a certain amount of energy to push two hydrogen nuclei together close enough for them to fuse. Helium requires more energy to fuse because a helium nucleus has

This contraction heats up the interior of the star, but initially the core temperature does not rise enough to start helium fusion. Instead, a shell of hydrogen just outside of and in contact with the core becomes hot enough to ignite. This shell produces a large amount of energy, more than enough to balance gravity. The outward pressure increases drastically, and the star—except for its core—expands beyond its original size. The result is a star that is less dense and cooler at its surface. This is the so-called red giant phase. If our sun were to become a red giant, its outer surface would almost reach the earth, turning earth into a cinder and consuming its sister planets Mercury and Venus.

Eventually, the continued contraction of the core and the heat poured into it by the burning hydrogen shell raise the core temperature to several hundred million degrees. Then the helium in the core begins to fuse into carbon. This reaction stops the core from further collapse, but helium-carbon fusion produces less energy than fusion of hydrogen to helium and does not last as long as the main sequence phase. For a star like our sun, the red giant phase lasts about a billion years, only one-tenth the time our sun would spend on the main sequence.

Stellar demise

After the red giant phase a star begins to "die," although not immediately. For stars more massive than the sun, there is a brief period in which the carbon in the core fuses to successively heavier elements, but all this activity is merely the death throes of a star far past its prime.

Depending on its mass, a star's death may be violent or relatively quiet. Some stars pass through periods in which they fluctuate in brightness; others explode. Regardless, when the stellar fuel is exhausted, the relentless force of gravity begins to squeeze the star into a smaller and smaller volume.

Stars with masses no more than 1.4 times that of the sun gradually contract into white dwarfs, which are very hot, small stars. A typical white dwarf has the mass of the sun, but its diameter has shrunk from about a million miles to only about 12,000 miles, becoming an object slightly larger than earth. Since the mass of the white dwarf is about that of the sun, its density is enormous—a cubic inch weighs several tons! In the course of trillions of years, the white dwarf slowly cools off and ceases to radiate, becoming a black dwarf.

Stars with masses greater than 1.4 times the sun's die catastrophically, but they leave exotic objects behind. If the star is between 1.4 and 8 solar masses, it forms a neutron star instead of a white dwarf. In this case, the force of gravity is so strong that the electrons and the protons combine to form neutrons, which take up much less space than electrons and protons. The resulting star is less than 20 miles in diameter and weighs millions of tons per cubic inch!

Still more massive stars leave black holes behind. Gravity is so strong near a black hole that space itself is bent to form a kind of closed container from which not even light can escape! Black holes themselves are invisible, but their presence is detected by radiation given off when other objects have the misfortune of being torn apart when they come into contact with them. Many such events have been observed.

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two positive charges, and this increases the repulsion between them four-fold compared to hydrogen. Only by heating the core to a couple hundred million degrees can helium fuse into heavier elements.

Stellar life-cycles and age

By now you may be wondering, "What does all this have to do with the age of the universe?" We are finally ready to answer that question. This has a great deal to do with age, because *observations substantiate our theories about stars, and this includes their great age*! To show how this is the case, we first refer to a Hertzsprung-Russell diagram (or H-R diagram for short), named after the two astronomers who independently devised this method of cataloging stars. (Figure 1)

Figure 1 shows a graph of absolute luminosity (intrinsic brightness) and surface temperature for the brightest stars near the sun.[34] Notice that the stars fall into three basic groups. Those along the line bending through the middle of the diagram are the main sequence, into which the vast majority of stars fall. The second group (upper right) encompasses red giants, while white dwarfs form the third group at the lower left.

If we could follow the life cycle of a star like the sun, we would see it begin on the main sequence.[35] In about 10 billion years it would move to the area of the red giants, and a billion years after that it would join the white dwarfs. As such, the position of a star on the H-R diagram indicates how far along it has progressed in its life cycle. This, when compared to theoretical calculations, indicates its age. Such a comparison for the sun puts its age at five billion years.

The accuracy of age calculations can be significantly improved if we use star clusters rather than individual stars. Stars in a cluster are pretty much the same distance from us, and there are good theoretical and observational reasons to believe that they formed at the same time out of the same material. In short, cluster stars are like fraternal twins—they have many things in common because they were born at the same time, at the same place, from the same parent cloud. Using cluster stars, therefore, reduces the number of variables that can make randomly chosen stars differ from one another.

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[34] For historical reasons, astronomers define absolute luminosity as the apparent brightness of a star if it were 32.6 light-years away. Absolute luminosity can be calculated from a star's apparent brightness and its distance; one simply makes use of the inverse-square law discussed earlier (footnote 19). Absolute luminosity is very important; when we observe a faint star, we must know whether the star is intrinsically dim, or whether it is really bright, but at such a great distance that it appears faint. Placing stars at the same distance neutralizes the distance factor. The absolute luminosity of stars is given in terms of the sun's luminosity and in *magnitudes*, but unlike usual scales of measurement, the magnitude of a star is *smaller* the *brighter* it is. That is, a star of magnitude 5 is *brighter* than a star of magnitude 10. Magnitudes include the number zero and negative numbers as well. Astronomers customarily work in magnitudes, but scientists from other fields have been known to mutter obscenities when trying to correlate their own data to magnitudes.

[35] For this discussion, we ignore the relatively short time it takes for the sun to form from a cloud and collapse to the main sequence.

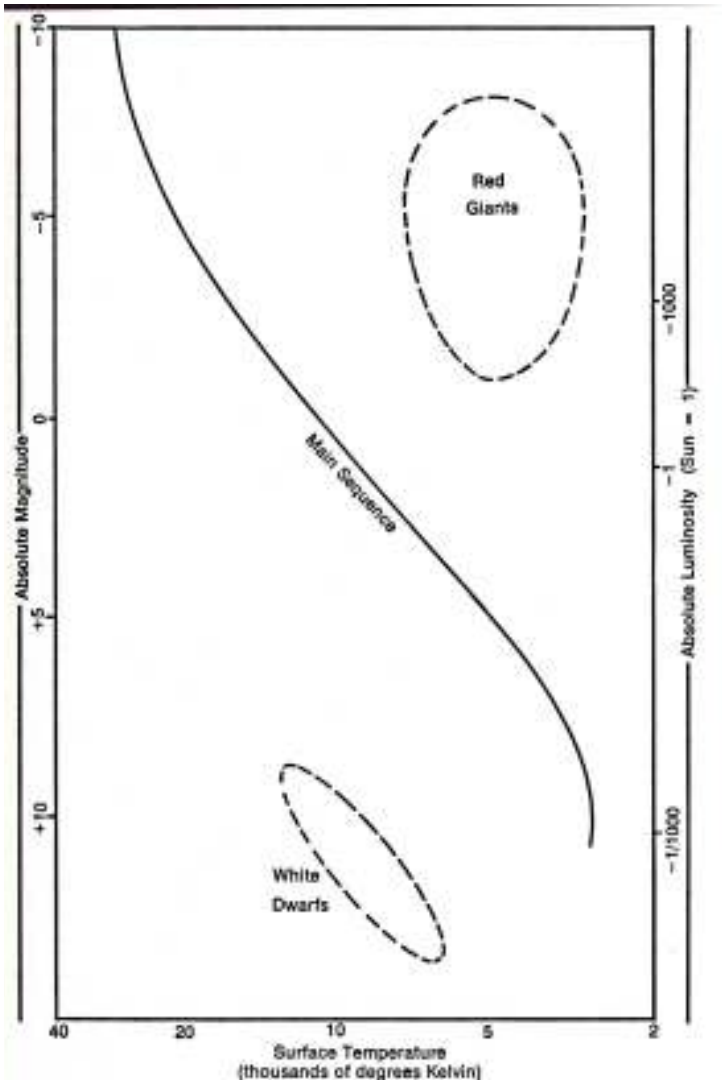

Figure 1: H-R diagram of brightest stars near the sun.
Adapted from Robert Jastrow and Malcolm H. Thompson, Astronomy: Fundamentals and Frontiers, 2nd ed. (New York: John Wiley and Sons, 1974), p. 129.[36]

Star clusters and age

Cluster stars begin their lives at the same time and have the same chemical composition, but they differ widely in their masses. It turns out that a star's mass and its chemical composition are the determining factors controlling its life-cycle, so it follows that differences in appearance between stars in the same cluster result from mass differences and not from variations in their initial conditions. Thus, we basically

[36] For a nice tutorial on the H-R diagram, see http://casswww.ucsd.edu/public/tutorial/HR.html. A deeper discussion is found at: http://en.wikipedia.org/wiki/Hertzsprung-Russell_diagram. (Both sites accessed 12 September 2007)

limit the variables affecting age to one—mass—thereby greatly simplifying calculations that simulate the appearance of a cluster.

As mentioned earlier, massive stars run through their life-cycles far more quickly than less massive ones. For example, a star twice as massive as our sun completes its life-cycle about ten times faster than the sun, and a star ten times the mass of the sun runs through its life 20,000 times faster. Hence, we expect to see more massive cluster stars further along in their life-cycles than their less massive siblings.

To understand how to determine the age of a cluster, consider stars that have just begun to fuse their hydrogen into helium. They lie totally along the main sequence and are said to have "zero age."[37] In fact, we call the line delineated by such stars the "zero-age main sequence."

Since more massive main sequence stars live proportionately shorter lives, they are first in the cluster to become the red giants. These stars originally appear in the upper part of the main sequence, but as they age, their position on the H-R diagram shifts towards the right. (Figure 2) The net effect of age, therefore, is to turn the upper main sequence towards the red giant region, starting from the top and moving towards the bottom as the age of the cluster increases. This turn-off point is distinct, and *the lower down the turn-off occurs, the older the cluster*. To establish the age of a cluster, therefore, one compares the observed cluster with the best theoretical model whose age simulates the cluster's main sequence and turn-off point.

For example, if we apply this technique to cluster NGC 2362, we discover it is about 5 million years old. The corresponding age for the Pleiades is 200 million years. Cluster M67, which has lost a considerable number of upper main sequence stars, is about seven billion years old. The oldest clusters we can observe (not shown in figure 2) reach ages close to 13 billion years, which is just under the age of the universe inferred from Hubble's Law. Old clusters, therefore, were among the first objects formed after the Big Bang.

Assumptions used to date clusters

This chronological method using star clusters is called "main sequence fitting." It depends on several assumptions: (l) The observed physical laws hold throughout the nearby universe over its entire history; (2) our understanding of these laws is adequate for the required calculations; and (3) the stars were not created instantaneously somewhere in the midst of their life-cycles.

The first assumption is basically a uniformity principle, and though it cannot be proved, it is consistent with the vast majority of observations. Opponents of this principle, in order to get a hearing in scientific circles, need to propose an alternative postulate that demonstrably explains a comparable amount of data. So far, they have failed miserably.

[37] The time it takes for a star to collapse from a gas cloud to the point where it begins to burn hydrogen is minuscule compared to the length of time it spends on the main sequence. That is why we can ignore collapse times and speak of stars as having "zero age" when they first arrive on the main sequence.

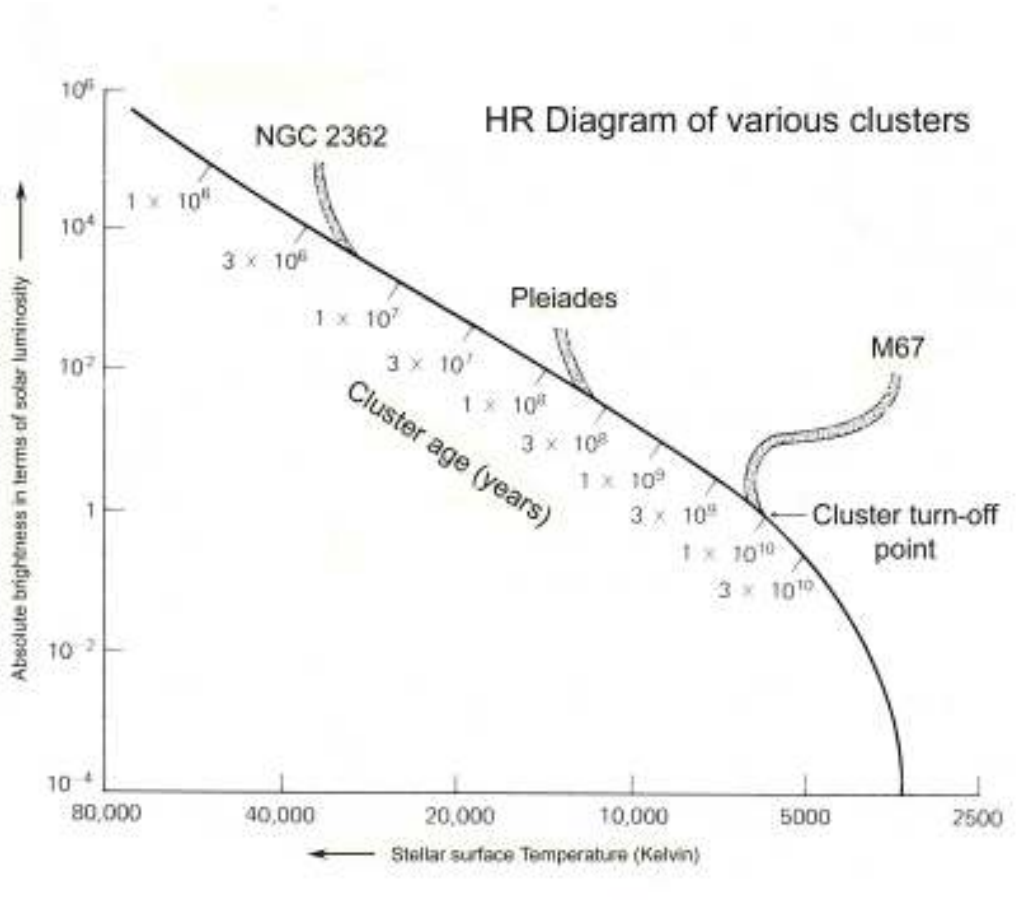

Figure 2: Sketch of the H-R diagram for three star clusters.
The numbers on the main sequence indicate the cluster's age at "turn-off" toward the red giant region. The cluster ages are approximately 5 million, 200 million, and 7 billion years, respectively. Adapted from William H. Jefferys and R. Robert Robbins, Discovering Astronomy (New York: John Wiley and Sons, 1981), p. 307.

The second assumption is also difficult to test. Much work can be done in laboratories on earth to understand the behavior of stars, but it is not possible to match all the physical conditions relevant to stars. A great deal depends on computer simulations of stellar conditions. Astronomers, however, track millions of stars, and these provide ample input data and checks on theoretical calculations. So far, agreement between theory and observation is excellent!

The third assumption, likewise, cannot be checked directly. Those who believe that the Genesis account requires a universe only a few thousand years old will naturally assume that observed stars were created instantaneously in various stages of their life-cycles. This view, however, resurrects the problem of "creation with apparent age" and leads to fictitious history.

We reject apparent age in this context for the same reasons we mentioned before, but we will revisit this problem in connection with Biblical evidence regarding chronology. At this point we merely note that in light of evidence that star formation is still happening, it does not appear that all stars were formed at the same time a few thousand years ago.

Summary of Astronomical Evidence

We have discussed three methods for gathering and interpreting astronomical evidences of age. Each method depends on somewhat different assumptions, and each gives ages for different events; yet they all reveal a very old cosmos. First, the light travel-time method is based on the fact that the universe is at least as old as the time necessary for light to reach us from distant objects. Presently, the Hubble Space Telescope has imaged galaxies that are 8–10 billion light years away, so the universe is at least 8–10 billion years old. It will probably be only a matter of time before Hubble (or another telescope) is able to image even more distant objects, thereby extending the measurements of light travel time beyond 10 billion years.

Second, the redshifted spectra of galaxies reveal that the universe is expanding. This observation points to a universe created a finite time in the past in a very compact condition. The best measurements of the Hubble constant point to creation some 14 billion years ago.

Third, studies of the structure and the evolution of stars enable us to compute the ages of individual stars and of star clusters. This method gives an age for the oldest star clusters consistent with results of the previous two methods. The oldest observable clusters have an age of about 13 billion years.

Briefly then, according to the methods discussed above, the universe is about 14 billion years old, and the sun is about 5 billion years old. In the next section we will "come back to earth" and find that its age is about 4.6 billion years old.

Geological Evidence

Geology provides excellent scientific evidence for the age of the earth. For convenience, we shall divide this evidence into radioactive and non-radioactive.

Radioactive evidence[38]

Eighty-four chemical elements occur naturally on earth. An element is an atom of a specific type. An atom has a positively charged nucleus surrounded by a cloud of negatively charged electrons. The nucleus consists of protons and neutrons. The protons carry a positive charge, and their number determines which element that atom belongs to. The neutrons are neutral particles slightly more massive than protons. They protect the nucleus from disintegration by providing attraction to overcome the repulsion of the protons' positive charges.

Most elements have more than one *isotope* (from the Greek, "same kind"). Atoms of isotopes have the same number of protons but a differing number of neutrons. Out of the 339 isotopes found in nature, 269

[38] For a concise review of radiometric dating, see the three articles by Davis A. Young, "How Old is it? How Do We Know? A Review of dating Methods—Part One: Relative Dating, Absolute Dating, and Non-radiometric Dating Methods," *Perspectives on Science and Christian Faith* 58 (no. 4, December, 2006): 259-266; "How Old is it? How Do We Know? A Review of dating Methods—Part Two: Radiometric Dating, Mineral, Isochron and Concordia Methods," *Perspectives on Science and Christian Faith* 59 (no. 1, March, 2007): 28-36; "How Old is it? How Do We Know? A Review of dating Methods—Part Three: Thermochronometry, Cosmogenic Isotopes, and Theological Implications," *Perspectives on Science and Christian Faith* 59 (no. 2, June, 2007): 136-142.

are stable and 70 are radioactive, meaning that the latter can spontaneously change into an isotope of another element.[39]

A radioactive nucleus, or *parent*, can decay into a stable *daughter* by: (1) emitting an electron—also called "beta decay"—which converts a neutron into a proton; (2) capturing an electron—known as "electron capture"—whereby a proton changes into a neutron; or (3) shedding an alpha particle—a helium nucleus consisting of two protons and two neutrons. In each of these three cases the number of protons in the nucleus changes; thus, radioactivity transforms one element into another.

Physicists understand the process of radioactive decay rather well, and they can use this knowledge to establish the age of a sample. Basically, the method of radioactive dating depends upon two main facts: (1) the number of decays of a radioactive element is proportional to the amount of the parent in the sample to be dated; and (2) the rate of decay is constant over very long periods of time.[40]

To determine the age of a sample, we need to compare the present amount of parent to the original amount when the sample was formed. Clearly, the older the sample, the less parent will remain. It turns out that a simple relationship exists between the amount of remaining parent and the age of the sample. To see this, let P_0 be the original amount of parent. Then the equation that gives the amount of remaining parent element, P_t, after time t is:

$$P_t = P_0(1/2)^{-t/T_{1/2}}$$

where $-t/T_{1/2}$ is the exponent of the fraction (1/2). $T_{1/2}$ is the familiar *half-life* of the element; this is the amount of time it takes for one-half of the parent to disappear through radioactivity. If P_t, P_0, and $T_{1/2}$ are known for a given element in a sample, the elapsed time t— the age of the sample—can be computed.[41]

The half-life for any isotope depends upon its decay rate, and since decay rates are constant, so are half-lives. These half-lives can be accurately measured in the lab.[42] The table below gives the half-lives of the eight most useful isotopes for determining the age of the earth.

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39 G. Brent Dalrymple, *The Age of the Earth* (Stanford: Stanford Univ. Press, 1991), p. 80.

40 We will deal with objections to radioactive dating later.

41 For the mathematically inclined, the decay equation can be rearranged to give the time t directly as $t = 1.44T_{1/2}\ln(P_t/P_0)$. In this form one can compute t directly from the other three quantities.

42 See below under *Objection #2* for details on how this is done.

Table 1. Half-Lives of Commonly Used Isotopes in Radioactive Dating[43]

Radioactive Parent	Stable Daughter	Half-life (Ma)*	Mode of Decay
Potassium-40	Argon-40	1,250	Electron capture
Rubidium-87	Strontium-87	48,800	Beta decay
Samarium-147	Neodymium-143	106, 000	Alpha decay
Lutetium-176	Hafnium-176	35,900	Beta decay
Rhenium-187	Osmium-187	43,000	Beta decay
Thorium-232	Lead-208	14,000	Various intermediates
Uranium-235	Lead-207	704	Various intermediates
Uranium-238	Lead-206	4,470	Various intermediates

* "Ma" stands for *mega-annum*, or millions of years.

Since the parent is radioactive, the amount of parent element P_t is easily determined by measuring the intensity of the radiation it gives off. The age of the sample, however, also depends upon the original amount P_0. How does one determine this quantity? This is where the daughter element comes in. The amount of daughter equals the amount of parent that has decayed, which means that $P_0 = P_t + D_t$, where D_t is the amount of daughter element in the sample after time t has elapsed.

Several questions, however, suggest themselves: How do we know that the amount of daughter element has come solely from decay of the parent and has not been added or subtracted by chemical means over the course of a sample's history? And how can we be sure that some of the parent element has not leached into or out of the sample? These are very important questions because the addition or the subtraction of daughter or parent will distort the age measurement.

Unfortunately, no single answer to either of these questions works for all isotopes. Each dating method has its own peculiarities, along with its advantages and disadvantages, which we briefly discuss below.

Potassium/Argon (K/Ar)

The K/Ar method works particularly well for igneous rocks—those rocks that were once molten. Argon is an inert gas; it does not form compounds with other elements. As a gas, it easily escapes from molten rock, just as the fizz escapes from an open soda can. Once the rock solidifies, though, the argon produced by its radioactive parent remains imprisoned in the rock's mineral structure and can be

[43] From Dalrymple, *Age of the Earth*, p. 80. The number following the name of the isotope is the so-called *mass number*, which is the number of protons plus the number of neutrons. Physicists use the mass number to delineate isotopes.

measured in the lab. Because of these properties, the K/Ar method is the only scheme in which one does not have to worry much about the presence of initial daughter element.[44]

Potassium-40, unlike its daughter, is a large atom with strong affinity for other elements, so it remains locked in its crystal structure from the beginning. Hence, a subsequent change in the amount of K-40 is not an issue.

The K/Ar method is the most used of all dating techniques. Since K-40 is found almost everywhere, ample supplies of material to date exist throughout the earth. In addition, the half-life of K-40 is 1.25 billion years, which means that enough K-40 can decay in as little as 50,000 years to give measurable quantities of Ar-40. This method is also used to date rocks as old as the solar system, or about 4.6 billion years. The K/Ar method, therefore, enjoys a wide range of applicability.

Rubidium/Strontium (Rb / Sr)

Strontium, the daughter element in this decay process, does not readily migrate through molten rock as argon does, so initial amounts of Sr-87 are often present at a rock's birth. Nevertheless, this does not disqualify Rb/Sr as a valid dating tool.[45] Actually, the relative immobility of Sr has been an advantage to geologists, for this enables them to use the Rb/Sr method on a wider variety of rocks than permitted by K/Ar.

Rb-87 has a very long half-life of 48.8 billion years and so must be used for rocks older than 50 –100 million years. Younger rocks do not have time to accumulate measurable amounts of Sr-87 for accurate dating. Like potassium, rubidium remains locked in a rock once it has solidified.

As noted above, Sr-87 is typically present at a rock's formation, but its amount can be determined using isochrons. The isochron technique was developed by South African geologist L. O. Nicolaysen in 1961. The advantage of this method is that it can be used to determine the original amount of Sr-87. Isochrons are self-checking; that is, the method displays an internal consistency that helps the user determine if the inferred ages make sense.

The isochron method depends upon the fact that Sr-87 is not the only isotope of strontium. In fact, strontium has several isotopes, but Sr-87 is the only one that originates from the decay of Rb-87. The isotope Sr-86 is chemically identical to Sr-87, and this is the key to determining the original amount of Sr-87 in a sample. When a rock is molten, both Sr-86 and Sr-87 are free to migrate throughout the molten rock (melt). Since they are chemically identical, neither isotope is preferred to the other, so both isotopes are uniformly distributed in the ratio of their initial abundances. As the melt cools and forms the minerals composing the rock, the homogenized ratio of initial Sr-87 to Sr-86 is locked in the minerals. Although the *amount* of strontium varies among the minerals, *the ratio of Sr-87/Sr-86 is identical for all minerals*.

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[44] This is not true for all igneous rocks. Nevertheless, through extensive experimentation, geologists have learned which rocks and minerals to use for accurate K/Ar age determinations. Moreover, even with argon loss, techniques exist such that valid ages can still be determined. (Cf. Dalrymple, *Age of the Earth*, pp. 109-115.)

[45] Some rocks contain a class of minerals that readily include Rb but totally exclude Sr. These rocks can be dated directly without resorting to isochrons—an age determination technique we discuss below. These minerals are not universal, however, so the overwhelming number of Rb/Sr dates is based on isochrons.

The ratio of Rb-87 to Sr-86 is also set while the rock is molten, but since rubidium and strontium are chemically different, the Rb-87/Sr-86 ratio differs from one mineral species to another. Some minerals begin with a higher Rb-87/Sr-86 ratio than others.

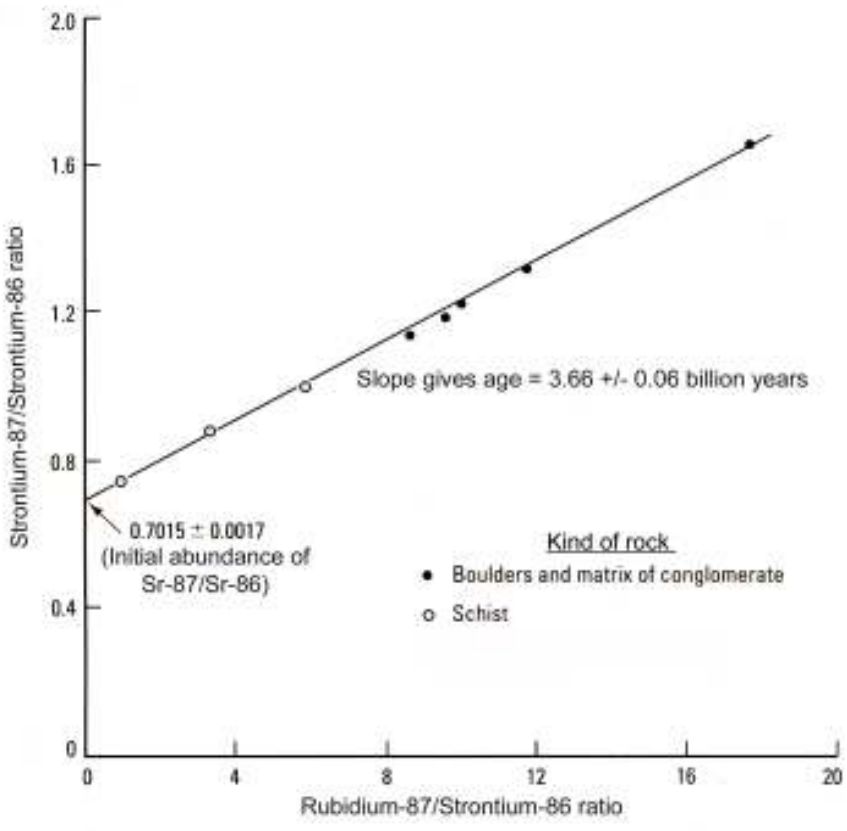

Figure 3: Example of a typical isochron.

Isotopic ratios have been determined for different samples in the Greenland Isua formation, which is one of the oldest rock formations on earth. The straight line confirms that this isochron is a valid age indicator; otherwise, the data points would be scattered. The slope of the line indicates an age of 3.66 billion years. Adapted from G. Brent Dalrymple, *The Age of the Earth*, p. 143.

As time passes, Rb-87 decays to Sr-87, so the Sr-87/Sr-86 ratio increases while the Rb-87/Sr-86 ratio decreases. Minerals with the highest original Rb-87/Sr-86 ratio will show the greatest change—the greatest increase in their Sr-87/Sr-86 ratio and the greatest decrease in their Rb-87/Sr-86 ratio. (Remember, Sr-86 is not radioactive, so its amount remains constant.)

Here is where Nicolaysen's genius comes into play. He realized that if he plotted the Sr-87/Sr-86 ratio against the Rb-87/Sr-86 ratio for the different minerals in a rock, he would get a straight line whose slope represents the age of the rock. (The line is straight because the *rate* at which Rb-87 decays to Sr-87 is constant for all minerals regardless of the initial amount of Rb.) In addition, the place where the line intersects the Sr-87/Sr-86 axis gives the initial ratio of daughter element when the rock formed. Figure 3 illustrates such an isochron.

If an isochron plot does not generate a straight line, then the rock experienced a convoluted history and cannot be accurately dated. In this way, isochrons are self-checking. They ensure that age measurements are valid, for it is highly improbable that all minerals of a rock, or all rocks as a whole used as samples, would gain or lose Rb or Sr in just the right way so as to give a straight-lined isochron that is not really an age measurement.

The success of isochrons for Rb/Sr has encouraged their use for other decay schemes, thereby adding credence to those age determinations as well.[46]

Uranium (U), thorium (Th), lead (Pb) methods

The decay of uranium and of thorium to lead differs from the previous methods in that the Pb daughter element is not the immediate descendant of its uranium or thorium parent. Rather, numerous intermediate radioactive daughters intervene between U/Th parent and the Pb end product. Table 2 gives an overview of these decay schemes.

Table 2: Parent/Daughter Decay Schemes for U/Pb

Parent	End product (Pb daughter)	Number of distinct intermediates (not including isotopes)	Decay schemes
U-238	Pb-206	13	8 alpha + 6 beta
U-235	Pb-207	10	7 alpha + 4 beta
Th-232	Pb-208	8	6 alpha + 4 beta

In spite of these complications, one should not conclude that these decay modes are useless as geologic clocks. On the contrary; they have become proverbial workhorses for geologists. Two interesting happenstances account for this. First, each final Pb daughter is unique to that particular parent. For example, only U-238 decays to Pb-206. U-235 and Th-232 do not produce Pb-206. The net result is that the U-238 decay scheme is independent of the others, so cross-contamination between decay modes does not occur. The same can be said for U-235 and Th-232 decay.

Second, all of the intermediate radiogenic daughters have extremely short half-lives compared to their parents. Hence, for all practical purposes, the Pb daughters are forming as fast as the parents decay. Thus

[46] It is neither our intent nor the scope of this book to give a full explanation of the isochron method. We only wish to assure the reader that in spite of an initial abundance of Sr, accurate dates can still be determined. We strongly encourage those who wish to understand this method more deeply to consult the following works: Henry Faul, *Ages of Rocks, Planets, and Stars* (New York: McGraw-Hill, 1966). Faul serves as a good introduction to the following excellent works: Gunter Faure, *Principles of Isotope Geology*, 2nd ed. (New York: Wiley, 1986). G. Brent Dalrymple, *The Age of the Earth* (Stanford: Stanford Univ. Press, 1991). Two excellent web sites that describe isochrons and also answer objections from young-earth creationists are www.talkorigins.org/faqs/isochron-dating.html and http://www.asa3.org/ASA/resources/Wiens.html. (Both sites accessed 16 June 2007) Also see Davis A. Young, "How Old is it? How Do We Know? A Review of dating Methods—Part Two: Radiometric Dating, Mineral, Isochron and Concordia Methods," *Perspectives on Science and Christian Faith* 59 (no. 1, March, 2007): 28-36.

there are no "road blocks" in any of the decay schemes that hold back or delay the Pb that eventually forms from the parent. As such, the amount of lead present is a true indication of the amount of parent that decayed. One does not have to compensate for lead that has not yet formed from the decay of intermediate elements.

U/Pb dating can be done directly on *zircon*-type minerals where the crystal lattice of the mineral prevents any initial Pb from becoming a part of the crystal. On a practical level, however, zircons can lose Pb and gain or lose U, although the latter is not as common. Through the years, however, geologists have met the challenge of U/Pb abundance changes and have developed procedures that enable them to assign valid ages to zircons for which migration of U parent or of Pb daughter has occurred.

The procedure used is called *concordia-discordia*. Specifically, concordia-discordia makes use of the fact that the U-238 and U-235 are, for the most part, chemical twins. The same holds for their corresponding Pb daughters. As such, geologists are able to examine how *ratios* of parent/daughter change for each scheme and plot one against the other to determine the amount of parent and/or of daughter that has migrated out of a sample.[47] Interestingly enough, concordia-discordia enables geologists to determine when the rock initially formed and the age at which it underwent changes that perturbed the original parent/daughter amounts. Concordia-discordia, in combination with other methods, enables a reconstruction of complex histories of rocks, thereby enhancing our understanding of forces that have shaped the earth.[48]

As with isochrons, concordia-discordia graphs are self-checking. Data plotted on these graphs, if valid, will produce a straight line. Data plots that deviate from straight lines are not used. Figure 4 illustrates a concordia-discordia graph and the associated age of the sample.

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[47] This method works for U that has entered or left a sample, and for Pb that has leached out of a sample. It does not work for Pb that migrates *into* a sample. In that case, none of these methods work.

[48] For more on concordia-discordia dating, consult Faul, Faure, and Dalrymple (footnote #43).

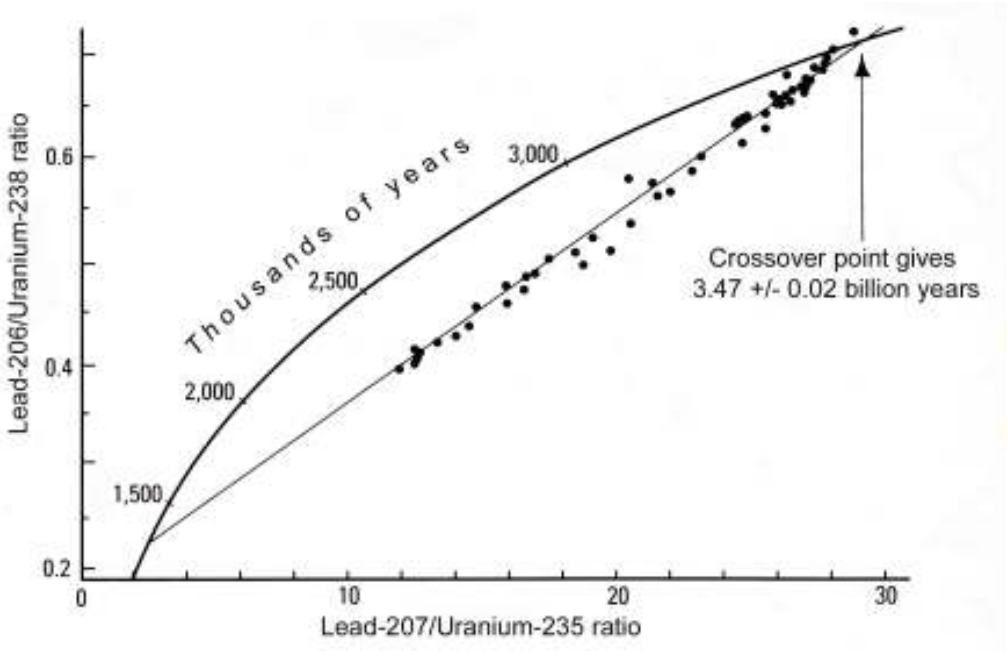

Figure 4: Example of a concordia-discordia plot.

Note that the measured ratios fall on a straight line, which is a powerful indicator that the measured age is valid. This sample comes from Western Australia and displays an age of 3.47 billion years. Here, it is not the slope of the line that gives the age, but the upper intercept between the concordia-discordia curve and the straight line. Numbers along the curve represent ages in millions of years. Adapted from G. Brent Dalrymple, *The Age of the Earth*, p. 174.

Samarium/Neodymium (Sm/Nd), Lutetium/Hafnium (Lu/Hf), Rhenium/Osmium (Re/Os)

Technical improvements since the early 80s have enabled geologists to add these three decay schemes to their dating arsenal. In spite of measurement difficulties and minute quantities of the isotopes, these methods have advantages over others. For instance, Sm/Nd is used for ancient basalts (and for so-called achondrite meteorites) for which too little potassium, rubidium, and uranium exist for accurate age determination.

Lu/Hf is probably the least used of the methods, but when applicable, it allows another independent check for the age of a sample.

Rhenium and Osmium are fairly rare, but iron meteorites contain considerably greater proportions of Re and Os than found on earth. Thus Re/Os decay has become a prime method for dating iron meteorites where parent elements for other decay modes are negligible.

Age of earth rocks

Radiometric dating gives us the age of a rock since the last time it was molten. Remelting a rock lets the radioactive materials redistribute, effectively "resetting the clock." Past age information, then, is lost. Given that the surface of the earth is a very active place, the reworking of the earth's crust since the time of its formation has caused considerable remelting and recrystallization of rocks. Hence, we do not find—nor do we expect to find—rocks on earth dating from the time of the planet's formation. Even so,

very old crustal rocks have been found in Greenland, South Africa, Australia, and Canada. These rocks show ages as old as 3.5 billion years, and a few zircons from Western Australia have ages close to four billion years. These are the oldest materials found on earth.

Age of meteorites and lunar material

Material from outer space provides another source of age information. For two centuries scientists have realized that objects fall from the sky. Dating this material began in the 20th century with the advent of geologic dating methods. Rocks and minerals from the lunar surface and its immediate subsurface have also been available for study since the United States landed astronauts on the moon in 1969. Researchers have more recently found that some meteorites on earth originated on the moon and on Mars.[49] These also have been dated, thereby giving ages of several bodies in the earth's neighborhood.

The methods and the assumptions used in dating extraterrestrial matter are the same as those used for earth-bound materials. Meteoritic materials show ages as old as 4.6 billion years, which is thought to be the date of the formation of the solar system since older dates have not been observed. The age of lunar rocks ranges from 3.5 to 4.2 billion years, depending on their location on the moon.[50] Ages older than 4.6 billion years are not found in any extraterrestrial materials, so one may reasonably conclude that the solar system is about 4.6 billion years old. This agrees with the sun's age of five billion years, as we do not anticipate that planetary material would be older than the sun.

The importance of dating extraterrestrial materials is that they were not subject to the affects of weathering that one finds on earth. Hence, one cannot argue that their ages are spurious because of weathering, erosion, plate tectonics, or Noah's Flood.

Objections to radiometric dating

Young-earth objections to radiometric dating are legion, and we encourage interested readers to consult the works listed in footnote #46 for answers to these objections. Here we handle two of the most prevalent ones.

Objection #1: The constancy of the rate of decay over millions and billions of years is an assumption that cannot be proved.

Several lines of evidence argue very strongly that the rate of decay of isotopes has been constant over millions of years. Physicists have studied nuclear processes for decades and have a good theoretical understanding of their behavior. Our knowledge of the atomic nucleus has been instrumental in building atomic weapons, in harnessing atomic power for electricity and in medical cures, and for understanding processes inside of stars. This same knowledge assures us that decay of an isotope takes place at a constant rate, which means that long-term half-lives remain constant over millions and billions of years.

In addition, two factors prevent the nucleus from being chemically altered so as to change its properties,

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[49] Explosions on the moon and on Mars due to large objects crashing into their surfaces can propel material into outer space, which may subsequently fall to earth.

[50] Paul D. Spudis, "The Moon," in *The New Solar System* eds. J. Kelly Beatty, Carolyn C. Petersen, and Andrew Chaikin (Cambridge: Cambridge Univ. Press, 1999), pp. 138 – 140. For a thorough review of the history and ages of lunar rocks, see G. Brent Dalrymple, *The Age of the Earth*, pp. 218 – 256.

including its half-life. First, the nucleus of an atom is surrounded by a cloud of electrons that effectively shield it from chemical action. Chemical interactions between elements involve the outermost electrons, so the nucleus remains isolated. Thus, changing a nucleus requires high-energy particle accelerators and nuclear reactors that emit extremely energetic particles that can pierce the electron cloud and excite the nucleus. (This is why alchemy never succeeded.) Chemical changes in rocks may affect an isotope's abundance, but not its half-life, which is a nuclear property.

Second, the energy required to change a nucleus is a million times greater than what is released by chemical reactions—even from violent reactions resulting in explosions. Since the binding energy between particles in a nucleus is from one-thousand to one hundred thousand times stronger than the interaction between a nucleus and its own electrons, chemical activity involving the electrons has no effect upon the nucleus.

Finally, radioactive isotopes have been exposed to enormous electrical and magnetic fields and to extremely high and low temperatures. Isotopes have also been accelerated in centrifuges to increase the gravitational force upon them many times more than they would experience on earth. The only decay rate that has been influenced is electron capture, and that only by less than 0.2% (two parts per thousand), which is inconsequential.

Objection #2: Half-lives are not accurate. After all, who has been around for millions or billions of years to measure when one-half of an isotope is gone?

Clearly, if one had to wait until half of a long-lived isotope decayed, measuring half-lives would be hopeless. Half-life, however, is not measured directly. Rather, one measures the so-called *specific activity* of the element. Specific activity is the amount of radioactivity for a fixed quantity of a radioactive isotope, such as the number of disintegrations per gram of material per second. Measuring specific activity is fairly straightforward and bears a direct relationship to the half-life. Isotopes can be created with half-lives of hours or days, and their specific activities can be accurately measured along with their half-lives. Comparing the specific activity of long-lived isotopes to the short-lived ones enables calculation of the longer half-lives, for their half-lives are inversely proportional to their specific activity.[51]

Two concluding observations

We end this section with two observations in support of the accuracy of radioactive dating.

Observation #1: Differing decay schemes give the same age for a sample.

Ages of rocks are not based upon one or two measurements. Several methods are employed, some of them repeatedly, on the rock as a whole and on its component minerals. Geologists accept a determined age only if all the measurements agree within their experimental accuracy. The fact that disparate dating methods—each operating with a different decay scheme and running at a different "clock" rate—give the same age is a powerful indication that the age is valid.

[51] That is, if element A has a specific activity that is one-tenth that of element B, then element A's half-life is ten times longer than that of element B.

Observation #2: Elements with short half-lives are not found on earth, on the moon, or in meteorites.

There are strong theoretical reasons for believing that all radioactive isotope species were present at the formation of the solar system.[52] This includes isotopes with a range of half-lives of several thousand to billions of years. Why, then, have isotopes with half-lives shorter than 82 million years vanished?

The answer is that the short-lived isotopes have decayed away in the 4.6 billion year history of the earth.[53] In spite of technological advances for measuring minute quantities of radioactive isotopes, the passing of several tens of half-lives diminishes an isotope's abundance to immeasurable amounts. If the earth is 4.6 billion years old, then isotopes with half-lives shorter than 82 million years have decayed to undetectable levels. For longer-lived isotopes, a smaller number of half-lives has elapsed, so detectable amounts of these isotopes still exist.

This argument takes on added force when we realize that non-radioactive siblings of missing isotopes are all found, which is a strong indication that all isotopic species of the element were originally created. Missing short-lived isotopes does not provide a basis for dating the earth, but their absence does point to an earth that is far older than a few thousand years.[54]

Non-radioactive Evidence

Before the advent of radioactive dating, scientists used various methods to determine the age of the earth. Except for tree-ring counting and sediments deposited at the bottom of bodies of water, these methods proved unreliable for various reasons.[55] Some present non-radioactive techniques, however, give unambiguous ages for features on earth that are much older than several thousand years.

We refer the reader to Appendix 1, which presents a good deal of non-radioactive evidence for an old earth.

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52 See Dalrymple, *Age of the Earth*, pp. 75 – 95 for an expanded discussion of this point.

53 A few short-lived isotopes exist today because they are constantly created by cosmic rays and by other radioactive elements in which they are in contact. Examples are discussed by Dalrymple, *Age of the earth*, p. 376.

54 The Institute for Creation Research (ICR – San Diego, CA) has published a study of radiometric dating undertaken in their RATE project. (**R**adioisotopes and the **A**ge of **T**he **E**arth). The investigators conclude that an examination of the available data for radiometric dating confirms that the earth is thousands, not billions of years old. (Larry Vardiman, Andrew A. Snelling, and Eugene F. Chaffin, eds., *Radioisotopes and the Age of the Earth*, vol. II [Waco, TX: Institute for Creation Research, 2005.] A non-technical version of this work is by Donald DeYoung, *Thousands, not Billions: Challenging an Icon of Evolution: Questioning the Age of the Earth*, [El Cajon, CA: Institute for Creation Research, 2006.]) This work is billed as "ground breaking" and as a definitive answer to the proponents of an old earth who base their conclusions on radiometric dating. We find, however, that the RATE authors themselves admit that their position is not compatible with present scientific data, and that they depend upon future yet-to-be-discovered solutions that will (hopefully) support their conclusions. In short, in spite of ICR's assurance that the question of the age of the earth has been solved, their conclusions are based on nothing less than the geologic equivalent of the "hopeful monster." (See the excellent review of RATE by Randy Isaac, "Assessing the RATE Project" [*Perspectives on Science and Christian Faith*, vol. 59, no. 2, June (2007), pp. 143-6.])

55 Cf. Dalrymple, *Age of the Earth*, pp. 12-78, for a history of attempts.

Chapter 2: The Inner Workings of the Solar System[56]

Recognizing the very old age of the earth is foundational for developing a model of its origin. Before proceeding, however, we first lay out the physical characteristics of the solar system and of the earth.

The earth is one of eight presently known planets that orbit the sun.[57] Other members of the solar system include many moons, numerous asteroids, and countless comets. Several striking details about our solar system stand out, and they must be taken into account in any theory of its formation.

Angular momentum

We have all been enthralled by an ice skater's performance. During her routine she gracefully plants the tip of her skate in the ice and pushes off with the other into an elegant pirouette. Her arms extend as she spins effortlessly on the ice. She pulls in her arms and she spins faster; she extends her arms and her spin rate slows down.

The change in rotation speed of a pirouetting skater depends upon the principle of *angular momentum*. Basically, angular momentum is a property of all objects in circular motion. Whether it's a pirouetting skater, a star spinning on its axis, or planets revolving around the sun, they all have angular momentum.

"Angular momentum makes the world go 'round"—so goes a familiar refrain (among physicists, at least). This saying states a well-established physical principle: the angular momentum of an object remains constant unless acted upon by a torque.[58] Even without torque, however, the rotation speed can change. One of the properties of angular momentum is that rotation speed is *inversely proportional* to how closely an object's mass is distributed about the spin axis.

Compacting a spinning object will increase its spin rate, but not its angular momentum. A skater spins faster when she pulls in her arms and slows down when she extends them, but her angular momentum stays constant. (Of course, she eventually stops spinning because of friction between her skate and the ice.)

We will show later how angular momentum played a fundamental role in structuring the solar system.

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56 For fuller discussions of the material that follows, see Stuart Ross Taylor's *Destiny or Chance: Our Solar System and its Place in the Cosmos* (Cambridge: Cambridge University Press, 1998). *Destiny or Chance* is a popular level discussion. Taylor's *Solar System Evolution: A New Perspective*, 2nd ed. (Cambridge: Cambridge University Press, 2001) is more mathematical and deeper in its physical explanations.

57 Pluto is not considered a *bona fide* planet. Rather, it is a so-called *Kuiper Belt* object that has been jostled from its original orbit into its present, highly elliptical orbit. The Kuiper Belt contains a number of icy asteroids that lie, for the most part, in the plane of the solar system beyond the orbit of Neptune. As such, we will not include Pluto in our planetary discussions. For a history of the demotion of Pluto from planet to Kuiper Belt object, see Owen Gingerich, "Losing it in Prague: The Inside Story of Pluto's Demotion," *Sky & Telescope* 112 (no. 5, November, 2006): 34-39. Available online at: http://www.physics.sfsu.edu/~cool/TEACHING/a490/spring07/readings/gingerich_pluto_S&T_nov06.pdf. (Accessed 12 September 2007)

58 Torque is force applied with a lever arm. A wrench, for example, applies a torque when loosening or tightening a bolt. An ice skater applies torque with her skate to start spinning.

Angular Momentum and the Solar System

All objects in the universe rotate, whether they are gas clouds, planets, stars, star clusters, galaxies, or galactic clusters. As a result, they, too, have angular momentum. For these objects we find, generally speaking, that their angular momentum is distributed in proportion to the mass of its individual components. That is, the more massive components contain most of the angular momentum.

The solar system has two major sources of angular momentum: the sun spinning on its axis and the planets revolving around the sun. (Lesser quantities of angular momentum arise from planets spinning on their axes.) But here is something odd: The sun is about 750 times more massive than the rest of the solar system combined, yet it contains only 2% of the solar system's angular momentum. Ninety-eight percent of the angular momentum arises from the planets' revolving around the sun even though their combined mass is a paltry 0.13% of the total mass of the solar system.

Why is the solar system's distribution of mass and angular momentum so different from other astronomical objects? This is a key question that must be answered by any scientific model of the origin of the solar system. We will tackle this question in due course.

Orbital Regularity

The solar system displays some remarkable uniformities. The orbits of the planets, for instance, are very regular, particularly when contrasted with the orbits of the comets. All the planets move around the sun in the same direction. Their orbits are almost circular, and they lie nearly in the same plane. Table 3 gives the eccentricity[59] and the inclination of each planetary orbit.

Table 3: Eccentricity and inclination of planetary orbits. Inclination is with respect to the earth's orbital plane.

Planet	Eccentricity	Inclination
Mercury	.206	7.0°
Venus	.007	3.4°
Earth	.017	—
Mars	.093	1.9°
Jupiter	.048	1.3°
Saturn	.056	2.5°
Uranus	.047	0.8°
Neptune	.009	1.8°

Each planetary orbit, which lies in a plane, is an ellipse. These planes are very nearly aligned, as shown in the third column of Table 3. Only two planets have inclinations larger than 3.0 degrees—the

[59] Eccentricity measures the shape of the planetary orbit, which, by Kepler's First Law, is an ellipse. An eccentricity of zero indicates a circular orbit. Values between zero and one indicate ellipses with increasing elongation. An eccentricity of one denotes an "ellipse" squashed into a straight line. Notice in Table 3 that all but one of the planetary orbits have eccentricities under 0.100. Orbiting comets, by contrast, have much more elongated orbits, with eccentricities usually in excess of 0.500.

innermost planets Mercury and Venus. As we shall see in the next chapter, this regularity places a strong restriction on feasible models for the origin of the solar system.

Two other regularities bear mentioning. All planets, except Venus and Uranus, spin on their axes in the same direction, which is counterclockwise as seen from the North Star.[60] Also from this perspective, almost all of the planetary moons revolve counterclockwise around their respective planets.

Chemical Evidence

The chemistry of the solar system is also a significant class of data that relates to its origin. The sun, a massive sphere of gas, consists mostly of hydrogen (80 percent by mass) and a large minority of helium (18 percent). Only a small fraction (2 percent) remains for all the heavier elements. Earth, however, has comparatively little hydrogen or helium, but is primarily composed of the heavier elements that, for the most part, display similar relative proportions as those on the sun.

The planets, moreover, fall into two distinct groups: The *inner planets* (Mercury, Venus, Earth, Mars) and the *outer planets* (Jupiter, Saturn, Uranus, Neptune).[61] The inner planets have average densities that range from about four to five and a half times that of water. The chemical composition of the inner planets is primarily rock. These planets possess a very thin atmosphere.

The outer planets' densities range from under three-fourths to twice that of water. Compositionally, the outer planets can be broken down into two classes. Jupiter and Saturn are the *gaseous* outer planets. Each has a small rocky core (about ten earth masses) and an enormous atmosphere of hydrogen, helium, methane, and ammonia. Most of the interior of these two planets is *metallic hydrogen*, a form of liquid hydrogen that conducts electricity. Hydrogen is normally a gas, but under the extreme pressures in the interiors of these large planets, hydrogen becomes a liquid with good electrical conductivity.

Uranus and Neptune are the *icy* planets; they contain very little gas and a lot of ice in their interiors. Astronomers use the term "ice" loosely, not necessarily referring to water ice. In this case, the ice is made up of frozen water, methane, and ammonia. Both of these planets also have rocky cores. Uranus and Neptune are not massive enough to compress hydrogen into its metallic form.

Four gases—hydrogen, helium, methane, and ammonia—compose the thick upper atmospheres of both sets of outer planets.

Except for the cores of the outer planets, the rest of their constituents are extremely volatile (easily vaporized) compared to the metals and the silicates (compounds formed of silicon) that are the principal components of the inner planets. But how did most of the volatile materials come to be at the center (sun) and at the outside (outer planets) of the solar system with only a little in-between? This problem, too, places a severe constraint on any theory for the origin of the solar system.

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[60] Astronomers account for the odd rotations of Venus and of Uranus, along with the differing spin axis orientation of the other planets, by collision processes during the formation of the solar system. See Stuart Ross Taylor, *Solar System Evolution*, pp. 180-182.

[61] The inner planets are also called the "terrestrial planets." Other names for the outer planets are the "giant planets" and the "Jovian planets."

Earth's composition

Earth is our home, so we use it as a standard to compare other planets. Since we have more information about the earth than for other planets, we will describe the earth in more detail to help us see what sort of data a model for its origin must fit.

Seismology, the study of earthquakes, indicates that the earth—like an onion—is composed of layers. The earth's center has a solid inner core and liquid outer core. Both sections of the core are very dense. The core extends from earth's center out to about half its radius. Geologists believe the core is an alloy principally of iron and nickel. They base this conclusion on the bending of seismic waves as they pass through the core. They also have good theoretical reasons for equating the composition of the earth's core with that of iron-nickel meteorites. Geologists also have a sound basis to believe that the flow of material in the liquid part of the core generates electric currents, which in turn produce the earth's magnetic field.

Above the core lie several layers that form a thick region called the mantle. The mantle is a solid that is very close to being liquid, roughly like warm asphalt or "silly-putty." As a result, it behaves as a solid in reaction to rapidly changing forces, such as earthquakes, but flows under the influence of long-term forces.[62] Chemically, the mantle is more like our surface rocks than is the core, for it appears to consist of various metals that have formed compounds with silicon, magnesium, and oxygen. Its density is intermediate between that of average surface rocks and the core. The mantle carries heat outward from the earth's interior by means of slow convection currents (the hotter material rising, the cooler sinking) which, incidentally, cause the continents and sea floors to drift slowly along the surface of the earth in a process called *continental drift*, or *plate tectonics*. (More on this later.)

At the earth's surface is a thin layer of solid rock called the crust. This crust is of two kinds: One is rich in silicon-aluminum compounds and forms the continents. This continental crust may be as much as 35 miles thick in places. The other kind, a heavier sort, is richer in silicon-magnesium compounds and forms the ocean basins where the crust is sometimes as little as 4 to 5 miles thick.

The oceans cover two-thirds of the earth's surface to an average depth of nearly three miles. If the crust were smoothed out to remove all height variations, the whole earth would be covered by about two miles of water!

Above the earth's surface flows an "ocean" of air, which gradually thins out to blend with the solar "atmosphere" several hundred miles up. Earth's atmosphere is mostly nitrogen (78%), with a large fraction of oxygen (21%) and about 1 percent of heavier gases composed mostly of argon that has arisen from decay of potassium-40. These percentages neglect small, locally varying amounts of dust, water vapor, methane, and carbon dioxide, which make up a few of the atmosphere's other constituents.

By contrast, the other inner planets differ substantially from earth. Mars and Venus have atmospheres that are almost entirely carbon dioxide, and Mercury is so hot that it has no atmosphere. Free water, the

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[62] This kind of property is called "plastic flow," also illustrated by salt-water taffy. A bar of this candy bends when one applies a force slowly, but the same bar breaks when one attempts to bend it too quickly.

largest component of the surface of the earth, is scarce on Mars and nonexistent on Venus or Mercury. Lastly, the other terrestrial planets have weak and insignificant magnetic fields compared to earth.

With this brief sketch of the solar system, and of earth in particular, we proceed to examine various scientific models of their origin that seek to account for their attributes.

Chapter 3: Selecting a Model

In the past two centuries many models have been proposed for the origin of the earth and of the solar system. Basically, they fall into three classes: (l) our sun captured the planets—or the material from which the planets formed—from interstellar space; (2) a passing star pulled material from our sun, out of which the planets condensed; and (3) the planets and the sun formed simultaneously from the same cloud of condensing interstellar matter. We examine each model in turn.[63]

Interstellar Capture Theories

Model 1: Random Capture of Planets

There are two subclasses to this model. In the first, the planets originally formed somewhere beyond our solar system by an unknown process. After traveling for ages through space, the planets were captured into orbits around the sun. This model, notice, does not explain the origin of planets; it merely removes the process from our locality. Another model must then be proposed to explain the origin of the individual planets.

An additional problem arises from the fact that a single star cannot capture a solitary planet to form a bound, orbiting system without the help of a third body. Thus, we must postulate one of the following: (a) the sun already had a planet in orbit around it when the first planet to be captured approached (but then we need another model for the origin of this planet.); (b) the sun had another star in orbit with it (but what happened to the other star?); (c) the sun captured the planet that was orbiting another star that passed close to the sun (but how did that star have a planet in the first place?); or (d) two or more planets, traveling together, encountered the sun and one or more of them were captured (but the probability is minuscule that two planets traveling together would encounter our sun).

In any case, these models are all inadequate to explain the great regularity in the planetary orbits. For example, such captures should give random inclinations for the orbital planes of the captured planets. The probability of capturing eight planets by chance with the existing inclinations of those in our solar system is only one in 10 trillion trillion (10^{25}).

Even if we assume, in spite of these odds, the planets were captured with such nearly-aligned orbital inclinations, another problem arises concerning the shape of the orbits. The planetary orbits in our solar system are nearly circular (Refer to Table 3). Captured planets, on the other hand, would naturally start out with highly elongated orbits that would not have had enough time to become circular in the 4.6 billion years since the solar system formed. From a probabilistic standpoint, the chance that the orbits

63 For a historical summary of these views, see Michael M. Woolfson, *The Origin and Evolution of the Solar System* (Bristol and Philadelphia: Institute of Physics Publishing, 2000), pp. 111 – 155. A three-volume set detailing the history of the search for a viable theory for the origin of the solar system is Stephen G. Brush's *A History of Modern Planetary Physics* (Cambridge: Cambridge University Press, 1996).

would just happen to be circular when the planets were captured, or that they would become as circular as they are by near collisions among one another, is roughly one part in a trillion (10^{12}). Both these odds and those of the preceding paragraph disqualify planetary capture models from serious consideration.

Model 2: Random Capture of Gas and Dust

The other subclass of random capture models suggests that our planets formed from interstellar dust and gas captured by the sun. This vastly increases the chances that the captured material would eventually form planets in a single plane traveling in one direction.[64] One problem with this model, however, is the fact that the sun's equator is aligned only seven degrees from the plane of the planetary orbits. There is only one chance in 250 of such a close alignment, which suggests that it is not accidental. In addition, this type of theory does not account for the unusually small angular momentum of the sun relative to the solar system as a whole, or to the gas cloud from which the sun would presumably have formed.

Finally, neither random capture model cleanly accounts for the regularity in the chemical composition of the planets. This problem, along with those mentioned above, has forced astronomers to look for another theory for the origin of the solar system.

Close Approach Theories

Another model proposes that our planets are the result of a near-collision between our sun and another star. This theory began with a suggestion of Georges Louis de Buffon[65] in 1745 and was popular into the 1950s. T. C. Chamberlin, F. R. Moulton, and Sir James Jeans are most closely associated with this sort of view.

In this model, two stars approach each other and their mutual gravitational attraction raises tides on each. If the stars pass extremely close to each other, the tides are so large that some material is pulled off into orbit around each star. As the stars separate, the material cools off and eventually condenses into planets.

This model is superior to the planetary capture theory in two ways: it predicts that the orbits will lie in a single plane described by the movement of the two stars, and it solves the angular momentum problem because the material condensing into planets gains momentum from the motion of the passing star. The plane of each planet's orbit would probably also be near the plane of the sun's equator, since the sun's rotation would surely have been influenced by such a near encounter with another star.

Unfortunately, the sudden pull exerted by a star passing this close to the sun would bring material from both stars out into space very quickly, and the hot gas would disperse instead of condensing to form

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64 The reason for this is that the tiny particles in the gas and dust constantly collide with one another, which eventually leads to motion in one direction around the star. (Think of a lot of "bumper cars" that start out going in random directions but which eventually wind up going around the track in one direction as a result of mutual collisions.) The combination of collisions and tidal forces upon the gas and dust eventually brings about the planar orbit of the cloud.

65 Buffon actually suggested a comet rather than another star; at the time he was not aware of the miniscule size and mass of comets.

planets. And even if a portion of the material condensed, its orbit would be very elongated and soon be recaptured by both stars.[66]

Finally, even if the above difficulties of the close-approach model could be surmounted, planetary systems would be extremely rare. The stars in our galaxy are widely separated, and statistical calculations indicate that only a few hundred of the kind of near-collisions required for this theory would have occurred in the lifetime of our galaxy. Recent evidence, however, indicates that planetary systems are much more common than this, perhaps being a feature of most single stars.[67] Therefore, this model, too, is inadequate to account for the origin of our solar system.[68]

Accretion Theories

The third model considers the planets as natural byproducts from the formation of a single star as it condenses from a cloud of interstellar gas and dust. Immanuel Kant (late eighteenth century) and Pierre Laplace (early nineteenth century) first proposed this kind of theory. A vast increase in our observational data and theoretical understanding since then has led to numerous modifications and revisions, yet most investigators today hold some variation of this view. We will discuss a modified version of this model first advanced by Fred Hoyle and Herman Bondi. They introduced the idea that magnetic fields would solve the so-called "angular momentum problem." Though magnetic fields have not solved the problem entirely, their proposal infused new life into the science of planetary formation. Research sparked by their work continues unabated and has led to considerable advances in our understanding of planetary formation, to which we turn below.[69]

What's between the stars?

Stars are the most abundant objects we see when we gaze at the sky on a clear night. One might think the space between stars is totally empty, but this would be a mistake. Interstellar space contains innumerable clouds of gas and dust that have not yet contracted into stars. Some clouds are so thin as to be invisible; others are thick enough to scatter or completely absorb the light from stars lying beyond them.[70]

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66 D. N. C. Lin, "The Nebular Origin of the Solar System" in *The Solar System: Observations and Interpretations* ed. Margaret Kivelson (Englewood Cliffs: Prentice-Hall, 1986), p. 30.

67 R. Paul Butler, "Other Planetary Systems" in *The New Solar System* eds. J. Kelly Beatty, Carolyn C. Petersen, and Andrew Chaikin (Cambridge, MA: Sky Publishing, 1999), pp. 377 – 386.

68 Michael M. Woolfson has attempted to revitalize the close approach theory. See *The Origin and Evolution of the Solar System* (Bristol and Philadelphia: Institute of Physics Publishing, 2000). Most researchers in the field, however, do not find his arguments convincing.

69 We recognize that numerous planets have been discovered associated with other stars besides the sun. Most are so-called "hot Jupiters"—large planets that revolve closely around their parent star. The formation of these planetary systems may differ from that of our own. Their existence, however, does not negate our discussion below on the formation of the Solar system. For more on extrasolar planets, including earth-like planets, we refer the interested reader to the excellent article and links at http://en.wikipedia.org/wiki/Extrasolar_planet. For more on earth-like planets, see http://www.physorg.com/news11909.html. (Both sites accessed 6 June 2007.)

70 For an example of this phenomenon, gaze overhead a couple hours after sunset on a summer's night and observe a swath of stars of the Milky Way extending from the northeast to the southwest (from the constellations of Cassiopeia and Cygnus to

No matter how low the density of an interstellar cloud, if it has enough mass and is not too hot, the mutual gravitation of its particles (atoms, molecules, and dust) will overcome its gas pressure and the cloud will collapse.[71] Most clouds are right on the edge between expanding and collapsing. Generally, a "nudge" is required to push a cloud "over the edge" so as to collapse. External forces, such as magnetic fields or shock waves, can start such a collapse. Astronomers today believe supernovas (massive exploding stars) occurring near a cloud usually provides the shock wave that does this.

In the early stages of the contraction, the cloud is tenuous enough to be transparent. An imaginary observer located inside the cloud can look out of it with no difficulty and see previously formed stars in the neighborhood. As the contraction proceeds, however, the cloud eventually becomes dense enough to scatter and then to absorb all light from outside; hence, the cloud becomes dark everywhere within.

Other processes also proceed as the cloud contracts. Collisions between gas atoms and molecules tend to cancel their random, individual motions, but two large-scale motions of the cloud remain: (1) the movement of the cloud as a whole through space, and (2) the rotation of the cloud about a definite axis. The latter is more significant for the eventual development of the planets because the rotation direction determines the orbital direction of the planets and, for the most part, their spin direction as well.

The cloud spins faster as it collapses

The collapse of a cloud to form a star involves an enormous contraction in size. A cloud forming a star like our sun initially is on the order of a light-year across (6 trillion miles), but the star's diameter is only about a million miles when the contraction stops. Even if the original gas cloud spins very slowly, this large contraction increases its rotation speed greatly. This increase in rotation speed is the result of what is known as the law of *conservation of angular momentum*. This is the same law that causes pirouetting ice skaters to spin faster when they draw in their arms.

If the angular momentum becomes sufficiently high, the contracting cloud will subdivide into smaller clouds and a multiple star system is born. In this case, the production of planets is much less likely since multiple stars allow for very few stable planetary orbits. Since our solar has one central star, it appears that the cloud out of which it and the planets formed was small enough and spinning slowly enough to exclude a companion star for our sun.

Sagittarius). In the vicinity of the southwest horizon (near Sagittarius), you will see a number of dark blotches devoid of stars. These blotches are massive dark clouds that are blocking the light from stars beyond.

[71] It is essential that readers keep several points in mind that will greatly aid their understanding of what follows. Temperature is a measure of the average speed of the particles comprising the cloud. The higher the temperature, the faster the particles move, thereby increasing the pressure inside the cloud. Stated alternatively, the higher the temperature, the greater the pressure; the lower the temperature, the less the pressure. Clouds have stable sizes when the gravitational force matches the outward pressure. If, however, gravity dominates, the cloud collapses; if pressure dominates, the cloud expands. Squeezing a cloud to a smaller size takes work, which requires energy, and this energy goes into heating the cloud. If the cloud cannot get rid of this energy, the pressure continues to rise and the collapse stalls. As it turns out, even though a contracting cloud heats up, contraction continues because the cloud can radiate away enough excess energy. Only the sudden onset of nuclear fusion, when the central temperature of the cloud reaches several tens of millions of degrees, provides a heat source powerful enough to counteract the gravitational contraction. At that point, a zero-age main sequence star is born.

The cloud flattens

For a cloud forming a planetary system, the relentless work of gravity continues to pull the cloud together into a smaller unit, but its rotation produces a third force, called *centrifugal force*, which is directed outward. This force is strongest at the equator of the cloud because that is where the cloud's rotation speed is fastest. As a result, the cloud collapses more slowly near its equator than near its poles, so its shape becomes flatter. Mathematically, the cloud now resembles an oblate spheroid. Less technically, this is the shape of an "M&M" chocolate candy, non-peanut variety.

If this flattening effect continued unabated, the cloud would become pancake-shaped rather than oblate. To see how rotation can flatten a (somewhat) spherical body, watch a master pizza maker spin a lump of dough in the air to flatten it for the crust. (Lesser pizza makers use a rolling pin.) (Figure 5)[72]

Ionization and radiation

As the cloud collapses, its temperature rises from the energy released from the infalling material.[73] Eventually, the cloud heats up and begins to glow visibly. At this point, an observer inside the cloud would see everything glowing around her. It appears that this transition from "no glow" to "glow" occurs in a matter of months—very quickly on the astronomical time-scale.

The glowing of the gas cloud indicates substantial ionization, which occurs when electrons are separated from their parent atoms. At temperatures of several thousand degrees, the collision of atoms in the cloud is sufficiently violent to rip electrons off the atoms. The electrons, now released from their parent atoms, are free to roam, making some of the gas into an *ionized plasma*, which some consider to be fourth state of matter, distinct from solid, liquid, or gas.

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[72] We recognize that the star-disk interaction is more complicated than what we have described. For example, some of the material falling directly into the central core is expelled by the polar jets of the star, which is similar to what we observe in so-called T-Tauri stars. Additionally, the disk is not uniformly thick; it widens out as one moves away from the center. Including these details, however, does not change the description of planetary formation presented here. For more details, including diagrams, consult Taylor, *Solar System Evolution*, pp. 32, 33.

[73] The material falling towards the center of the cloud gains energy, just as a rock released from a height off the surface of the earth gains energy as it falls to the ground. The contracting cloud also becomes denser because the same amount of matter is confined to a smaller volume; thus, the particles more easily collide with one another. The combination of increased particle energy and the rate of collision heats the cloud, but not to the point of halting the collapse. Most of the heat is radiated away.

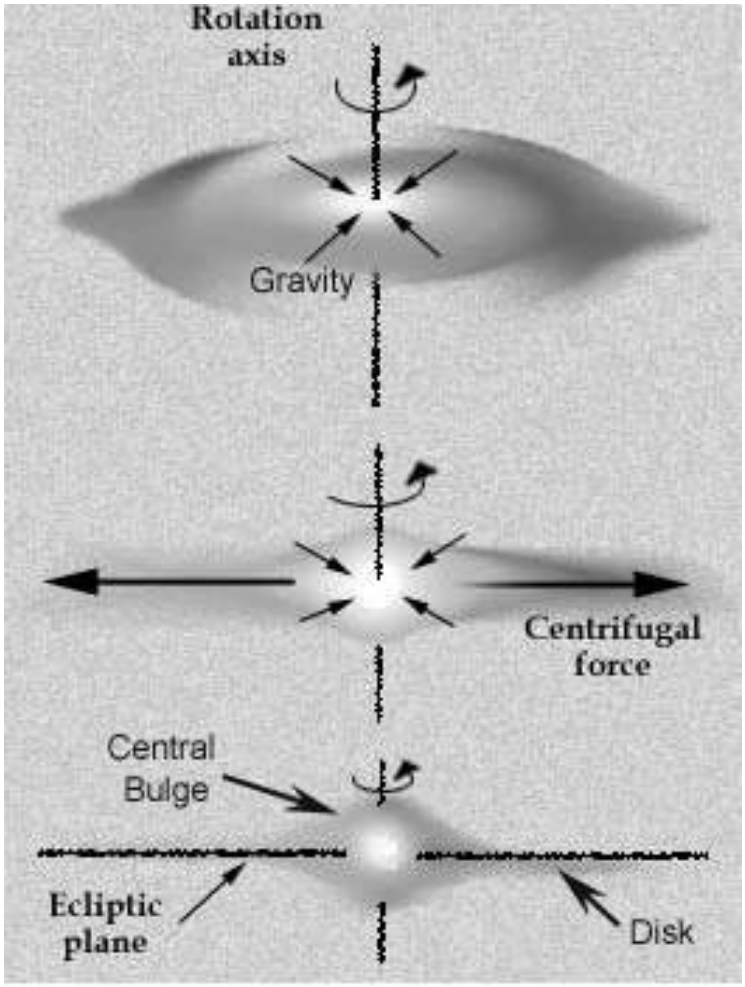

Figure 5: Stages in the collapse of a gas cloud to form a star and planets.
From left to right, the spherical cloud becomes oblate and then forms an equatorial band. The disk arises from the transfer of angular momentum from the core to the equatorial band.

The transfer of angular momentum

The appearance of plasma along with gravitation, gas pressure, and centrifugal force introduces a fourth force: *electromagnetism* that creates a tangle of magnetic field lines which, somewhat like rubber bands, resist stretching. (Figure 6) These magnetic fields influence the further development of the cloud as follows: Since the inner part of the cloud has collapsed more than the outer part, conservation of angular momentum means the inner part of the cloud is rotating faster than the outer. This differential rotation tries to stretch the magnetic field lines connecting the inner and the outer regions of the cloud. The magnetic field lines, however, resist stretching, and their resistance effectively slows down the rotation of the inner part of the cloud while transferring angular momentum from its inner to its outer part. It is

estimated that the sun lost one-half of its original angular momentum through this process of "magnetic braking."[74]

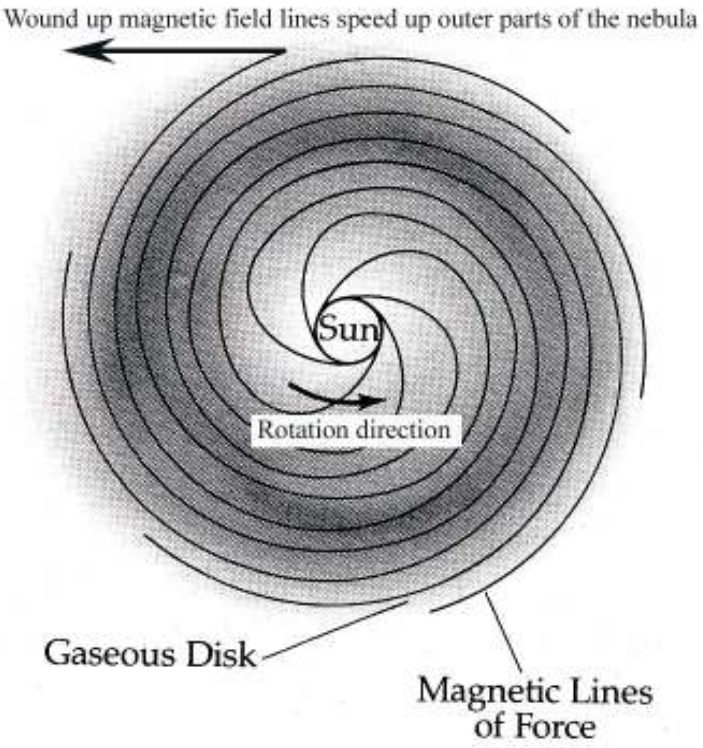

Figure 6: Magnetic lines of force, behaving somewhat like rubber bands.
They transmit angular momentum from the inner to the outer part of the cloud, thereby slowing down the core's rotation while and speeding up the disk's rotation. Adapted from Michael Zeilik and Elske v. P. Smith, *Introductory Astronomy and Astrophysics* (Philadelphia: Saunders College Publishing, 1981), p. 136.

Asymmetries in the cloud also allow angular momentum to be transferred from its inner to its outer regions (Figure 7). Basically, for an asymmetric disk with "tails," such as those illustrated in Figure 7, rotational energy is tapped from the inner part of the disk and transferred to the outer part. As a result, the inner part loses angular momentum while the outer part gains angular momentum.[75]

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[74] M. M. Woolfson, The Origin and Evolution of the Solar System, p. 232.

[75] For some time, many have questioned whether adequate mechanisms exist that could transfer sufficient quantities of angular momentum from the sun to the planets via the planetary disk. M. M. Woolfson has shown, however, that for a star like our sun, "It is concluded that, assuming an active early Sun with plausible values of rate of mass loss and magnetic field, there are no problems with the early Sun models … as far as the present spin rate is concerned." M. M. Woolfson, *The Origin and Evolution of the Solar System*, p. 161. Also see the discussion by D. N. C. Lin, "The Nebular Origin of the Solar System" in *The Solar System: Observations and Interpretations* ed. Margaret Kivelson (Englewood Cliffs: Prentice-Hall, 1986), pp. 40 – 42, and Lee Hartmann's, *Accretion Processes in Star Formation* (Cambridge: Cambridge University Press, 1998), Chapter 5. An asymmetric disk also transfers angular momentum from the inside to the outside of the disk. (M. M. Woolfson, *The Origin and Evolution of the Solar System*, p. 167.) This latter mechanism is especially efficient in galactic angular momentum

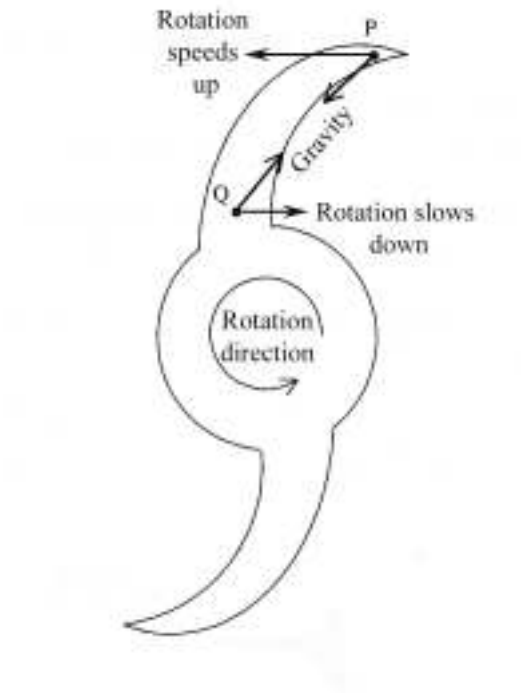

Figure 7: Differential rotation and transfer of angular momentum.
Through mutual gravitational attraction, point P speeds up and point Q slows down. The net result is a transfer of angular momentum from Q to P. Adapted from M. M. Woolfson, *The Origin and Evolution of the Solar System*, p.168.

As the inner region slows down, it has less centrifugal force to contend with, so it begins to collapse more rapidly and returns to a more spherical shape. The outer region, however, now has more centrifugal force applied to it and more effectively resists contraction. As the transfer of angular momentum continues, the flattened, outer region begins to move radially outward in the equatorial plane of the cloud such that the whole cloud begins to resemble the planet Saturn with its rings. In short, angular momentum is transferred from the central mass, which will eventually form the sun, to a flat disk of ionized gas and dust rotating in the same direction as the cloud. Later, the planets will form from the flattened disk and carry most of the angular momentum of the solar system.

As the outer portion of the disk gets sufficiently distant from the glowing, central gas cloud, it begins to cool off and become un-ionized. It also becomes more symmetric. As a result, this section of the disk "unhooks" from the central core. It ceases to move farther outward, and its constituent particles take up fairly circular orbits about the core. At this point, the outer planets begin to form. The inner planets, on the other hand, will have to wait for the inner part of the disk to cool off further before they can form.

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transfer and would have been operative in the early solar nebula before it became symmetric. The long and short of angular momentum transfer is that the planetary disks "appear to provide sufficient angular momentum transport to solve much of the angular momentum 'problem' for star [and planetary] formation." (Lee Hartmann, *Accretion Processes in Star Formation*, p. 34.)

The central part of the cloud continues to collapse as the inner part of the disk, still ionized, saps more angular momentum from the core. Also possible at this time is the throwing off of angular momentum by means of concentric rings of material.[76] Such rings and the remaining cloud may have slightly different planes of rotation because of small differences in the detailed distribution of mass, angular momentum, convective currents, and magnetic fields in the disk. The resulting planets, therefore, will also have slightly different planes of rotation around the sun, but the planes will differ by only a few degrees, which is what we presently observe in our solar system.

Finally, by continual collapse, the central cloud becomes sufficiently hot at its center for fusion to begin. The conversion of hydrogen into helium produces sufficient heat to cause the gas pressure to balance the force of gravity. The collapse ceases and the star begins its life on the main sequence.

The role of solar wind

All stars emit what is known as "stellar wind," which is particularly intense at a star's birth. This wind is made up of ionized particles that are flung off the star's surface with speeds of several hundred miles *per second*. This wind acts like a stellar leaf-blower that sweeps less dense material from the inner to the outer part of the disk. The net effect is to enhance the outer part with materials such as hydrogen, helium, methane, and ammonia, while leaving behind a greater proportion of denser materials (silicon and metals) in the inner part of the disk.

It follows that planets forming in the outer part of the solar system will generally be larger (they have more time to form) and less dense (they incorporate a greater proportion of lighter material). Conversely, inner planets will be smaller (they have less time to form) and denser (as more dense material has been left behind by the solar wind). We see, therefore, how size, density, and compositional differences between the inner and the outer planets arise naturally in this scenario.

Planetary accretion

Both outer and inner planets form by the process of *accretion*, in which smaller particles collide and stick together to make larger particles. As accretion progresses, larger and larger objects form, which draw in more material with their progressively increasing surface area and gravitational attraction. These larger objects, about the size of asteroids, are called *planetesimals*.

The accreting material in a thin disk conglomerates rather quickly into planetesimals, perhaps in as little as one hundred thousand to a few million years, though it may take up to ten million years for a planet to reach its final size. Contrary to earlier views, in which each planet was thought to have been an individual gas cloud that cooled to a molten ball and then solidified, it now appears that the planets were formed "cold" from the accretion of small particles and subsequent planetesimals.[77]

Near the end of this process, a number of violent collisions occur (called "the last heavy bombardment") as the larger competitors in each orbital area "fight it out" for final control of the remaining planetesimals. The presence of massive Jupiter, for example, seems to have interfered with the formation

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[76] M. M. Woolfson, The Origin and Evolution of the Solar System, pp. 151-154.

[77] D. N. C. Lin, "The Nebular Origin of the Solar System" in *The Solar System: Observations and Interpretations* ed. Margaret Kivelson (Englewood Cliffs: Prentice-Hall, 1986), pp. 54 – 70.

of a planet in the present asteroid belt, and it probably captured considerable material that would otherwise have gone to form Mars. These collisions are also responsible for the disorder in some of the regularities of the solar system, such as the direction of rotation of the planets and the tilt of their spin axes. For example, a collision of an earth-sized object with Uranus would modify the latter's axis of rotation. Smaller objects colliding with Venus modified its spin motion and direction, though it may be that Venus escaped collisions and that is why it spins so slowly and is rotating "backwards." There is also good evidence that a large collision of a Mars-sized object with earth formed the moon.[78]

The Development of the Earth

As a result of energy released by the last heavy bombardment, the newly formed earth had a molten surface. No ocean existed. A few choking gases—primarily carbon dioxide—lingered in the atmosphere. Water, which covers most of the earth today, was not present. Along with other volatiles, water had been driven off by the heat and energy generated by the last heavy bombardment and by the formation of the moon. Thus, liquid water, which we discuss below, was a late arrival on the earth's surface.

Eventually, radioactive elements with short half-lives (under a few million years) heated the interior. As the earth is a good insulator, its internal temperature rose, melting some materials and breaking down others. Some of these contained *hydrates*, minerals that have absorbed water into their crystal structure. Heating hydrates drives off water, so this is what happened in the earth's interior. Since water is less dense than rock, it rose to the surface.[79] Conversely, heavier materials, such as iron and nickel, flowed towards the center of the earth to form its core. Gradually, the various minerals settled at differing distances from the center, providing the earth with the three-tiered structure of core, mantle, and crust we see today.

The formation of seas and atmosphere

As water and various gases accumulated on the surface, an ocean and an atmosphere formed. Today, the gases spewing out of earth's volcanoes, along with gases found in the atmospheres of Venus and Mars, provide reliable clues allowing us to conclude that earth's early atmosphere had little or no free oxygen. Instead, the oxygen was locked up in carbon dioxide, of which there would have been plenty since volcanism—the major channel for carbon dioxide—was much more active during the early years of earth's development. Carbon dioxide is quite effective in trapping heat from the sun (the greenhouse

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[78] John A. Wood, "The Origin of the Solar System" in *The New Solar System* eds. J. Kelly Beatty, Carolyn C. Petersen, and Andrew Chaikin (Cambridge, MA: Sky Publishing, 1999), pp. 20 – 21. Paul D. Spudis, "The Moon", in *The New Solar System* eds. J. Kelly Beatty, Carolyn C. Petersen, and Andrew Chaikin (Cambridge, MA: Sky Publishing, 1999), pp. 138 – 140. A good review of the role of collisions in the formation of the solar system is Taylor's *Destiny or Chance: Our Solar System and its Place in the Cosmos* (Cambridge: Cambridge University Press, 1998).

[79] Some planetologists (those that study planets) believe that the ferocity of the last heavy bombardment entirely rid the earth of water. They propose that water is a later arrival from vaporized comets and lingering icy planetesimals. Some water may have arrived on earth this way, but we believe that water on earth arose primarily from hydrates. After all, the most plentiful material in molecular clouds is water, followed by silicates. Water and silicates easily form hydrates, of which the early earth would have plenty. Although the last heavy bombardment would have eliminated water from the surface, we find it hard to believe that all water would have been eliminated in the interior of the earth. For more on this, see Ross, *Solar System Evolution*, pp. 99-101.

effect). Thus, earth's surface temperature was higher than we would expect if no carbon dioxide were present.

This higher temperature evaporated more water, producing a cloud cover much thicker than we have today. An observer on earth then would have had great difficulty seeing astronomical objects through the clouds. Even the sun and the moon would not be visible, though enough light from them would penetrate to provide diffuse lighting along with the day/night cycle at the earth's surface.

Today, earth's atmosphere is clear enough to view astronomical objects consistently, so sometime later in earth's history something happened to change the atmosphere. Von R. Eshleman, commenting on the differences between the present atmospheres of earth, Venus, and Mars, suggests that plant life on the earth has replaced most of our carbon dioxide by oxygen.[80] This would have decreased the greenhouse effect, lowered the temperature, precipitated much of the water vapor, and cleared up the atmosphere.[81]

As for the oceans, the current surface of the earth has enough relief that the oceans cover only two-thirds of the earth's surface while one-third remains above water. With plate tectonics, however, mountains formed, and deep ocean basins between continents opened to limit the extent of the oceans.[82] Interestingly, most areas of the earth, including high mountains, contain marine fossils of very early life forms. All this suggests that the surface relief of the solid earth was once small enough for oceans to cover the entire planet.

Volcanic action, such as we see forming islands in the Atlantic and in the Pacific (Iceland and the Hawaiian Islands)—but on a larger scale—eventually formed large islands, called continental shields (e.g., Japan). The combination of plate tectonics, volcanic action, erosion, and metamorphosis of preexisting material separated heavier, so-called *siamic* materials (dominated by the elements silicon and magnesium) from the lighter, so-called *sialic* materials (dominated by silicon and aluminum). In the

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[80] Von R. Eshleman, "The Atmospheres of Mars and Venus" in *Frontiers of Astronomy*, ed. Owen Gingerich (San Francisco: W. H. Freeman and Co, 1970), pp. 48 – 58. We note that a debate exists among geologists and paleontologists concerning the role of plants in reducing the atmosphere's carbon dioxide that led to a clearing of the atmosphere. Some suggest that the so-called silicon cycle is responsible for taking care of most of the carbon dioxide, while others attribute this action to plants. Our view is that there was too much carbon dioxide on earth to be eliminated solely by the silicon cycle.

[81] Interestingly enough, the amount of carbon dioxide in the earth's early atmosphere (about 1000 times its present value) decreased at just the right rate to counter the sun's increase in luminosity. Stellar theory shows that the sun was 30 % dimmer four billion years ago. If the original amount of carbon dioxide in the earth's atmosphere had not decreased, the increasing energy output from the sun would make earth intolerable for life. The temperature of the earth's surface today would be hot enough to boil away the oceans. On the other hand, if the carbon dioxide level four billion years ago was the same as today, there would not have been enough of a greenhouse effect to warm the earth above freezing, and all the oceans would have frozen. The interaction between the sun's luminosity and the earth's response to keep temperatures within tolerable limits is truly amazing. See Bruce M. Jakosky, "Atmospheres of the Terrestrial Planets" in *The New Solar System* eds. J. Kelly Beatty, Carolyn C. Petersen, and Andrew Chaikin (Cambridge, MA: Sky Publishing, 1999), p.186.

[82] Walter Sullivan, *Continents in Motion: The New Earth Debate* (New York: American Institute of Physics, 1991), pp. 251 – 266.

molten state, the heavier, siamic materials sank while the lighter, sialic materials rose to the surface and formed the bulk of the continents we observe today.[83]

Summary

In this chapter we sketched a model for the origin of the solar system and of the earth that explains: (l) the regular orbital characteristics of the planets; (2) the smaller-scale irregularities in their rotational motion; (3) the unusual distribution of mass and angular momentum between the sun and the planets; and (4) the chemical makeup of the solar system in which the sun and outer planets are composed largely of volatile materials, whereas the inner planets are mostly non-volatile. We have also appended a brief résumé of the formation and early history of the earth as best we can discern from the scientific evidence available today.

It is now appropriate to compare the scientific evidence with the Biblical materials.

[83] For the origin and evolution of continents, see *Earth's Dynamic Systems*, 9th ed., W. Kenneth Hamblin and Eric H. Christiansen (Upper Saddle River, NJ: Prentice Hall, 2001), pp. 592 – 595; 604 – 606.

PART 2: THEOLOGY

Chapter 4: Chronological Evidence from Scripture

What is the Biblical teaching on the age of the earth? The answer is commonly assumed to be only a few thousand years. After all, this is the traditional (though not unanimous) position. Even before the time of Christ, Jewish writings—such as the book of Jubilees—proclaimed such a view.[84] Several early Christian writers make explicit statements that human history lasts only a few millennia.[85] Later, Archbishop Ussher (1581-1656) fixed the date of creation at 4004 B.C.,[86] and Dr. John Lightfoot (1602-75) went so far as to name the day and the hour![87]

Basically, those who believe the earth is young use two lines of Biblical argument. First, they assert that the genealogies in Genesis 5 and 11 do not allow for more than a few thousand years from Adam to Abraham. Second, they suggest that the creation account itself teaches that Adam is only a day younger than the oldest animals, and less than a week younger than the universe. We examine each of these arguments in turn.

The Genesis genealogies

The argument for a young earth based on the genealogies in Genesis 5 and 11 runs as follows: The approximate dates for the life of Abraham, obtained from the Biblical data and from archaeology, are 2000 to 1700 B.C. Abraham, however, is in the last generation listed in the genealogy of Genesis 11. Since this genealogy gives the age of each father at the birth of his son, one can calculate the time elapsed from the birth of Shem (the first mentioned in the Genesis 11 list) to the birth of Abraham, which is 390 years. Similarly, Shem is in the last generation in the genealogy in Genesis 5. Here, too, we have the age of each father at the birth of his son; thus, we can calculate the time elapsed from the creation of Adam to the birth of Shem, namely 1,556 years. Adding the figures obtained from both genealogies, the total elapsed time from Adam to Abraham is 1,946 years. This figure, added to the accepted date for Abraham, results in a creation date for Adam around 4000 B.C.

Is this the teaching of Scripture, or is this merely an inference that is in fact mistaken? We suggest the latter, based on the arguments of William Henry Green, professor of Old Testament at Princeton Seminary late in the 19th century, who vigorously defended the inerrancy of Scripture. In 1890 he wrote an article that should lay to rest any idea that we can obtain a date for creation or the age of humanity

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84 For instance, Jubilies 11:14-15 has Abram born early in the 39th jubilee after Creation, so that (taking Abram's birth about 2000 BC) creation would be about 4000 BC. See the text of Jubilees in R. H. Charles, *The Apocrypha and Pseudepigrapha of the Old Testament* (Oxford: Clarendon Press, 1913), 2:30 and in James H. Charlesworth, *The Old Testament Pseudepigrapha* (Garden City, NY: Doubleday, 1985), 2:79.

85 E.g., Hippolytus, *On Daniel*, 2.4.

86 James Ussher, Annales Veteris et Novi Testamenti (1650 - 1654).

87 Cited in A.D. White, *A History of the Warfare of Science with Theology in Christendom* (New York: Macmillan, 1896; reprint ed., New York: Dover, 1960), I, 9.

from the genealogies of the Bible.[88] (Green's article is reprinted in Appendix 2 this book.) Briefly, Green points out that:

1. By a comparison of the genealogies that appear in various portions of Scripture, it is apparent that omission of unimportant names from such lists is the rule rather than the exception. Hence, gaps of unknown lengths exist in the genealogies.
2. The use of the terms "father," "son," and "begot" (was the father of) are shown from Scriptural usage to be far broader than we might expect. These terms are often used for persons related at a distance of several generations, and sometimes even of persons not physically related at all.
3. It is not unusual for Scripture to pass over very long periods of time with little or no remark.
4. If the years are added in a straightforward way in Genesis 11.10, it appears that Shem, Arphaxad, Selah, and Eber outlived Peleg, son of Eber (Genesis 10.25) and Terah, Abraham's father. Yet the narrative of Abraham implies that the events of the Flood are long past and that God is beginning a new phase of redemptive history.
5. The records of Egyptian civilization seem to preclude a date for the flood in line with the genealogical calculations made from Biblical genealogies (about 2300 B.C.). After all, the Flood would have wiped out Egypt as a nation, but scholars find Egyptian history dating a thousand years before this.[89]
6. No summation is made in Scripture of the years mentioned in Genesis 5 and 11. Note, however, that sums do appear for other events: Exodus 12.40 (430 years in Egypt); and 1 Kings 6.1 (480 years after the exodus).
7. The genealogies of Genesis 5 and 11 have a symmetry that suggests intentional arrangement. For example, Noah is tenth from Adam and Terah is tenth from Noah. Each genealogy in these chapters ends with a father having three sons, which is the same as in Cain's genealogy (Genesis 4.17-22). It also appears that the seventh in each line epitomizes the good or the evil of the lineage. For example, Enoch, the seventh in Adam's line, is good; Lamech, the seventh from Cain, is a murderer and a polygamist. (Matthew utilizes a similar format with his 14 - 14 - 14 scheme for the genealogy of Jesus.)

Professor Green summarizes:

> On these various grounds we conclude that the Scriptures furnish no data for a chronological computation prior to the life of Abraham; and that the Mosaic records do not fix and were not intended to fix the precise date either of the Flood or of the creation of the world.

Professor Green makes a number of additional comments of significance, and we recommend that the reader examine his paper in full. We reprint it in Appendix 2.

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88 William Henry Green, "Primeval Chronology," *Bibliotheca Sacra* 47 (1890): 285 - 303. Reprinted in Walter C. Kaiser, ed., *Classical Evangelical Essays in Old Testament Interpretation* (Grand Rapids: Baker Book House, 1972).

89 *The Oxford History of Ancient Egypt*, ed. Ian Shaw (Oxford: Oxford University Press, 2000).

John D. Morris, a noted proponent of a recent creation, feels the strength of Green's arguments and of evidence from archaeology. He is willing to consider a date of creation back to 12,000 B.C., but feels that further concessions would make the gaps between names in the genealogies too large.[90] Although one has some sympathy for this feeling, it is not based on any specific exegetical data. The Bible does not specify the date of creation of the universe or of humans. One must, therefore, obtain this information elsewhere—specifically, through scientific investigation.

Other Scripture passages implying age

It is interesting to note that certain passages of Scripture fit especially well into the view that creation occurred much more than a few thousand years ago. For example, the "last days" or "last times" are seen as starting with the first coming of the Messiah (Acts 2.17; Hebrews l.2; l Peter 1.20). Using about the same terminology as in Matthew 28.20, Hebrews 9.26 states that Jesus appeared once "at the *end of the age* to put away sin by the sacrifice of Himself" (our emphasis). The Apostle John, writing near the end of the first century, tells his readers that it is already "the last hour" (1 John 2.18). But these expressions hardly make sense if one-fifth to one-third of human history was yet future to their writings. Likewise, Jesus's frequent promises to come soon (e.g., Revelation l.3; 21.10, 12, 20) are more easily understood if human history extends for tens or even hundreds of thousands of years before his first coming.

The Length of the Creation Period

Scientifically, the evidence is overwhelming that creation took place a very long time ago. Even so, do the Bible and science agree on the *length* of the creation period? We answer in the affirmative, but we acknowledge conflicts do exist between some *models* constructed using the Biblical data and some using the scientific data. We will investigate three models (Table 4) and then choose the one that we believe best fits the Biblical and the scientific facts.[91]

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[90] John D. Morris, *The Young Earth* (Colorado Springs: Creation-Life Publishers, 1994), p. 39.

[91] We only summarize chronological views – that is, ones that consider the "days" of Genesis as sequential. Thus, we will not be discussing the so-called framework model.

Table 4. Three Basic Models of Creation

Name of creation model	Meaning of "day" in Genesis 1	Length of the creative "week" of Genesis 1	Proposed age of the earth
Young Earth Creationism Recent Creationism Mature Creationism	Literal, 24 hours	Literal week with seven contiguous, 24-hour days	6,000 – 10,000 years
Day-Age View	Periods of time much longer than 24 hours	Hundreds of millions to billions of years	4.6 billion years
Intermittent-Day View	Literal, 24 hours, but separated by long periods of time	Hundreds of millions to billions of years	4.6 billion years

As we see from the table, these views hinge not only upon the meaning of "day" in Genesis 1, but also whether the days are (1) sequentially contiguous, 24-hour periods; (2) long periods of time; or (3) sequential, non-contiguous 24-hour periods. Since the interpretation of "day" is fundamental to each view, we discuss below the reasons for understanding "day" in the senses we have indicated above.

The "days " of Genesis[92]

An elaborate word study of the Hebrew word for "day" (Hebrew: *yom*) is not necessary to show that it possesses nuances similar to our English word "day." Often, *yom* means a period of activity during which the sun is up (Gen 1.5; 1.14a). At other times it represents a day-night pair, or a 24-hour day (Genesis 1.14b; Numbers 3.13). Less frequently it means a period of time of unspecified length (Genesis 2.4a; Ecclesiastes 12.3). Genesis 2.4a is of particular interest, since here *yom* encompasses the entire creation period. Whether one accepts *yom* as a 24-hour day or as a period of time, the fact that the entire creation week is said to have taken place in one *yom* adds credence from the creation account itself that *yom* can represent a period of time longer than 24 hours.

What about using "day" with a number?

One argument often encountered in support of *yom* being 24-hours is: In all instances outside of Genesis one, when a number appears with *yom*, a literal day is meant. Because a number appears with the days of Genesis one, they must be literal.

[92] The discussion of word usage in Genesis chapter one follows *Are the Days of Genesis Longer than 24 Hours? The Bible Says "Yes!"* by Perry G. Phillips. (Hatfield, PA: Interdisciplinary Biblical Research Institute, Research Report No. 40, 1991). Also available online at http://ibri.org/DVD-1/RRs/RR040/40genday.htm, (Accessed 16 June 2007)

This argument fails on two counts. First, the premise is false. There are at least two instances where a number appears with a figurative use of *yom*—Isaiah 9.14 (9.13 in Hebrew) and Hosea 6.2. In the Isaiah passage, the expression "one day" is exactly the same in Hebrew as the one often translated "the first day" in Genesis 1.5. From context, however, "one day" in the Isaiah passage and the numbered "days" in the Hosea passage are clearly figurative.

Second, in all cases purportedly illustrating the number/literal day correlation, it is already apparent from the context that a literal day is intended. The number is simply descriptive; it does not define "day." Hence, the proposed connection between the presence of a number and the meaning of "day" does not exist.

What about "evening" and "morning ?"

Each "day" in Genesis one is bounded by an "evening" and a "morning." Does not their use in conjunction with "day" strengthen the literal interpretation? The answer is "not necessarily." Hebrew uses "morning" and "evening" with wider meanings than the beginning and the end of daylight.

For example, we read in Psalm 90, attributed to Moses, that human beings are like the grass that "though in the *morning* it springs up new, by *evening* it is dry and withered" (verse 6). We know of no grass that literally springs up in the morning and then is dead by the same evening. Rather, the psalmist has in mind the life cycle of grass in the Levant, which begins its growth with the November rains and dies with the hot, dry, desert winds of March. In this psalm, therefore, "morning" stands for the period of growth and "evening" stands for the period of death. This interpretation fits in with the tenor of the entire psalm, which encourages humans to be mindful of their time on earth; for just as the life cycle of grass is short with respect to human life, human life itself is short with respect to the ongoing activities of God. The same comparison is made between humans and grass in Isaiah 40.6-8 and in 1 Peter 1.24, 25.

"Morning" and "evening" are also used figuratively in Psalm 30.5. In this verse we read that God's anger "lasts only a moment, but his favor lasts a lifetime; weeping may remain for a night [literally: evening], but rejoicing comes in the morning." Given the parallelism in the phrases, "evening" corresponds to the time of weeping over God's anger, and "morning" corresponds to the time of rejoicing over God's favor. The writer envisions a time longer than a literal morning or evening.

Finally, we read in Psalm 49.14, 15 that the wicked are

> Like sheep ... destined for the grave, and death will feed on them. The upright will rule over them in the morning; their forms will decay in the grave far from their princely mansions. But God will redeem my soul from the grave; he will surely take me to himself.

Again, "morning" must be interpreted figuratively, for in what way can the upright literally rule over the dead the morning after they die? After all, one rules over those who are alive, not over those who are dead. We suggest that the psalmist is looking ahead to the time of his ultimate redemption—his resurrection—spoken of in verse 15. In short, he is looking forward to a new age that he calls "morning."

As with the word "day," English speakers do not regularly use "morning" and "evening" figuratively, but perhaps the expressions "the dawning of a new age" and "in the twilight of her years" parallel the Hebrew idiom that uses portions of a day figuratively for periods of time.

Some propose that when we try to decide which appearances of *yom* are "literal" and which are "figurative," we should follow the rule "always take the literal meaning where possible." We may do this if we wish, but it does not guarantee success. Jesus' disciples sometimes had trouble understanding him for just such a reason (e.g., Matt. 16.5-12). In any case, merely deciding to adopt the more common meaning of a word can only give a result that is probable, not one that is certain, and such interpretations should give way to available contextual evidence.

Of course, even if we grant that the "days" of Genesis are literal, this does not prove that they are contiguous. To resolve this question, we need more data. (We will discuss this issue below.)

Exodus 20 and the literal creation week

The reference to creation in Exodus 20.8-11 has often been brought forward to prove that the creation week consisted of contiguous 24-hour days:

> Remember the Sabbath day, to keep it holy. Six days you shall labor and do all your work, but the seventh day is a Sabbath of the LORD your God; in it you shall not do any work, you or your son or your daughter, your male or your female servant or your cattle or your sojourner who stays with you. For in six days the LORD made the heavens and the earth, the sea and all that is in them, and rested on the seventh day; therefore the LORD blessed the Sabbath day and made it holy.

The Sabbath is a 24-hour day, which (the argument goes) is preceded by six, contiguous 24-hour workdays; hence, creation week consisted of contiguous 24-hour days.

This argument, we contend, is not necessarily valid—it is an argument from analogy, not from identity. In fact, the workweek with its associated Sabbath differs from the creation week at one critical point—the present-day work/Sabbath week is repeated again and again, but the "week of creation" is not. This passage does not explicitly state or imply that "day" is to be understood the same way in both cases. As such, we claim that the meanings of "day" may differ in the same way as Protestants agree that the "blood" we drink in the Lord's Supper is different from the "blood" Jesus shed on Calvary, and that the "baptism" we experience as we enter the church is different from the "baptism" Jesus experienced (Luke 12.50). In each of these cases, our human actions serve as parabolic actions commemorating God's activities—they are not identical. It is not unreasonable, therefore, to suggest that our 24-hour day workweek/Sabbath is commemorative of God's six "day" work and one "day" Sabbath in creation "week," in spite of the latter's length.

In the words of theologian J. Oliver Buswell:

> If we had no other example of Moses' language, this passage [Exodus 20.8-11] might be taken as evidence for a twenty-four hour creative day, but we have Scriptural evidence that Moses made a radical distinction between God's attitude toward time and the attitude of man. What Moses is saying, in the total Scriptural context, must be understood as teaching that man should observe a periodicity in the ratio of work to rest, of six days to one day, because God in the creation set an

> example of an analogous periodicity of six and one of his kind of days. Surely the fourth commandment gives no right to say that God's days always must be understood to be of the same length as man's days, when we have so much evidence to the contrary[93]

Also, we should not forget that God established two other kinds of Sabbaths, one of which is in the ratio of six to one: a year-long Sabbath rest for the land following six years of use (Exodus 23.10-11; Leviticus 25.3-7); and a jubilee Sabbath following "seven weeks of years," or 7 x 7 = 49 years. (Leviticus 25.8-17). These examples should caution us to pause and reflect before claiming that Exodus 20.8-11 proves the creation week consisted of seven contiguous 24-hour days.

Events of the sixth day

R. John Snow has examined the events of creation week usually assigned to the sixth day. He has shown that a much longer period than 24 hours is implied by the context. (See "How Long Is the Sixth Day?" printed here as Appendix 3.) According to Genesis 1.24-31 (if it is proper to assign all the activities listed between the mention of the fifth day in 1.23 and of the sixth day in 1.31 to the latter day, as has traditionally been done), the land animals and humans were created on the sixth day.

Genesis 2 gives us an expanded view of God's activity in creating Adam and Eve. We see that the following activities must be assigned to day six according to the traditional view:

1. Land animals were created.

2. Adam was created.

3. God planted a garden in Eden.

4. God brought all animals before Adam, who named them.

5. God put Adam to sleep and constructed Eve from his side.

This sequence of events cannot be reconciled in any reasonable way with a 24-hour period.

Snow also shows that Adam's expression upon seeing Eve, specified by the Hebrew word *happa'am* that is translated "now" in the KJV and NASB (Gen. 2.23), actually has the force of "at last," or "finally," and strongly suggests a long period of time has elapsed between the creation of Adam and his being presented with Eve.

Some have suggested that Adam, before the Fall, could think far more rapidly than humans can now. Therefore, naming a few thousand animals in a few hours—even if their names reflect their character—was within the range of his ability. Hence, Adam would have no problem accomplishing his task within 24 hours.

This, however, is pure speculation and ignores other time indicators in the passage. We note that on this scheme Adam became lonely very quickly—even more quickly than most fallen humans would

93 J. Oliver Buswell, Jr., *A Systematic Theology of the Christian Religion* (Grand Rapids: Zondervan, 1962), vol. 1, pp. 144-145.

experience. Could not Adam—a perfect being—last longer than one day in a state of being alone?[94] After all, he had no concept of a partner until he observed the other animals for a while. And it appears that God did not seek to remedy Adam's being alone until sometime after Adam became aware of it. Surely, more than a literal day is involved here.

More evidence for non-literal creation week

There is yet further Scriptural evidence that favors models other than a literal creation week. Hebrews 4.1-11 tells us that believers can still enter into God's rest mentioned in Genesis 2.2. The Hebrews passage can be understood to mean that we, too, can someday rest just as God did long ago. But the writer's emphasis that "Today" is the same as the day of God's rest, and that "Today" has been continuing at least since the time of Joshua, encourages an interpretation of this passage that either God is still resting and we are living now in the seventh "day" (Day-Age view), or that God has not yet *begun* to rest, as the seventh day is still in the future when "Today" ends and eternity begins.

The authors diverge on these views. One of us (Phillips) favors the Day-Age interpretation, and the other (Newman) favors the latter suggestion, which is advanced in this book. The reasoning is as follows:

The major objection to the Day-Age view is that if the days are taken to represent astronomical and geological periods of time, then they must overlap. For example, fruit trees are said to be created on day three, birds and sea animals on day five, and land animals and humans on day six. In the fossil record, however, which we accept as a valid testimony to the progression of life on earth, fruit trees appear rather late—after the appearance of birds, sea animals, and most land animals. One must posit, therefore, that the creation of the diverse kinds of plants mentioned in day three is not bounded by day three's "evening" and "morning." This means that God *began* creating plants in day three, and that he continued plant creation and diversification through days four, five, and six until the appearance of fruit trees.[95] Allowing the days of Genesis to overlap is neither an insuperable nor a fatal problem for the Day-Age view; nevertheless, there is an alternative.

Jesus implies that God's work has not yet ceased. On the basis of his answer to the Pharisees in John 5.17—when he was indignantly questioned for healing a sick man on the Sabbath—he answered, "My Father is working still, and I am working." This response to his opponents' charge is most easily understood as: "God is continuing his work, and since I am God's son, I am also continuing to work." In particular, God's present creative activity is the regeneration of sinners, which is an ongoing, creative work of the sixth creative period.[96]

Considering all the data, this book emphasizes an alternative to the Day-Age view. To wit, the "days" of Genesis l are the 24-hour kind, they are chronological, *but they are not contiguous*. That is, long periods of time separate these literal 24-hour days. Furthermore, all the creative activity does not take place on

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[94] Adam was not bored. The newness of the garden and all its inhabitants would have kept him occupied for a very long time.

[95] It may be that fruit trees are mentioned here to connect the creation of plants literarily with their vital role in the Garden of Eden.

[96] 2 Corinthians 5:17: "Therefore, if anyone is in Christ, he is a *new creation*; the old has gone, the new has come!" (Emphasis ours. Cf. Galatians 6:15.)

these days, for then the "sixth-day problem" remains unresolved. Rather, these days have a commemorative purpose.

The proposal is that each day serves as a distinct preface to a new creative period in which God is beginning *for the first time* to bring forth that which has never appeared. Each day, therefore, introduces the activities of the subsequent creative period. The previous creative period continues and overlaps with the new one just initiated, and the overlap persists well into the future (Figure 8).[97] As such, the creative periods overlap, but the individual, prefatory days do not.

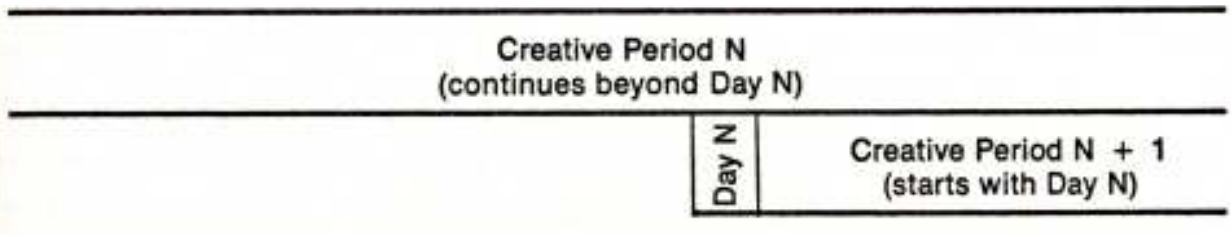

Figure 8: Relationship between the "days" and the creative periods.

One advantage of this scheme is that God himself, from the very beginning of his creation, selected six distinct days to memorialize his creative activity. Likewise, we commemorate his activity by working six days ourselves. As we argued above, the rest of the seventh day is still to come, but we commemorate God's rest by setting aside one day in seven for our own rest.

Of course, this raises questions about the interpretation of Genesis 2.2:

> And in the seventh day God completed his work that he made, and he rested on the seventh day from all his work that he made.
>
> Then God blessed the seventh day and sanctified it, because in it he rested from all his work that God created and made. (Our literal translation)

In what way can one say that God "completed" his work and "rested" on the seventh day if this day is still in the future? The suggestion is that God's rest is partially fulfilled presently but will be fulfilled completely with the beginning of the "new heavens" and "the new earth." (Revelation 21.1) This is based partly on the combination of the Hebrews 4 and the John 5 passages discussed above, and also on the interesting fact that day seven in Genesis 2.2 has no "evening" and "morning" assigned to it. God has rested from creating *new forms* since the creation of humans. That is, "there is nothing new under the sun" in the sense that all that we see in the cosmos has already been created and has not changed materially since Adam and Eve walked the Garden. On the other hand, the creation of the new heavens and the new earth will usher in redeemed humanity's eternal rest, and at that time God will enter into his

[97] After all, we still have light and dark from day one, seas and atmosphere from day two, dry land and plants from day three, etc.

total rest vis-à-vis creation. It is then that we expect the literal seventh day to preface the new, restful order.[98]

We have shown that the young-earth position of creation in six, contiguous 24-hour days overlooks important Biblical data. Scriptural and scientific evidence strongly suggests that creation lasted far longer. But how do the scientific and the Biblical accounts fit together? To this question we now turn.

Chapter 5: Genesis One

Genesis chapters one and two provide the basic source of Biblical information on creation. For our more restricted concern, which is largely non-biological, the first nineteen verses of Genesis 1 are primary. We examine these verses in order, focusing on the range of meanings allowed by the Hebrew text. We then propose an interpretation that ties them together as a coherent whole.

Genesis 1.1

In the beginning God created the heavens and the earth.

The meaning of the first verse in the Bible seems straightforward. It appears to present God as creating the universe out of nothing (creation *ex nihilo*). An alternative rendering of Genesis 1.1, however, implies that God created the heavens and the earth from preexisting material. The latter interpretation regards the verse as a temporal clause and it is translated, "In the beginning, *when* God created (or *began* to create) the heavens and the earth, the earth was without form...." This implies that the heavens and the earth were already around—albeit in an unformed state—when God decided to transform them from chaos into orderly entities. According to the alternative interpretation, the acceptance of the traditional doctrine of creation out of nothing was a gigantic mistake; nevertheless, it fortuitously advanced religion to a higher plane.

We accept the traditional understanding of Genesis 1.1.[99] It has a long history, beginning with the Septuagint (the Greek translation of the Old Testament from a couple of centuries before Christ), and is also accepted by recent Jewish and Christian translations of the Hebrew Bible. In addition, the next verse speaks of an earth as already existing in some sense; hence, verse 1 is presumably a description of its creation. Otherwise, no description of the earth's creation is given. As such, we will follow the traditional rendering of Genesis 1.1 as the first event of a creation sequence rather than as a temporal clause or a summary of what is to follow.

Further interpretation of Genesis 1.1 also requires that we ascertain the meaning of two key Hebrew words: *shamayim (*"heaven" or "heavens"), and *eretz* ("earth"). First, s*hamayim* displays three senses in the Bible: (1) the unseen abode of God, which is presumably uncreated (Deuteronomy 26.15; 1 Kings 8.30, 32); (2) the realm of the sun, moon, and stars (or outer space) (Deuteronomy 4.19; Isaiah 13.10);

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98 We note a similar "presently-here-but-yet-to-come" phenomenon for the "Kingdom of God." One aspect of the Kingdom of God is future (Luke 22:16; Acts 1:6, 7) while the other aspect is present. (Luke 11:20; 17:21).

99 For a historical and grammatical summary of the interpretation of this clause, see John J. Davis, "Genesis 1:1 & Big Bang Cosmology" in *The Frontiers of Science & Faith: Examining Questions from the Big Bang to the End of the Universe*, by John Jefferson Davis (Downers Grove, IL: InterVarsity Press, 2002), pp. 11-23. We accept Davis's analysis.

and (3) the atmosphere where the birds fly (Genesis 1.20, Deuteronomy 4.17). From context, Genesis 1.1 uses *shamayim* in the second or third sense, or possibly more broadly to encompass both.

The word *eretz* also possesses several meanings, including: (1) the whole world (Genesis 18.18, 25; Isaiah 37.16); (2) the dry land (Genesis 1.10); and (3) a country or region (as "land of Canaan." cf. Genesis 11.31; 12.5). The first sense prevails in Genesis 1.1, as the separation of the dry land from the seas has not yet occurred, and the scope of the account makes the third usage too limited.

Scripture does not consider the creation complete until Genesis 2.1. We suggest, therefore, that Genesis 1.1 refers to the creation of the material that is to make up the universe.[100] The following verses describe God's activity in fashioning this material into various finished products. At this point, the planet earth, rather than the whole cosmos, receives most of the attention.

As a final but important matter, ancient Hebrew is far less abstract than ancient Greek or Modern English. Historical events in the Old Testament are relayed from a personal standpoint; that is, events are written as though the writer is personally present and saying, in effect, "This is what I saw." Accordingly, we propose that Genesis 1 gives a description of what the various creation events would have looked like to an *earthbound observer* had one been present to see God's work. Rather than a description of the creation from heaven, the language portrays creation as viewed by one caught up in its midst.

Genesis 1.2

And the earth was formless and void, and darkness was over the surface of the deep; and the Spirit of God was moving over the surface of the waters.

Both *tohu* ("formless") and *bohu* ("void") occur rarely in the Bible, and their meaning is difficult to pinpoint. But the translation given above (similar to the KJV) is certainly possible. The traditional Hebrew lexicon of Brown, Driver, and Briggs (BDB) gives "formlessness, confusion, unreality, emptiness" for *tohu*,[101] while the translation by Holladay of the Koehler and Baumgartner (HKB) lexicon has "wasteland, nothingness, nonentity."[102] For *bohu*, BDB gives "emptiness,"[103] while Holladay lists "void, waste."[104]

Many interpreters see the earth as already a solid planet at this juncture, so they translate *tohu* and *bohu* as "waste and empty," meaning that the planet has its present shape and size, but that its surface is not yet fit for living creatures. Others go further and suggest that the planet had been devastated by the

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[100] We view the phrase "heaven and earth" as a *merism*, which is the use of two opposite terms to signify a whole. In this case, "heaven" refers to everything above, and "earth" to everything below. In short, "heaven and earth" signifies the entire cosmos, not just the sky and the ground as observed from the earth's surface. Big bang cosmology fits well with Genesis 1:1.

[101] F. Brown, S. R. Driver, and C. A. Briggs, *A Hebrew and English Lexicon of the Old Testament* (Oxford: Clarendon Press, 1907), p. 1062.

[102] William L. Holladay, *A Concise Hebrew and Aramaic Lexicon of the Old Testament*, (Grand Rapids: Eerdmanns, 1971), p. 386.

[103] Brown, Driver, and Briggs, *Lexicon*, p. 96

[104] Holladay, *Lexicon*, p. 34.

judgment of God in conjunction with the fall of Satan, but nothing specific is mentioned about this in Scripture.

The Septuagint renders these two words by *aoratos* ("invisible") and *akataskeuastos* ("unprepared, unfurnished") respectively.[105] Although these translations may be periphrastic, they do fit in well with our correlation with cosmogony, and the men who made these translations cannot be accused of attempting to harmonize Genesis with modern science!

In agreement with the Septuagint, the KJV, and most modern translations, and within the range suggested by modern lexicographers, we suggest that the earth at this point in the narrative is not yet a solid body, but is shapeless and empty, perhaps even invisible. This is an excellent, though non-technical description of the gas cloud that would eventually form the sun and the planets—including earth—as discussed in chapter 3.

The second clause of verse 2 suggests that the earth is in darkness. Whether it has been dark from creation up to this time (the usual interpretation), or whether it became dark at some time after its creation is not stated in the narrative. This would depend on whether the second clause expands upon the description of the earth given in the first clause or, alternatively, narrates a further development. The context does not remove this ambiguity, but we suggest the latter—that the shapeless, unformed cloud out of which the earth will form becomes dark as contraction raises the density enough to block out starlight.

The words *tehom* ("deep") and *mayim* ("waters") in the third clause immediately suggest the sea. This is certainly a possible translation, which if true implies that the planet is already formed and covered with water. This fits the model of those who would describe the earth at this point as "waste and uninhabited" rather than "shapeless and vacuous."

But although *tehom* is usually associated with the sea, this is not always the case. Ezekiel 31.4 speaks of a tree growing because of waters, but the "deep" mentioned is presumably in the earth rather than in the sea. The blessings upon Joseph in Genesis 49.25 and Deuteronomy 33.13 also seem to refer to moisture deep in the ground instead of ocean depths. Psalm 71.20 refers to resurrection from the grave as being brought up from the "depths of the earth," and there seems to be no connection with water here. The Septuagint version of Genesis 1.2 uses *abyssos* ("abyss, bottomless, unfathomable") for *tehom*. A good fit may be made with the scientific model proposed in chapter 3 if this is understood as a description of the dark, cloudy, unfathomable gas cloud that will form the sun and the planets.

Likewise the word *mayim*—which is nearly always translated "water" or "waters"—has a broader meaning than one might at first suppose. It is occasionally used for other fluids (or at least mixtures involving more than water (for example, urine, 2 Kings 18.27; semen, Is. 48.1). It is also used in reference to the solid and vapor states of water (ice: Job 37.10; 38.30; vapor or droplets: 2 Samuel 22.5; Job 26.8; 36.27-28; Jeremiah 51.16).

The exact meaning of *mayim* in Genesis 1.2, therefore, is uncertain, but a large body of ice or water, a mass of ice crystals or droplets, a large cloud of water vapor, or even some other fluid altogether would

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[105] Alfred Rahlfs, ed., *Septuaginta*, 7th ed. (Stuttgart: Württenbergische Biblelanstalt, 1962), ad loc.

be within range of the usage of the word throughout Scripture. All of these would have a surface over which the Spirit of God might "move" or "hover." Interestingly, water comprises the largest component of molecular clouds out of which astronomers believe stars and planets formed.[106]

Some have translated "Spirit of God" here as "wind of God" or even "mighty wind," so that a natural or supernatural movement of the "deep" might be pictured.[107] This is certainly possible, but the very frequent use of this phrase for the Holy Spirit, as well as the continual action of God throughout the creation account, supports the traditional interpretation.

Genesis 1.3 - 4

And God said, "Let there be light"; and there was light. And God saw that the light was good; and God separated the light from the darkness.

After the darkness comes the light. This is certainly in agreement with the scientific model proposed in chapter three, in which the contracting gas cloud, having become dark within, eventually heats up to the point that it begins to glow. But this is a strange sort of light, for we are explicitly told that God separates it (later?) from the darkness. Taking these clauses to be ordered chronological developments rather than further description of a static situation, it would appear that our imaginary observer would first see darkness everywhere, then light everywhere, then some of both after they are separated.

This is just what our scientific model would predict from the viewpoint of an observer riding along with the material out of which the earth is forming. When the gas cloud first begins to contract, the observer can see stars (not mentioned yet in Genesis) outside of the cloud. Later, the contraction becomes sufficient to block light from outside the cloud, and the observer within is in the dark ("darkness was over the surface of the deep"). After further contraction and heating, the whole cloud lights up and the observer, immersed in light, can see no darkness anywhere ("and there was light"). Eventually, from the standpoint of the position where the earth is forming (in the equatorial disk of gas and dust), an observer eventually experiences both darkness and light. The light comes from the central, brilliant bulge of the cloud and the darkness from the opposite direction.

Genesis 1.5

And God called the light day, and the darkness he called night. And there was evening and there was morning, one day.

Darkness has been mentioned previously, but only now is it called "night." The same is true for "light" and "day." But just as we ordinarily do not call the darkness of a cave "night," or the light of a lamp "day," it appears that this is the beginning of night and day as ordinarily understood. That is, "one day" in this context is a normal 24-hour day, and we encourage the reader to review our arguments in chapter four to understand why we have come to this conclusion.

Now, it is just at this point in time in our scientific model, when the planet earth condenses out of the equatorial dust and is rotating on its axis (chapter three), that it is proper to identify light with "day" and

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[106] Steve Nadis, "Searching for the Molecules of Life in Space," *Sky and Telescope*, 103 (January 2002), pp. 32 – 37.

[107] E.g., the *New Revised Standard Version* of the Bible (New York, etc.: Oxford University Press, 1986)

darkness with "night." That is, the illuminated side of earth is experiencing day and the darkened side, night. We suggest, then, that the planet Earth becomes a solid body at this point in the Genesis account and not before.

Genesis 1.6-8

Then God said, "Let there be an expanse in the midst of the waters, and let it separate the waters from the waters." And God made the expanse, and separated the waters that were below the expanse from the waters that were above the expanse; and it was so. And God called the expanse heaven. And there was evening and there was morning, a second day.

The word *raqiah*, here translated "expanse" (KJV: "firmament"), means something spread out. Most scholars associate it with the sky; some see it as a huge dome and others as the atmosphere. For several reasons, it appears to us that "firmament" refers to the atmosphere: (1) Nothing is said of any space between the expanse and the lower waters, nor of the expanse moving to separate the waters, so the expanse seems to fill the space between the upper and lower waters. (2) The birds are said to fly "upon the face" of the expanse (Genesis 1.20, literal Hebrew). The preposition *'al* used here means "upon" not "below," suggesting that the birds are flying *upon* the air rather than *beneath* a dome. (3) The Hebrews were well aware that the air supported water in the form of clouds, and the phrase "waters which were above the expanse" is actually broad enough in the Hebrew to describe clouds floating in the sky.[108]

Given this understanding of the expanse, or firmament, the Genesis account then describes the formation of the atmosphere after the earth has become a solid body. The presence of water is indicated in the text, so either the sea is already present, or it is formed simultaneously with the atmosphere.

As noted earlier, many interpreters would put the origin of the earth as a solid body at Genesis 1.2 or before, understanding the "waters" in verse 2 to be the sea. On the other hand, we suggested that the earth was not a solid object at that time and understood the "waters" to be the gas cloud from which the proto-earth was forming. Job 38.8-9 seems to speak of the origin of the seas, an event not explicitly mentioned in Genesis 1:

> Or who enclosed the sea with doors,
> When, bursting forth, it went out from the womb;
> When I made a cloud its garment,
> And thick darkness its swaddling band....

These verses in Job speak of confining the seas in designated locations, but this seems to be the subject of the following two verses (Genesis 1.9-10). Naturally, then, the sea is in existence no *later* than Genesis 1.6-8. But how much *earlier* was it in existence? Not earlier than the solid earth, according to Job. That Job calls the clouds the garment that God put around the sea when it was born suggests that the clouds (and therefore the atmosphere) were present when the sea was formed. To reconcile Job and Genesis, we suggest that the sea "burst forth" from its "womb"—the earth—at the same time that the

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[108] For more detail, see Robert C. Newman, *The Biblical Firmament: Vault or Vapor?* (Hatfield, PA: Interdisciplinary Biblical Research Institute, 2000). Also available as a PowerPoint talk at http://www.ibri.org/DVD-4/NewmanPpt/BiblFirm.htm. (Accessed 16 June 2007)

atmosphere was forming by out-gassing from the earth's interior, and this just happens to be in agreement with modern geophysical understanding.

Therefore, as the second day opens another period of creative activity, the solid earth is completely covered with water and enshrouded with a thick, cloud-covered atmosphere.

Genesis 1.9-10

Then God said, "Let the waters below the heavens be gathered into one place, and let the dry land appear"; and it was so. And God called the dry land earth, and the gathering of the waters He called seas; and God saw that it was good.

The Genesis account strongly implies that the earth was once totally covered with water, after which time dry land appeared. (Even today enough water exists on earth to cover the entire globe to an elevation greater than two miles if the earth were smooth.) So what process brought the dry land out of the water-covered earth?

As discussed in chapter 3, the present crust of the earth consists of two different kinds, one corresponding to the continents and the other to the ocean bottom. The continental-type crust is relatively thick, on the order of 25 to 30 miles, but consisting of lighter sialic minerals. By contrast, the ocean bottom crust is much thinner, usually only 4 to 6 miles thick, and composed of relatively denser siamic minerals.

The original surface beneath the primeval, universal ocean was once like the present siamic sub-oceanic crust. But volcanic activity, which was intense early in earth's history, produced islands and small continents. Volcanic processes, however, separate sialic material from its denser siamic parent (p. 56) through a process known as Bowen's reaction series.[109] Hence, the land that was appearing above the ocean was composed of lighter materials. Erosion of sialic material and its subsequent deposition on the ocean floor also added light, water-laden material on top of the siamic base. As such, continents and continental depositions continued to grow at the expense of areas covered entirely by water.

Throughout this process, convection currents in the mantle continued to carry parts of the crust (tectonic plates) in different directions.[110] Eventually, some plates collided. At the collision boundaries, one of two events occurred: (1) either one plate was dragged under the other by the descending mantle convection; or (2) neither plate "gave way" but continued to push against the other, thereby piling material together and raising the elevation of the collision boundary in the same way that pushing opposite ends of a sheet of paper together on a table raises the paper's middle.[111]

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[109] Any introductory geology text discusses the Bowen reaction series, such as Edward J. Tarbuck and Frederick K. Lutgens, *The Earth: An Introduction to Physical Geology*, 3rd ed. (Columbus, OH: Merrill Publishing Co., 1990), pp. 55-58. One can also find information about the Bowen reaction series online at: http://en.wikipedia.org/wiki/Bowen%27s_reaction_series.

[110] Ascending convection currents from the mantle eventually break through the crust and force plates apart. These are called "divergent" zones." At "convergent zones," currents descend back into the earth. Thus, tectonic plates are constantly being ferried back and forth across the earth's surface by mantle convection.

[111] Plates can also slide past each other, as at the St. Andreas Fault in California, but this kind of boundary is not relevant to our discussion.

Let us consider the first scenario. Both plates consist of the denser siamic material capped by less dense sialic material. As one plate is dragged under the other, the denser material subducts, but the less dense material is too light to sink, so it remains on top. As more and more of the plate subducts, greater quantities of the lighter material pile up at the subducting boundary. Continuation of this process on a global scale eventually builds the continents from sialic material. In this way, an earth completely covered with ocean eventually brings forth what Scripture calls "dry land."

Some Christians have thought the Genesis account suggests a single continent at this point because it speaks of the waters being gathered into "one place," which, on the surface of a sphere, permits only one continent.[112] Proper interpretation of Scripture, however, does not require us to treat the phrase "one place" as though an observer looking at the globe would see only one ocean as the land emerged. This seems to be refuted in the context by the use of the plural *yammim* ("seas") instead of the singular *yam*. Instead, we should understand "one place" as one *kind* of place, namely, ocean basins.

Genesis 1.11-13

Then God said, "Let the earth sprout vegetation, plants yielding seed, and fruit trees bearing fruit after their kind, with seed in them, on the earth"; and it was so. And the earth brought forth vegetation, plants yielding seed after their kind, and trees bearing fruit, with seed in them, after their kind; and God saw that it was good. And there was evening and there was morning, a third day.

The Genesis account first mentions plant life with the appearance of dry land. This is not to say that there was no plant life on earth before this time; rather, an observer would now, for the first time, begin to see life of a size and kind for which there were words in ancient Hebrew.

This passage mentions the creation of fruit trees before the later creation of animals. At first, this seems to be at odds with the fossil record, which clearly shows numerous animal kinds were created before the appearance of fruit trees. One must keep in mind, however, the scheme previously suggested for the days of Genesis 1: These are 24-hour days that introduce new creative periods; they are not the creative periods themselves. As such, creative periods overlap (refer to figures 8 and 9), so it is not necessary to suppose that the fruit trees of this passage were created before any kind of animal life.

Instead, this passage simply states that the creative period involving land vegetation began before the later creative periods of the animals. In any case, since Genesis one mentions vegetation only once in the whole account, it is possible that all vegetation is mentioned together merely for economy of expression, or to indicate its significance as the foundation upon which animal life, including humans, builds.[113]

Without further revelation, it is not possible to say for certain why God chose to introduce the plants at this point in the narrative, but it is undeniably logical for the appearance of land to precede land vegetation! Also, since the Genesis account seems to be aimed at humans as the climax of God's

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[112] This would fit the geologists' picture of the continent Pangaea, which later broke up into Laurasia and Gondwanaland. The current data, however, are not yet sufficient to support such a conclusion. The geological evidence for a single continent goes back only a few hundred million years, which is long after the original dry land appeared. Much more geological research is necessary in order to determine the situation that existed when dry land first appeared from the ocean.

[113] We note that Genesis chapter two explicitly mentions fruit trees. It may be, therefore, that the account is setting up the discussion for chapter two by indicating that the garden into which Adam was placed was already created back in day 3.

creation, the account naturally proceeds from the creation of the non-living environment, to vegetation, and then to the animal environments as prerequisites to human life.

The only real exception to this logical order occurs during the creative period opened by day four. Genesis 1.14-19 narrates what seems to be one of the most significant and striking details of the whole creation account.

Genesis 1.14-19

Then God said, "Let there be lights in the expanse of the heavens to separate the day from the night, and let them be for signs, and for seasons, and for days and years; and let them be for lights in the expanse of the heavens to give light on the earth"; and it was so. And God made the two great lights, the greater light to govern the day, and the lesser light to govern the night; [He made] the stars also.

And God placed them in the expanse of the heavens to give light on the earth, and to govern the day and the night, and to separate the light from the darkness; and God saw that it was good. And there was evening and there was morning, a fourth day.

Traditionally, it has been held that the sun and the moon did not exist until this point in the creation account. Such a view is still maintained by young-earth creationists. We know today, however, that sunlight and the earth's rotation cause the day-night sequence. It seems gratuitous, therefore, to suppose that on day four God substituted the sun for some other unspecified source of light (previously created in Genesis 1.3) without any statement to this effect.[114] In addition, the Genesis account has already mentioned atmospheric water, and Job 38.9 speaks of clouds and "thick darkness" covering the seas. Hence, it is more reasonable to suppose that Genesis 1.14-19 describes the breakup of the earth's cloud cover as seen by an earthbound observer who witnesses the first *appearance*—rather than the creation—of the sun, moon, and stars now that the cloud cover breaks up.

It is worth noting that the Genesis account emphasizes the purpose of these heavenly bodies: (1) to appear as lights in the sky to mark off seasons, days, and years;[115] (2) for the sun and the moon to dominate the day and the night, respectively. These purposes could not be accomplished if clouds continually covered the sky, even if the clouds were sufficiently thin for diffuse sunlight to produce a definite period of daylight. Until the clouds had cleared enough to expose the sun, an earthbound observer would not be able to see what was producing the day/night sequence.

If this is the proper understanding of Genesis 1.14-19, then the sequence of the Genesis account is striking indeed. The author delayed one important aspect of the physical environment—the final clearing and preparation of the atmosphere in its present breathable form—until after he mentioned the plants.

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[114] Henry Morris, however, insists on such gratuity. He states, "…light rays were impinging on the earth as it rotated on its axis during the first three days of essentially the same intensities and directions as those which would later emanate from the heavenly bodies to be emplaced on the fourth day. Light was coming during the day as though from the sun and during the night as though from the moon and stars, even though they had not yet been made." *The Genesis Record: A Scientific and Devotional Commentary on the Book of Beginnings* (Grand Rapids: Baker Book House, 1976), p. 65.

[115] We note that the word for "seasons" refers to festival seasons, not climatic seasons. One needs to see the progression of the sun and the moon—along with the moon's phases—amongst the stars to determine the precise start of festivals, months, and years.

This appears at first to be an illogical "wrinkle" in the otherwise ordered sequence of the Genesis account. But as we stated in chapter 3, vegetation was the immediate cause of the oxygenation of the atmosphere and the removal of the cloud cover. Hence, there is no "wrinkle," and the appearance of - vegetation in the narrative prior to the appearance of the sun, moon, and stars is quite natural.

Summary

Figure 9 summarizes the thesis of this book. The long, horizontal bars in are creative periods, but these periods are not identified with the days of Genesis 1. The days are represented by the narrow, vertical bars. The creative periods overlap. Although they begin in sequence, they end together at the seventh day (still future) when God will have completed the creation begun in Genesis 1.1.

We submit that the creation events described in Genesis took place over a long period of time, are subdivided into six parts, and each part is introduced by a literal day. Some of the activity initiated in each of the creative periods continues through today.

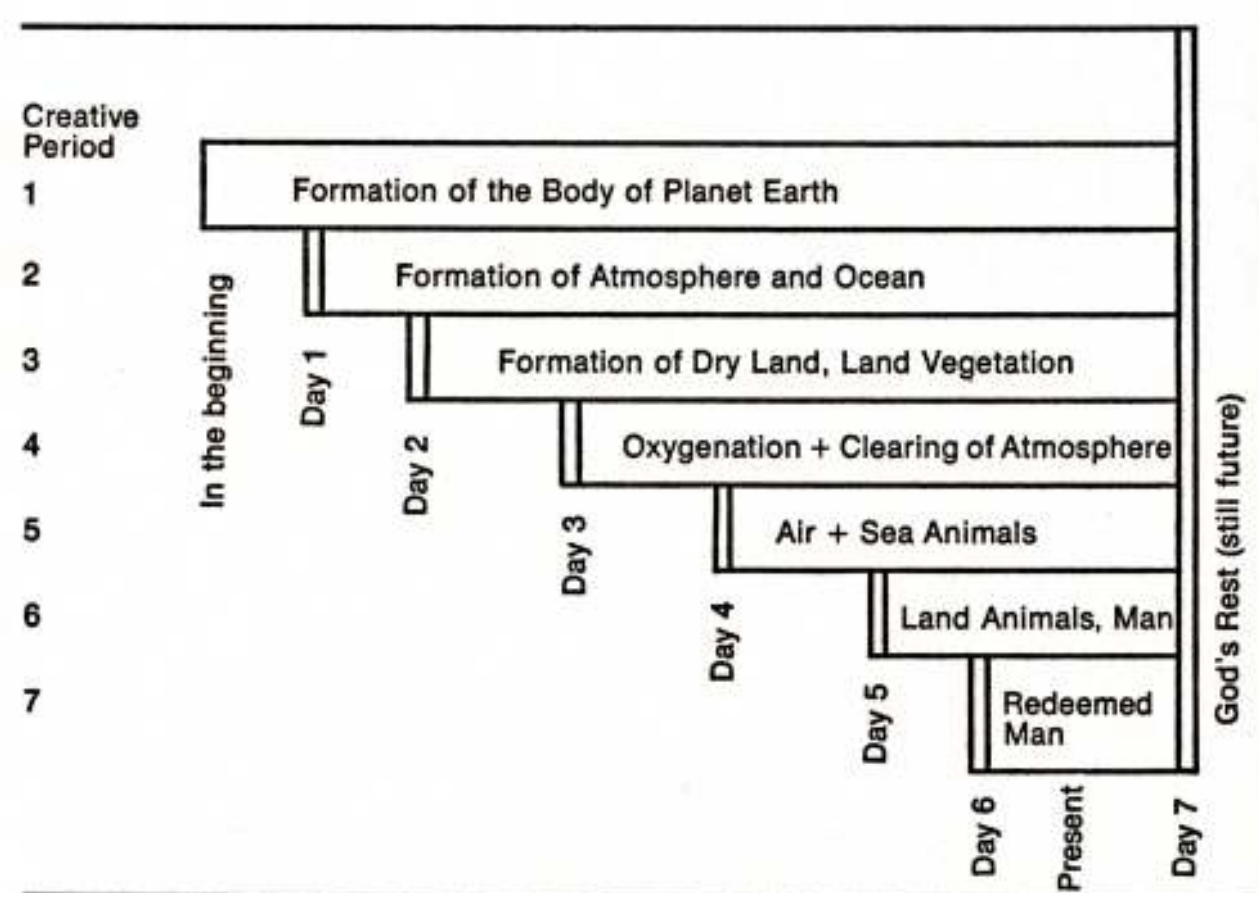

Figure 9: Diagrammatic synopsis of creative activity according to proposed modified intermittent day view.

More specifically, God began his creation some 14 billion years ago with the Big Bang. Earth's creation came later through the process of accretion, and its bulk structure was essentially completed 4.6 billion

years ago. Accretion was the method that formed the earth, and even today the earth continues to gather small quantities of meteoritic material.

Likewise, the major activity in forming the atmosphere and the ocean occurred long ago, but volcanoes continue to bring smaller amounts of gases and water to the earth's surface. Similarly, continental drift (or plate tectonics), which brought about the appearance of dry land, continues shifting the crust of the earth, occasionally producing more dry land in the process, though its major work in creating new dry land is over.

Land vegetation was created long ago, yet God built into it an adaptability to meet changing environments. The original clearing of the atmosphere occurred through the silicon-carbon dioxide cycle and the appearance of large quantities of vegetation. Plant life continues to protect animal life from asphyxiation by converting carbon dioxide to oxygen. Forests, especially in the northern hemisphere, snare carbon dioxide out of the atmosphere. Ocean algae and plankton turn carbon dioxide into limestone, and the silicon cycle sequesters large amounts of carbon dioxide in the earth's mantle. These factors, in turn, prevent a planetary "heat death" (as on Venus) by moderating the earth's greenhouse effect. All of these processes cleaned up (and continue to clean) the earth's atmosphere so the sun, moon, and stars are observable from earth.

The most unusual feature of this model is that day seven is in the future, The present age is characterized as principally concerned with the creation of redeemed human beings (that is, the redemption of fallen humans). As pointed out in chapter 4, Hebrews 4.1-11 indicates that God's Sabbath rest described in Genesis 2.2 was either present or future in the first century A.D. In John 5.17, Jesus portrays God as still creating at that time, so the Sabbath rest appears to be future. We suggest that the redemption of creation from the bondage to which God subjected it (Romans 8.18-25), the appearance of the new heavens and the new earth (Revelation 21.1-8), and the beginning of God's complete rest will be heralded by a literal seventh day.

But what is the significance of these peculiar literal days in the proposed model? After all, even though each day introduces a new creative period, only the seventh marks the complete cessation of creative activity of the previous periods. Our suggestion is that God highlights these seven days, among the many actually occurring during creation, in order to set up an ordinance by which humans are to commemorate creation. Six days of work remind humans that God created them along with the rest of the world in which they live and work. The seventh day of rest looks forward to God's complete rest when redeemed humans will rejoice with all creation in the new heavens and the new earth (Romans 8.18-25; Hebrews 4.1-11, Revelation 21.1).

One also finds the practice of highlighting one feature in a context in other covenantal enactments of God. The rainbow, for example, is taken from among the events following the flood as a sign of God's covenant with Noah (Genesis 9.13). Bread and wine are taken from a Passover supper as a sign of Christ's covenant with believers (Mark 14.12, 22-24). In each case (the rainbow, bread and wine, and the seven days of the week), the sign looks both backward (to the flood, Genesis 9.11; to Christ's death, Mark 14.22-24; to the Creation, Exodus 20.11) and forward (no future destruction by water, Genesis 9.15; Christ's coming kingdom, Mark 14.25; the new heavens and new earth, Hebrews 4.1-11).

Our scheme also correlates well the Biblical information with the scientific theory on the formation of the earth. Figure 10 displays the principal parallels between the Biblical materials and scientific theory.

Biblical Material (see chap. 5)	**Scientific Theory (see chap. 3)**
In the beginning God created heaven and earth (Gen. 1:1)	A beginning—the "big bang," perhaps
Earth without form, void (Gen. 1:2)	Earth an amorphous, tenuous nebula
Darkness on face of deep (Gen. 1:2)	After some contraction, cloud becomes opaque, dark within
Spirit of God moves on face of waters (Gen. 1:2)	(Providential oversight and occasional intervention)
Let there be light (Gen. 1:3)	Further contraction causes cloud to glow
Light divided from darkness (Gen. 1:4)	Planetary material thrust outside glowing cloud
Light = day, darkness = night (Gen. 1:5)	Planet condenses from planetesimals; sun and rotation give day-night sequence
First day intervenes (Gen. 1:5)	
Waters burst forth from womb of earth (Job 38:8-9); firmament appears in midst of waters (Gen. 1:6)	Earth is heated within by pressure and radioactivity, driving out water and gases to form atmosphere and ocean
Division of waters above and below firmament (Gen. 1:6-7)	Presence of atmosphere allows both surface and atmospheric water
Second day intervenes (Gen. 1:8)	
Gathering of waters, dry land appears (Gen. 1:9-10)	Continental material develops from sub-oceanic by means of vulcanism, erosion
Earth brings forth vegetation (Gen. 1:11-12)	Land vegetation appears
Third day intervenes (Gen. 1:13)	
Lights appear in the sky to mark off days, seasons, to dominate day (sun) and night (moon) (Gen. 1:14-18)	Photosynthesis by vegetation replaces CO_2 by oxygen, lowering temperature and clearing atmosphere so astronomical objects visible; also prepares atmosphere for animals and man
Fourth day intervenes (Gen. 1:19)	

Figure 10: Proposed correlation between Biblical materials and scientific theory.

Conclusion

In this work we have made some unusual suggestions for correlating Genesis 1 with modern scientific understanding of the origin and the early history of the earth. Although we believe this scheme fits the Biblical and scientific evidence better than others, we are not so presumptuous as to claim that we have the "last word." Rather, we add our proposal to the "marketplace of ideas" for discussion and critique in the hopes of advancing thinking along the science/theology interface in this area of origins.

Obviously, theories change as knowledge is gained. In the Biblical arena, with millions of people again speaking (modern) Hebrew as their native language, a much stronger foundation now exists for understanding the ancient Hebrew in which the Old Testament was written. The advance of archaeology, which has made enormous strides with the creation of the modern State of Israel, continues to aid our understanding of the Biblical world. Further aid is to be expected for our comprehension of ancient Hebrew as archaeology continues to uncover and to assimilate materials written in this and its cognate languages. Our understanding of the Bible will only improve with time.

From the side of science, enormous progress was made during the 1990s, which continues unabated into the 21st Century. Evidence in support of an inflationary Big Bang continues to pour in from the Hubble Space Telescope and from intricate radio and infrared investigations with exotic acronyms such as BOOMERANG, DASI, CBI, WMAP, and Maxima. These latter experiments build on the COBE satellite measurements of the early 90s that revealed the variations in the cosmic background radiation expected from Big Bang cosmology. Recent discovery that this radiation is polarized adds further evidence in favor of the Big Bang. In spite of young-earth protestations, the Big Bang is on very solid footing.

The Pioneer and Voyager probes of the 60s and 70s opened the doors for investigation of the rest of the solar system. Space probes continue to deliver outstanding photographs and other data from our planetary neighbors. Probes have collected data from Jupiter and Saturn – including their moons – analyzed soil on Mars, penetrated the cloud cover of Venus with radar to give us high resolution maps of its surface, and photographed the core of a comet. All this information helps us to piece together the history of the solar system and to enhance our understanding of our environment beyond the imagination of earlier investigators.

Large ground-based telescopes and interferometers have detected other stellar systems with planets comparable to Jupiter. We have identified stars surrounded with gas and dust—along with proto-planetary disks—similar to what we believe gave birth to our own solar system. All of this supports current theoretical models for stellar and planetary formation. The solar nebular theory is alive and well, thank you!

For those already convinced that the Bible is a reliable revelation from God, these times provide exciting opportunities to serve the Lord in proclaiming his Word to a world in desperate need of salvation. In our technological and scientific age, careful research in the interaction between theology and science can be an important means to this end. But to speak authoritatively, we must become thoroughly conversant with modern scientific results that impinge on topics we wish to address. We must also renew our dedication to Biblical exegesis to be sure that we are analyzing Scripture correctly and not just carrying over mistaken constructs of former exegetes. Only then will God's words and his works illuminate us

and provide us the knowledge to remove stumbling blocks from a world that, so frequently, sees only conflict between science and theology.

We hope that this book will encourage Christians to believe that God has communicated basic (and even complex) scientific truths in the non-technical vocabulary of ancient Israel, and that it is not necessary to limit the message of the first two chapters of Genesis to nothing more than the statement "God is really behind it all, however it happened." We also hope that Christians may realize that scientific research can perform a real service, just as archaeology has, in helping us to re-examine and retest traditional interpretations of various Biblical passages.

For those who feel that the scientific veracity of Scripture has been discredited since Galileo or Darwin, we hope this work will cause a sympathetic re-examination of orthodox Christianity that will lead to the Biblical Jesus of history, who alone can meet every need.

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Appendix 1: Non-radiometric Data Relevant to the Question of Age

Daniel E. Wonderly

Within the past twenty years several useful types of age indicating data have become available. An abundance of objective research reports on these subjects can now be easily found in scientific journals and other publications. It is time for creationists to begin to make far more use of such reports than we have in the past. We have often failed to realize that these are very helpful in making estimates of the earth's age. The record of God's work in nature is far more complete, informative and worthy of consideration than creationists have usually thought.

It is our purpose here to list some of the specific types of data available, giving a few selected bibliographic references for each type. These sources have been carefully chosen with a view to their being sufficient to serve as at least a "starter" for anyone wishing to pursue a given subject. Most of the sources themselves also have good bibliographies, which will readily enable any interested person to locate numerous additional articles on the subject. An effort has been made to choose those articles and monographs that consist primarily of the objective results of research rather than of theory. However, in the references in which evolutionary theory may appear the presence of some theoretical material need not obscure the facts that were obtained in the research. The reader should keep in mind, for example, that long periods of time do not necessarily imply evolutionary development. All of the types of data which are listed below appear to be in keeping with the historical account of creation found in Genesis 1 and 2.

Most of the bibliographic entries are available at the geology library of practically any large university. Other materials can be obtained from the geological societies of major oil-producing states and by means of interlibrary loans. The addresses of most of the geological societies can be found in the Directory near the back of each issue of the American Association of Petroleum Geologists Bulletin. Many of the sources can be used and understood without an extensive background in geology. This paper is basically a listing of types of data, rather than a composite monograph. Thus the reader will be able to consider any one subject separately and locate the bibliographic references for that subject easily.

Highly Organized Carbonate Deposits

Drilling records from the sedimentary carbonate deposits of the Great Bahama Bank, off the coast of Florida, indicate a multilayered deposit of various forms of limestone and dolomite somewhat in excess of 14,500 feet in thickness. In the deeper parts, dolomites alternate with limestones, with evidence of erosion between four major cycles of deposition. Identifiable fossils were found to a depth of at least 10,600 feet. Alternations between limestone and dolomites in this and similar formations indicate at least a corresponding number of changes of environment during deposition and during the process of dolomite formation. (See below on dolomite formation and limestone formation.) Also, the unconformities, at the levels where erosion is revealed, must represent significant amounts of time.[1]

[NOTE: The endnotes for each appendix appear in the "Notes for the Appendixes" section, p. 105.]

Ooids Formed Gradually

The distribution and rates of formation of the small, spheroidal bodies known as ooids, oolites (more properly refers to rocks containing the individual ooids) or ooliths yield evidence of the earth's age. Most ooids are concentrically laminated around a core of extraneous material such as a grain of sand, a small shell fragment or a recrystallized fecal pellet. This process of adding concentric layers (which can be readily observed with a microscope) is accomplished by a slow accretion of mineral that is extracted from the seawater on the beach where the ooids are being formed. The present-day formation of carbonate ooids is observable on numerous shores where shallow water carbonate deposition is taking place. Oolitic limestone, with ooids of various types, appears at numerous levels in the Great Bahama Bank and in many other carbonate deposits.[2]

Modern Sediments Compared to Ancient

The similarities between the order of deposition of present-day marine sediments and the order found in deep subsurface sedimentary deposits in oil fields are now being used by oil research geologists for understanding and predicting the arrangement of older deposits deep in the earth. The research also deals with paleogeological topics, such as the faunal associations and ecological succession found in ancient strata, comparing them to modern faunal associations observed in shallow-water depositional environments. Even though we cannot accept all the tenets of uniformitarianism, the close similarities between modern marine carbonate deposition and these ancient deposits demand that we recognize slow, natural deposition as accounting for many thick carbonate deposits in the oil fields.[3]

Oceanic Sedimentation

Oceanic sedimentation refers to the thickness and arrangement of the layers of carbonate and siliceous skeletal remains found on the ocean floor, formed by the accumulation of the shells of Foraminifera, Radiolaria and other planktonic organisms. A comparison of the thickness of such deposits with current rates of deposition of these skeletons in parts of the ocean floor where there is no evidence of rapid deposition or recent disturbance is meaningful. Of special significance are the pelagic sediments found in isolated parts of the ocean, such as the tops of certain seamounts and abyssal hills. These are far enough from landmasses that the rate of deposition is not appreciably affected by currents bringing sediments from those land masses.[4]

Fossilization Still Occurring

It has sometimes been said that the processes of fossilization are not occurring today, but recent studies have revealed numerous cases of the current burial and fossilization of calcareous plant and invertebrate animal skeletons in marine coastal environments, on the sea floor and in the subsurface of modern reefs.[5]

Dolomite Formation

The rate of dolomite formation in modern marine environments has been usefully compared to a study of ancient formations that exhibit alternating dolomite (dolostone) and calcium carbonate (limestone) strata. In recent years the process of natural dolomite production has been observed and studied in several marine environments that have the proper conditions for the necessary magnesium ions to be extracted from the seawater and deposited. There are many lines of very strong evidence indicating that practically all dolomites—both ancient and modern—are formed by a process of replacement of calcium

carbonate particles in lime sediment or limerock. In order for dolomitization of such a sediment or rock to occur there must be a ratio of Mg and Ca ions in the water which will favor the formation of dolomite, and there must be extensive circulation of the water over the sediment or through pores in the rock. Because dolomitization proceeds by ion exchange, it is of necessity a slow process and cannot occur to any appreciable degree without extensive circulation of water.[6]

Deposits of Evaporites

Multilayered deposits of the (water-soluble) evaporites anhydrite and salt often alternate not only with each other, but also with (relatively insoluble) calcium carbonate layers. The Castile Formation of west Texas and southeastern New Mexico is one such deposit. Its thickness is in excess of 2,000 feet in some places, and includes approximately 200,000 calcium carbonate-anhydrite "couplet" layers. The nature of these thin layers of anhydrite and of calcium carbonate definitely shows that they were deposited by precipitation. It should be remembered that these two substances do not precipitate at the same degree of concentration of the seawater. Calcium carbonate begins to precipitate when the sea water has been evaporated to about half the original volume, but the precipitation of anhydrite does not begin until a volume of about 19% has been reached.

Thus it is evident that a major change in the concentration of the seawater took place 200,000 times, the concentration returning each time to at least very near the same value. Furthermore, each of the precipitation events had to be accompanied by quiet water to allow the mineral to settle to the bottom and form a thin, uniform layer. (The areal extent of these layers is many miles, with almost uniform thickness of any given layer maintained over at least a distance of 18 miles.) These are processes that required very considerable amounts of time.

Another very significant evaporite formation which shows conclusive evidence that it was formed slowly is that found in the Mediterranean Sea. In several areas core drillings beneath the sea floor have revealed repeating layers of fossil-bearing oceanic sediments interbedded with evaporite layers. This shows that the Mediterranean Sea has had a long history encompassing several extended periods of very low water and desert-like evaporative conditions, alternating with periods of normal marine deposition of sediments. Since neither the evaporative nor the normal marine sediments are of the types which could have been deposited by rapidly moving water, or in the aftermath of a flood, we are forced to recognize that the deposition time for this alternating series of sediments extended over several millions of years. Also in the Balearic abyssal plain, west of Corsica and Sardinia, a "bulls-eye pattern" of evaporite deposition was found. In this deposit, layers of calcium carbonate, calcium sulfate, and salt were found in the normal order of precipitation when evaporation of sea water occurs. There is good evidence that this evaporite deposit is a few thousand feet in thickness.[7]

Deposits of Sandstone and Shale

An example of multilayered deposits of sandstone and shale is found in the Haymond Formation in the Marathon region of Texas. There are approximately 15,000 thin sandstone layers alternating with approximately the same number of contrasting shale layers in this formation. The study of such a deposit requires that we carefully consider the length of time required for the clay particles, which formed each layer of shale, to settle out of suspension. The clay particles that form uniform layers such as this are extremely small. Thus they settle slowly and only when a minimum of turbulence exists.[8]

Modern Coral Reefs

The thicknesses of modern coral reefs, when related to the growth rates of reef-forming organisms, imply an old earth. The thickest deposit of this kind measured to date is that of the Eniwetok atoll, where the test drill penetrated 4610 feet of coral deposit before reaching the volcanic seamount on which the reef was built. A study of such deposits in the light of present-day coral growth rates cannot produce an exact chronology of the past, but will nevertheless be very meaningful. This is so because of our recognition of the stability of God's natural laws, including the laws of nutrition, respiration and secretion in living organisms. According to detailed and extensive studies by A. G. Mayor (1924) on the growth rates of various genera of corals in the Samoan Islands (a tropical area where conditions are most favorable for rapid growth), the maximum rate of upward growth of the reef surfaces was only about 8 mm per year.[9]

Ancient Coral Reefs

In the oil fields of Canada there are ancient coral reefs, or atolls, which are frequently covered with extensive deposits of evaporites and other minerals. This is a geographic area where the process of comparing modern reefs and other modern carbonate deposits with the ancient has yielded spectacular results in predicting the best drilling sites (cf. reference 3). Some of the atoll reefs in the Rainbow Lake area of Alberta, Canada are 800 feet thick at the rim, and are strikingly similar to the crescent-atolls of the present-day Great Barrier Reef of Australia. The Rainbow Lake reefs contain abundant massive growths of colonial corals *in situ* (growth position), as well as crinoids, stromatoporoids, brachipods and gastropods. Thus, these were genuine, wave-resistant reefs that grew in ancient times when most of central North America was covered by relatively shallow ocean waters. The multiple layers of evaporites and other thick mineral deposits covering these reefs witness to the long periods of time which have elapsed since that geological period (the Devonian).[10]

Coral Growth Bands

Growth bands, exhibited by ancient and modern corals and mollusks, appear to be an accurate indicator of the daily growth rates of these organisms, as well as of the number of days in the year at the time when the animal was living. It has been known since the beginning of this century that the corallites of some kinds of modern corals possess annual growth bands. Within the last decade it has been learned that these corals possess two lesser orders of growth bands or ridges between the annual rings, one marking the growth increments of synodic lunar months, the other the increments of daily growth. When certain fossil corals from the deeper strata, e.g., from Devonian rocks of New York and Ontario, are examined, they are found to show growth bands very similar to those of modern corals, except that the number of daily bands between annual bands is approximately 400 instead of 365. This apparently indicates that these corals lived at a time when there were 400 days in the year, and consequently slightly less than 22 hours in the day. (The calculations of astronomers have shown clearly that the rate of rotation of the earth is decreasing, but that the period of the earth's revolution around the sun has been essentially constant. Thus, in earlier times, though the absolute length of the year was the same as now, the earth's rotation was more rapid, making the day shorter and also affecting the number of lunar—and tidal—months in a year.) The growth rings on the Devonian corals thus show that they lived and grew at a very early date; and the size of the rings shows that the growth rates of these corals were not very

different from the growth rates of modern corals. The growth bands that have been observed on certain ancient bivalve mollusk shells are in essential agreement with the findings in corals. [11]

Organic Banks

Various types of ancient carbonate organic banks and cyclic deposits include layers of definite, identifiable fossils. The larger of these banks are usually spoken of as reefs in geologic literature. Examples are the famous "Horseshoe atoll" (or Scarry reef) of west Texas, the numerous Silurian reefs of Indiana, and the Capitan reef of west Texas and New Mexico. Organic banks which are mound-like in shape and enclosed in rock of a contrasting type are usually called bioherms, though the terms reef and bioherm are often applicable to the same structure.

Some of these organic banks are very large, lie at great depths and are components of extensive local stratigraphic columns. For example, the Capitan reef is 350 miles long and 2,000 feet thick in places; its eastern half lies in a large oil field at a depth of some thousands of feet. Numerous alternating layers (cyclic deposits) of evaporites make up an extensive part of the formations that cover it. This reef has numerous bryozoan colonies and other fossils still in growth position (*in situ*). Beneath the Capitan reef there are, in some localities, more than 15,000 feet of sedimentary rock. This rock consists of numerous distinct layers of limestone, dolomite, sandstone, shale, etc., alternating with each other. Most of these deep layers underlying the reef possess identifiable fossils.

Often an organic bank will be associated with, or a part of, a group of repeating depositional units called cyclothems. A cyclothem is a series of sedimentary layers that repeats itself in the stratigraphic record in a particular locality. Each cyclothem represents the depositional results of a series of changing environments in the ancient locality involved. The fact that several very similar cyclothems sometimes exist in a local stratigraphic column, and that evaporite layers and other environmental indicators frequently make up a part of each cyclothem, is conclusive evidence that these are naturally formed series representing rather large units of time. It is also significant that some cyclothems contain sub-cycles.

Calcareous algal limestone banks and mounds are often found lying deep in the strata of oil fields. These are, of course, a type of organic bank, having been produced by calcium-secreting algae that are similar to the many species of calcareous algae that we have today. The fossilized remains of the algae in these banks give every evidence of being *in situ* and of having accumulated in a manner similar to the formation of algal deposits in modern tropical marine environments.

Recent extensive research has shed much light on the true nature of limestones such as those found in the organic banks. The study of the various types of organic banks, together with a comparison of the carbonate depositional processes in modern marine environments, has shown that a very high percentage of the limestone deposits of the earth was formed by the gradual accumulation of calcareous animals and plants rather than by inorganic processes. Even though diagenetic change obliterates many of the skeletons of these organisms, sufficient parts usually remain (with some of the substrate material on which they were growing) so that we can be sure, at least in many cases, that they were preserved either at or near the place where they grew. Since most limerocks have large amounts of microscopically identifiable particles, it has been observed that the layers of major limestone deposits are usually composed of normal assemblages of grains and other characteristic particles. These are frequently very

similar to the assemblages found in modern carbonate rock-forming environments such as those of the Caribbean area and other parts of the world.

Often the fossils found so abundantly in a given bed of limestone make up a typical marine faunal and floral community, and a significant percentage of the delicately articulated skeletons will be intact, showing that they were not transported any long distance. Also, the lack of signs of abrasion of certain carbonate grains, such as fecal pellets, in the rock, and the lack of size-sorting of the various types of grains are further evidence that the limestone was formed in situ without extensive transport of the materials of which it is composed. One of the most spectacular examples of evidence for the *in situ* formation of limestones as a result of the growth of organisms is the rounded, laminated masses of limestone that are called stromatolites. Extensive study of very similar structures being formed today in some carbonate depositional environments has made possible a detailed analysis of the ancient stromatolites. (Each stromatolite is formed by a large mass of algae growing in the water and collecting layers of carbonate grains on its gelatinous surface as the water sweeps over it.)

The presence in many formations of layers of shale between the layers of limestone has usually aided in the preservation of the skeletal material and in the identification of the environments in which the limestone layers were accumulated.[12]

Stratigraphic Columns

Well logs and drilling cores from oil fields provide us with the structure and composition of entire local stratigraphic columns. In the past we have too often neglected to study the deeper parts of the local stratigraphic columns in areas where we have focused attention upon a single geologic formation. There now are available in the literature of petroleum geology very complete records of the local columns in many geographic areas. For example, Hughes (1954) gives the 16,705-foot column of the Richardson and Bass No. 1 Harrison-Federal well, in the Delaware Basin of southeast New Mexico, as a 167-inch printed column. By devoting one inch to each 100 feet of well core he was able to show the lithology of the entire well in considerable detail. Also included are the generic names of some of the fossils, to a depth of 16,000 feet. Such records as this help make possible a study of both the chemical and physical nature of the contrasting layers in the column, as well as of some of the types of animals and plants present at the times of deposition. The availability of these well logs and drilling cores makes it possible for interested persons to study the geologic record directly, without having to depend on composite columns or abbreviated summaries.[13]

Distribution of Marine Fossils

Marine fossils are distributed unequally in limestone and other formations. An example of this is the abundance of certain kinds of very dense, thick-shelled mollusks of Class Pelecypoda in the upper strata, but the absence of the same types in lower layers. Conversely, some of the less dense animals, for example, numerous species of arthropods of Class Trilobita, are abundant in lower strata but are not found in upper layers. Recent electron microscope studies of the chitin of trilobite skeletons give evidence for a low density for these animals. Similarly, many species of the cephalopods, of Phylum Mollusca, though very buoyant due to the air chambers of their shells, are found only in the deeper strata of the earth, indicating that they were buried before the formation of the Mesozoic and Cenozoic strata and became extinct before those strata were laid down. Thus, the unequal distribution of marine fossils is

another indication of the long history that these organisms have. The theory of some proponents of "flood geology," which says that the unequal distribution is largely due to densities, is erroneous.

Even the very fact that many types of fossils are abundant in only a small percentage of the stratigraphic column in a given locality, but not found at all in other parts of that column, should be a cause for much serious study. In such columns a great many species, which are present at the lower levels, are not present in the upper strata at that site, or in the corresponding upper strata at other sites. The prevalence of this condition calls for recognition of a long period of time for the formation of the larger (thicker and more extensive) stratigraphic columns.[14]

Forest Deposits

Data collected during the study made by Dorf and his associates of the multiple forest deposits in Yellowstone National Park apparently have not been used to any extent by creationist writers. Numerous types of fossil vegetation and preserved foliage were discovered in the strata of Specimen Ridge and Amethyst Mountain. Whitcomb and Morris have tried to explain these forest deposits by saying the trees were floated into place during the Flood, forming a semblance of successive forests preserved in volcanic ash. The work of Dorf makes this theory completely unacceptable.[15]

Sea-Floor Spreading

Present and past rates of sea-floor spreading are exhibited in the oceanic ridges and in the thickness of pelagic sediments that lie upon the ocean floor at various distances from the present midline of the ridges. The present rate of sea-floor spreading along the Mid-Atlantic ridge is estimated to be only a few centimeters per year. The fact that the sediments are thin near the centerline of the ridge and become thicker farther away from the ridge, on each side, is an indication that the spreading has been practically continuous for a long period of time. Also, the linear strips of igneous rock that lie to the west of the ridge are practically identical to the linear strips extending along the ridge's east side. Thus, one side forms a "mirror image" of the other with respect to the chemical and magnetic nature of the parallel trends of igneous rock. This gives us much reason to believe that each pair of corresponding strips was formed at approximately the same time, from the same mass of magma along the ridge, and that the slow spreading of the floor at the rift has resulted in their being widely separate now. The above-mentioned symmetry along the Mid-Atlantic ridge has been carefully mapped, and the two sides correspond for a distance of about 125 miles out from the center of the ridge.[16]

Magnetic Reversals

Geologic records indicate magnetic reversals in igneous bodies of rock (both on the continents and in the ocean floors) and in sediment cores taken from the ocean floor. A great many extensive rock masses exhibiting an orderly series of reversals have been discovered during the past ten years. For example, there is a close agreement between the series of reversals found in ancient lava flows of the Rocky Mountains and those in the Atlantic sea floor. There are many strong evidences that most of the reversals which are "frozen" into the igneous rocks are separated from one another by at least hundreds of thousands of years.[17]

Potassium-Argon "Clock"[116]

Even though we are here presenting a list of types of non-radiometric data, there is one phase of radiometric dating which should be mentioned because it has apparently gone unnoticed by a great many creationists.

The potassium-argon "clock," in rocks which effectively retain radiogenic Ar^{40}, is restarted whenever the rocks are heated (or reheated) to a temperature of 300°C or more. Recent writers on this type of dating state that all original argon is lost when such heating of igneous and metamorphic rocks occurs. Thus, when the amount of argon present is measured, only the amount produced in the rocks since they were last heated can be detected. This characteristic is often listed as a disadvantage, because this means that potassium-argon dates can give only the length of time since the rock mass was last cooled to a temperature below 300°C. However, this feature is an advantage for those who are interested in determining how long it has been since igneous or metamorphic rock masses were in a heated condition. Perhaps we should also mention that Dalrymple, Moore and others recently discovered that some of the earlier potassium-argon dates obtained for igneous rocks which had been formed in deep water were very incorrect (much too old). Their research showed that whenever lava is erupted into a deep-water environment, the hydrostatic pressure and the rapid cooling caused by the cold water cause excess Ar40 to be "frozen" into the outer parts of the lava mass. Earlier, when this principle was not known, numerous samples of marine volcanic basalt were wrongly dated. However, now that the scientific world has been alerted to this principle, only the potassium-argon dates from continental formations and from samples taken from the interior of submarine masses of rock are considered reliable.[18]

[116] We have kept Dan Wonderly's original material of K/Ar dating in this legacy article. For a fuller discussion, see p. 29.

Appendix 2: Primeval Chronology

William Henry Green[1]

The question of the possible reconciliation of the results of scientific inquiry respecting the antiquity of man and the age of the world with the Scripture chronology has been long and earnestly debated. On the one hand, scientists, deeming them irreconcilable, have been led to distrust the divine authority of the Scriptures; and, on the other hand, believers in the divine Word have been led to look upon the investigations of science with an unfriendly eye, as though they were antagonistic to religious faith. In my reply to Bishop Colenso in 1863, I had occasion to examine the method and structure of the Biblical genealogies, and incidentally ventured the remark that herein lay the solution of the whole matter. I said:[2]

> There is an element of uncertainty in a computation of time which rests upon genealogies, as the sacred chronology so largely does. Who is to certify us that the antediluvian and ante-Abrahamic genealogies have not been condensed in the same manner as the post-Abrahamic?
>
> . . .Our current chronology is based upon the *prima facie* impression of these genealogies.... But, if these recently discovered indications of the antiquity of man, over which scientific circles are now so excited, shall, when carefully inspected and thoroughly weighed, demonstrate all that any have imagined they might demonstrate, what then? They will simply show that the popular chronology is based upon a wrong interpretation, and that a select and partial register of ante-Abrahamic names has been mistaken for a complete one.

Further reflection has confirmed me in the correctness of the opinion then expressed.

At the courteous request of the Editors of the *Bibliotheca Sacra* I here repeat, with a few verbal changes, the discussion of the Biblical genealogies above referred to, and add some further considerations which seem to me to justify the belief that the genealogies in Genesis chapters 5 and 11 were not intended to be used, and cannot properly be used, for the construction of a chronology.

Genealogies Frequently Abbreviated

It can scarcely be necessary to adduce proof to one who has even a superficial acquaintance with the genealogies of the Bible, that these are frequently abbreviated by the omission of unimportant names. In fact, abridgment is the general rule induced by the indisposition of the sacred writers to encumber their pages with more names than were necessary for their immediate purpose. This is so constantly the case, and the reason for it so obvious, that the occurrence of it need create no surprise anywhere, and we are at liberty to suppose it whenever anything in the circumstances of the case favors that belief.

The omissions in the genealogy of our Lord as given in Matthew 1 are familiar to all. Thus in verse 8 three names are dropped between Joram and Ozias (Uzziah), namely, Ahaziah (2 Kings 8.25), Joash (2 Kings 12.1) and Amaziah (2 Kings 14.1); and in verse 11 Jehoiakim is omitted after Josiah (2 Kings 23.34; 1 Chron.3.16); and in verse 1 the entire genealogy is summed up in two steps, "Jesus Christ, the son of David, the son of Abraham."

Other instances abound elsewhere; we mention only a few of the most striking. In 1 Chronicles 26.24 we read in a list of appointments made by King David (see 1 Chron. 24.3; 25.1; 26.26), that Shebuel,[3] the son of Gershom, the son of Moses, was ruler of the treasures; and again in 1 Chronicles 23.15-16 we find it written, "The sons of Moses were Gershom and Eliezer. Of the sons of Gershom Shebuel was the chief." Now it is absurd to suppose that the author of Chronicles was so grossly ignorant as to suppose that the grandson of Moses could be living in the reign of David and appointed by him to a responsible office. Again in the same connection (I Chron. 26.31), we read that "among the Hebronites was Jerijah the chief"; and this Jerijah, or Jeriah (for the names are identical), was, according to 23.19, the first of the sons of Hebron, and Hebron was (v. 12) the son of Kohath, the son of Levi (v. 6). So that if no contraction in the genealogical list is allowed, we have the great-grandson of Levi holding a prominent office in the reign of David.

The genealogy of Ezra is recorded in the book which bears his name; but we learn from another passage, in which the same line of descent is given, that it has been abridged by the omission of six consecutive names. This is made clear by the comparison below.

Still further, Ezra relates (8.1, 2):

“These are now the chief of their fathers, and this is the genealogy of them that went up with me from Babylon in the reign of Artaxerxes the king. Of the sons of Phinehas, Gershom. Of the sons of Ithamar, Daniel. Of the sons of David, Hattush.” Here, if no abridgment of the genealogy is allowed, we should have a great-grandson and a grandson of Aaron and a son of David coming up with Ezra from Babylon after the captivity.

	1 Chronicles 6.3-14	*Ezra 7.1-5*
1.	Aaron	Aaron
2.	Eleazar	Eleazar
3.	Phinehas	Phinehas
4.	Abishua	Abishua
5.	Bukki	Bukki
6.	Uzzi	Uzzi
7.	Zerahiah	Zerahiah
8.	Meraioth	Meraioth
9.	Amariah	
10.	Ahitub	
11.	Zadok	SIX names omitted by Ezra
12.	Ahimaaz	
13.	Azariah	
14.	Johanan	
15.	Azariah	Azariah

16.	Amariah	Amariah
17.	Ahitub	Ahitub
18.	Zadok	Zadok
19.	Shallum	Shallum
20.	Hilkiah	Hilkiah
21.	Azariah	Azariah
22.	Seraiah	Seraiah
		Ezra

Different Relationships Classed Together

This disposition to abbreviate genealogies by the omission of whatever is unessential to the immediate purpose of the writer is shown by still more remarkable reductions than those which we have been considering. Persons of different degrees of relationship are sometimes thrown together under a common title descriptive of the majority and all words of explanation, even those which seem essential to the sense, are rigorously excluded, the supplying of these chasms being left to the independent knowledge of the reader. Hence several passages in the genealogies of Chronicles have now become hopelessly obscure. They may have been intelligible enough to contemporaries, but for those who have no extraneous sources of information the key to their explanation is wanting. In other cases we are able to understand them because the information necessary to make them intelligible is supplied from parallel passages of Scripture. Thus the opening verses of Chronicles contain the following bald list of names without a word of explanation: "Adam, Seth, Enosh, Kenan, Mahalalel, Jared, Enoch, Methuselah, Lamech, Noah, Shem, Ham, and Japheth."

We are not told who these persons are, how they were related to each other or whether they were related. The writer presumes that his readers have the book of Genesis in their hands and that the simple mention of these names in their order will be sufficient to remind them that the first ten names trace the line of descent from father to son from the first to the second great progenitor of mankind and that the last three are brothers, although nothing is said to indicate that their relationship is different from the preceding.

Again the family of Eliphaz, the son of Esau, is spoken of in the following terms in I Chronicles 1.36: "The sons of Eliphaz: Teman and Omar, Zephi and Gatam, Kenaz and Timna, and Amalek."

Now by turning to Genesis 36.l 1-12 we shall see that the first five are sons of Eliphaz, and the sixth his concubine, who was the mother of the seventh. This is so plainly written in Genesis that the author of the Chronicles, were he the most inveterate blunderer, could not have mistaken it. But trusting to the knowledge of his readers to supply the omission, he leaves out the statement respecting Eliphaz's concubine, but at the same time connects her name and that of her son with the family to which they belong, and this though he was professedly giving a statement of the sons of Eliphaz.

So, likewise, in the pedigree of Samuel (or Shemuel, v. 33, the difference in orthography is due to our translators and is not in the original), which is given in 1 Chronicles 6 in both an ascending and

descending series. Thus in verses 22-24: "The sons of Kohath; Amminadab his son, Korah his son, Assir his son, Elkanah his son, and Ebiasaph his son, and Assir his son, Tahath his son," etc.

The extent to which the framer of this list has studied comprehensiveness and conciseness will appear from the fact, which no one would suspect unless informed from other sources, that while the general law which prevails in it is that of descent from father to son, the third, fourth and fifth names represent brothers. This is shown by a comparison with Exodus 6.24 and the parallel genealogy, 1 Chronicles 6.36-37. So that the true line of descent is the following:

Verses 22-24	*Verses 37-38*
Kohath	Kohath
Amminadab	Izhar
Korah	Korah
Assir	
Elkanah	
Ebiasaph	Ebiasaph
Assir	Assir
Tahath, etc.	Tahath, etc.

The circumstance that the son of Kohath is called in one list Amminadab and in the other Izhar is no real discrepancy and can create no embarrassment since it is no unusual thing for the same person to have two names. Witness Abram and Abraham, Jacob and Israel, Joseph and Zaphenath-paneah (Gen. 41.45); Joshea, Jehoshua or Joshua, (Num. 13.16) and Jeshua (Neh. 8.17), Gideon and Jerubbaal (Judg. 6.32), Solomon and Jedidiah (2 Sam. 12.24), Azariah and Uzziah (2 Kings 15.1, 13); Daniel and Belteshazzar, Hananiah, Mishael, Azariah and Shadrach, Meshach, Abednego (Dan. 1.7); Saul and Paul, Thomas and Didymus, Cephas and Peter, and in profane history Cyaxares and Darius, Octavianus and Augustus, Napoleon and Bonaparte, Feretti and Pius IX.

Genealogy of Moses and Aaron

The genealogy of Moses and Aaron is thus stated in the sixth chapter of Exodus:

> And these are the names of the sons of Levi according to their generations; Gershon, and Kohath, and Merari: and the years of the life of Levi were an hundred and thirty and seven years. The sons of Gershon.... And the sons of Kohath; Amram, and Izhar, and Hebron, and Uzziel; and the years of the life of Kohath were an hundred and thirty and three years. And the sons of Merari. . . . And Amram took him Jochebed his father's sister to wife; and she bare him Aaron and Moses: and the years of the life of Amram were an hundred and thirty and seven years. And the sons of Izhar.... And the sons of Uzziel.... (vv. 16-22)

There is abundant proof that this genealogy has been condensed, as we have already seen that so many others have been, by the dropping of some of the less important names.

This is afforded, in the first place, by parallel genealogies of the same period; as that of Bezaleel (1 Chron. 2.18-20), which records seven generations from Jacob; and that of Joshua (1 Chron. 7.23-27), which records eleven. Now it is scarcely conceivable that there should be eleven links in the line of descent from Jacob to Joshua, and only four from Jacob to Moses.

A still more convincing proof is yielded by Numbers 3.19, 27-28, from which it appears that the four sons of Kohath severally gave rise to the families of the Amramites, the Izharites, the Hebronites and Uzzielites; and that the number of male members of the families of a month old and upward was 8,600 one year after the Exodus. So that, if no abridgment has taken place in the genealogy, the grandfather of Moses had, in the lifetime of the latter, 8,600 descendants of the male sex alone, 2,750 of them being between the ages of thirty and fifty (Num. 4.36).

Another proof, equally convincing, is to be found in the fact that Levi's son, Kohath, was born before the descent into Egypt (Gen. 46.11); and the abode of the children of Israel in Egypt continued 430 years (Ex. 12.40-41). Now as Moses was eighty years old at the Exodus (Ex. 7.7) he must have been born more than 350 years after Kohath, who consequently could not have been his own grandfather.

This genealogy, whose abbreviated character is so clearly established, is of special importance for the immediate purpose of this paper because it might appear, at first sight, as though such an assumption was precluded in the present instance, and as though the letter of Scripture shuts us up to the inevitable conclusion that there were four links, and no more, from Jacob to Moses. The names which are found without deviation in all the genealogies are Jacob, Levi, Kohath, Amram and Moses (Ex. 6.16-20; Num. 3.17-19; 26.57-59; 1 Chron.6.1-3,16-18; 23.6,12-13). Now unquestionably Levi was Jacob's own son. So likewise Kohath was the son of Levi (Gen. 46.11) and born before the descent into Egypt. Amram also was the immediate descendant of Kohath. It does not seem possible, as Kurtz proposed, to insert the missing links between them. For, in the first place, according to Numbers 26.59, "the name of Amram's wife was Jochebed, the daughter of Levi, whom her mother bare to Levi in Egypt," this Jochebed being (Ex. 6.20) Amram's aunt, or his father's sister. Now it is true that "a daughter of Levi" might have the general sense of a descendant of Levi, as the woman healed by our Lord (Luke13.16) is called "a daughter of Abraham," and her being born to Levi might simply mean that she sprang from him (cf. Gen. 46.25). But these expressions must here be taken in a strict sense, and Jochebed accordingly must have been Levi's own daughter and the sister of Kohath, who must in consequence have been Amram's own father. This appears from a second consideration, namely, that Amram was (Num. 3.27) the father of one of the subdivisions of the Kohathites, these subdivisions springing from Kohath's own children and comprising together 8,600 male descendants. Moses' father surely could not have been the ancestor of one-fourth of this number in Moses' own days.

To avoid this difficulty Thiele and Keil assume that there were two Amrams, one the son of Kohath, another the father of Moses, who was a more remote descendant but bore the same name with his ancestor. This relieves the embarrassment created by the Amramites (Num. 3.27) but is still liable to that which arises from making Jochebed the mother of Moses. And further, the structure of the genealogy in Exodus 6 is such as to make this hypothesis unnatural and improbable. Verse 16 names the three sons of

Levi, Gershom, Kohath and Merari, verses 17-19, the sons of each in their order; verses 20-22, the children of Kohath's sons; verses 23-24, contain descendants of the next generation, and verse 25 the generation next following. Now according to the view of Thiele and Keil, we must either suppose that the Amram, Izhar and Uzziel of verses 20-22 are all different from the Amram, Izhar and Uzziel of verse 18, or else that Amram, though belonging to a later generation than Izhar and Uzziel, is introduced before them, which the regular structure of the genealogy forbids; and besides, the sons of Izhar and the sons of Uzziel, who are here named, were contemporaries of Moses and Aaron the sons of Amram (Num. 16.1; Lev. 10.4).

The subject may be relieved from all perplexity, however, by observing that Amram and Jochebed were not the immediate parents, but the ancestors of Aaron and Moses. How many generations may have intervened we cannot tell. It is indeed said (Ex. 6.20; Num.26.59), that Jochebed bare them to Amram. But in the language of the genealogies this simply means that they were descended from her and from Amram. Thus in Genesis 46.18, after recording the sons of Zilpah, her grandsons and her great-grandsons, the writer adds, "These are the sons of Zilpah.... and these she bare unto Jacob, even sixteen souls." The same thing recurs in the case of Bilhah (v. 25): "She bare these unto Jacob; all the souls were seven" (cf. also vv. 15, 22). No one can pretend here that the author of this register did not use the terms understandingly of descendants beyond the first generation. In like manner, according to Matthew 1.11, Josias begat his grandson Jechonias, and verse 8, Joram begat his great-great-grandson Ozias. And in Genesis 10.15- 18 Canaan, the grandson of Noah, is said to have begotten several whole nations, the Jebusite, the Amorite, the Girgasite, the Hivite, etc. (cf. also Gen. 25.23; Deut. 4.25; 2 Kings 20.18; Is. 2.2). Nothing can be plainer, therefore, than that, in the usage of the Bible, "to bear" and "to beget" are used in a wide sense to indicate descent, without restriction to the immediate offspring.[4]

It is no serious objection to this view of the case that in Leviticus 10.4 Uzziel, Amram's brother, is called "the uncle of Aaron." The Hebrew word which here is translated "uncle," though often specifically applied to a definite degree of relationship, has, both from etymology and usage, a much wider sense. A great-great-granduncle is still an uncle, and would properly be described by the term used here.

It may also be observed that in the actual history of the birth of Moses his parents are not called Amram and Jochebed. Instead, the text simply says (Ex. 2.1), "And there went a man of the house of Levi, and took to wife a daughter of Levi."

Genealogies of Genesis 5 and 11

After these preliminary observations, which were originally drawn up for another purpose, I come to the more immediate design of the present paper by proceeding to inquire whether the genealogies of Genesis 5 and 11 are necessarily to be considered as complete and embracing all the links in the line of descent from Adam to Noah and from Shem to Abraham. The analogy of the Scripture genealogies is decidedly against such a supposition. In numerous other instances there is incontrovertible evidence of more or less abridgment. This may be the case where various circumstances combine to produce a different impression at the outset. Nevertheless, we have seen that this first impression may be dissipated by a more careful examination and a comparison of collateral data. The result of our investigations thus far is sufficient to show that it is precarious to assume that any Biblical genealogy is designed to be strictly continuous, unless it can be subjected to some external tests which prove it to be so. And it is to be

observed that the Scriptures furnish no collateral information whatever respecting the period covered by the genealogies now in question. The Creation, the Flood, the call of Abraham are great facts which stand out distinctly in primeval sacred history. A few incidents respecting our first parents and their sons Cain and Abel are recorded. Then there is an almost total blank until the Flood, with nothing whatever to fill the gap, and nothing to suggest the length of time intervening but what is found in the genealogy stretching between these two points. And the case is substantially the same from the Flood to Abraham. So far as the Biblical records go, we are left not only without adequate data, but without any data whatever, which can be brought into comparison with these genealogies for the sake of testing their continuity and completeness.

If, therefore, any really trustworthy data can be gathered from any source whatever, from any realm of scientific or antiquarian research, which can be brought into comparison with the genealogies for the sake of determining the question whether they have noted every link in the chain of descent or whether, as in other manifest instances, links have been omitted, such data should be welcomed and the comparison fearlessly made. Science would simply perform the office, in this instance, which information gathered from other parts of Scripture is unhesitatingly allowed to do in regard to those genealogies previously examined.

And it may be worth noting here that a single particular in which a comparison may be instituted between the primeval history of man and Genesis 5, suggests especial caution before affirming the absolute completeness of the latter. The letter of the genealogical record (v. 3), if we were dependent on it alone, might naturally lead us to infer that Seth was Adam's first child. But we know from chapter 4 that he had already had two sons, Cain and Abel, and from 4.17 that he must have had a daughter, and from 4.14 that he had probably had several sons and daughters whose families had swollen to a considerable number before Adam's one hundred and thirtieth year in which Seth was born. Yet of all this the genealogy gives us no inkling.

No Summation of These Genealogies in Scripture

Is there not, however, a peculiarity in the construction of these genealogies which forbids our applying to them an inference drawn from others not so constructed? The fact that each member of the series is said to have begotten the one next succeeding, is, in the light of the wide use of this term which we have discovered in other cases, no evidence of itself that links have not been omitted. But do not the chronological statements introduced into these genealogies oblige us to regard them as necessarily continuous? Why should the author be so particular to state, in every case, with unfailing regularity, the age of each patriarch at the birth of his son, unless it was his design thus to construct a chronology of this entire period and to afford his readers the necessary elements for a computation of the interval from the creation to the deluge and from the deluge to Abraham? And if this was his design, he must of course have aimed to make his list complete. The omission of even a single name would create an error.

But are we really justified in supposing that the author of the genealogies entertained such a purpose? It is a noticeable fact that he never puts them to such a use himself. He nowhere sums these numbers, nor suggests their summation. No chronological statement is deduced from these genealogies either by him or by any inspired writer. There is no computation anywhere in Scripture of the time that elapsed from the creation or from the deluge, as there is from the descent into Egypt to the Exodus (Ex. 12.40), or

from the Exodus to the building of the temple (1 Kings 6.1). And if the numbers in these genealogies are for the sake of constructing a chronology, why are numbers introduced which have no possible relation to such a purpose? Why are we told how long each patriarch lived after the birth of his son, and what was the entire period of his life? These numbers are given with the same regularity as the age of each at the birth of his son and they are of no use in making up a chronology of the period. They merely afford us a conspectus of individual lives. And for this reason, doubtless, they are recorded. They exhibit in these selected examples the original term of human life. They show what it was in the ages before the Flood. They show how it was afterwards gradually narrowed down. But in order to do this it was not necessary that every individual should be named in the line from Adam to Noah and from Noah to Abraham, nor anything approaching it. A series of specimen lives, with the appropriate numbers attached, was all that was required. And, so far as appears, this is all that has been furnished us. And if this be the case, the notion of basing a chronological computation upon these genealogies is a fundamental mistake. It is putting them to a purpose that they were not designed to subserve and to which from the method of their construction they are not adapted. When it is said, for example, that "Enoch lived ninety years and begat Kenan," the well-established usage of the word "begat" makes this statement equally true and equally accordant with analogy, whether Kenan was himself born when Enoch was ninety years of age, or one was born from whom Kenan sprang. These genealogies may yield us the minimum length of time that it is possible to accept for the period that they cover; but they can make no account of the duration represented by the names that have been dropped from the register as needless for the author's particular purpose.

Analogous to Genealogy of Moses

The abode of the children of Israel in Egypt affords for our present purpose the best Scripture parallel to the periods now under consideration. The greater part of this term of 430 years is left blank in the sacred history. A few incidents are mentioned at the beginning connected with the descent of Jacob and his family into Egypt and their settlement there. And at its close, mention is made of some incidents in the life of Moses and the events leading to the Exodus.

But with these exceptions no account is given of this long period. The interval is only bridged by a genealogy extending from Levi to Moses and Aaron and their contemporaries among their immediate relatives (Ex. 6.16-26). This genealogy records the length of each man's life in the principal line of descent: Levi (v. 16), Kohath (v. 18), Amram (v. 20). The correspondence in the points just indicated with the genealogies of Genesis 5 and 11, and the periods which they cover, is certainly remarkable. And as they proceeded from the same pen, we may fairly infer from the similarity of construction a similarity of design. Now it has been shown already that the genealogy from Levi to Moses cannot have recorded all the links in that line of descent, and that it could not, therefore, have been intended to be used as a basis of chronological computation. This is rendered absolutely certain by the explicit statement in Exodus 12.40.It further appears from the fact that the numbers given in this genealogy exhibit the longevity of the patriarchs named, but cannot be so concatenated as to sum up the entire period; thus suggesting the inference that the numbers in the other genealogies, with which we are now concerned, were given with a like design, and not with the view of enabling the reader to construct the chronology.

Archaeology against Completeness of Genealogies

In so far as a valid argument can be drawn from the civilization of Egypt, its monuments and records, to show that the interval between the deluge and the call of Abraham must have been greater than that yielded by the genealogy in Genesis 11, the argument is equally valid against the assumption that this genealogy was intended to supply the elements for a chronological computation. For altogether apart from his inspiration, Moses could not have made a mistake here. He was brought up at the court of Pharaoh and was learned in all the wisdom of the Egyptians, of which his legislation and the marvelous table of the affinities of nations in Genesis 10, at once the admiration and despair of ethnologists, furnish independent proof. He lived in the glorious period of the great Egyptian monarchy. Its monuments were then in their freshness and completeness. None of the irreparable damage, which time and ruthless barbarism have since wrought, had been suffered then. The fragmentary records, which scholars are now laboriously struggling to unravel and combine, with their numerous gaps and hopeless obscurities, were then in their integrity, and well understood. Egypt's claim to a hoary antiquity was far better known to Moses, and he was in a position to gain a far more intelligent comprehension of it than is possible at present; for exuberant materials were ready at his hand, of which only a scanty and disordered remnant now survives. If, then, Egyptian antiquity contradicts the current chronology, it simply shows that this chronology is based upon an unfounded assumption. It rests upon a fundamentally mistaken interpretation of the ante-Abrahamic genealogy and assigns a meaning to it which Moses could never have intended that it should have.

As is well known, the texts of the Septuagint and of the Samaritan Pentateuch vary systematically from the Hebrew in both the genealogies of Genesis 5 and 11. According to the chronologies based on these texts respectively, the interval between the Flood and the birth of Abraham was 292 (Hebrew), 942 (Samaritan) or 1172 years (Septuagint). Some have been disposed in this state of the case to adopt the chronology drawn from the Septuagint, as affording here the needed relief. But the superior accuracy of the Hebrew text in this instance, as well as generally elsewhere, can be incontrovertibly established. This resource, then, is a broken reed. It might, however, be plausibly imagined, and has in fact been maintained, that these changes were made by the Septuagint translators or others for the sake of accommodating the Mosaic narrative to the imperative demands of the accepted Egyptian antiquity. But if this be so, it is only a further confirmation of the argument already urged, that the ante-Abrahamic genealogy cannot have been intended by Moses as a basis of chronological computation. He knew as much of the age of Egypt as the Septuagint translators or any in their day. And if so brief a term as this genealogy yields was inadmissible in their judgment and they felt constrained to enlarge it by the addition of nearly nine centuries, is it not clear that Moses never could have intended that the genealogy should be so interpreted?

Furthermore, it seems to me worthy of consideration whether the original intent with which these textual changes were made, was after all a chronological one. The principle by which they are obviously and uniformly governed, is rather suggestive of a disposition to make a more symmetrical division of individual lives than to protract the entire period. The effect of these changes upon the chronology may have been altogether unintentional, not deliberate.

Thus in the Hebrew text of Genesis 5, the ages of different patriarchs at the birth of a son named are quite irregular and vary from sixty-five to one hundred and eighty-seven. But the versions seek to bring

them into closer conformity and to introduce something like a regular gradation. The Septuagint proceeds on the assumption that patriarchs of such enormous longevity should be nearly two centuries old at the birth of their son. Accordingly, when, in the Hebrew, they fall much below this standard, one hundred years are added to the number preceding the birth of the son and the same amount deducted from the number following his birth; the total length of each life is thus preserved without change, the proportion of its different parts alone being altered. The Samaritan, on the other hand, assumes a gradual diminution in the ages of successive patriarchs prior to the birth of their son, none rising to a century after the first two. When, therefore, the number in the Hebrew text exceeds one hundred, one hundred is deducted and the same amount added to the years after the son was born. In the case of Lamech the reduction is greater still in order to effect the necessary diminution. The table below shows the years assigned to the several antediluvian patriarchs before the birth of their sons in these several texts.

A simple glance at these numbers is sufficient to show that the Hebrew is the original, from which the others diverge on the one side or the other according to the principle which they have severally adopted. It likewise creates a strong presumption that the object contemplated in these changes was to make the lives more symmetrical, rather than to effect an alteration in the chronology.

	Hebrew	*Septuagint*	*Samaritan*
Adam	130	230	130
Seth	105	205	105
Enosh	90	190	90
Kenan	70	170	70
Mahalaleel	65	165	65
Jared	162	162	62
Enoch	65	165	65
Methuselah	187	167 (187)[5]	67
Lamech	182	188	53
Noah	600	600	600

Symmetry of the Genealogies

The structure of the genealogies in Genesis 5 and 11 also favors the belief that they do not register all the names in these respective lines of descent. Their regularity seems to indicate intentional arrangements.

Each genealogy includes ten names, Noah being the tenth from Adam, and Terah the tenth from Noah. And each ends with a father having three sons, as is likewise the case with the Cainite genealogy (4.17-22). The Sethite genealogy (chapter 5) culminates in its seventh member, Enoch who "walked with God, and he was not, for God took him." The Cainite genealogy also culminates in its seventh member, Lamech, with his polygamy, bloody revenge and boastful arrogance. The genealogy descending from Shem divides evenly at its fifth member, Peleg: and "in his days was the earth divided." Now as the adjustment of the genealogy in Matthew 1 into three periods of fourteen generations each is brought about by dropping the requisite number of names, it seems in the highest degree probable that the symmetry of these primitive genealogies is artificial rather than natural. It is much more likely that this definite number of names fitting into a regular scheme has been selected as sufficiently representing the periods to which they belong, than that all these striking numerical coincidences should have happened to occur in these successive instances.

It may further be added that if the genealogy in chapter 11 is complete, Peleg, who marks the entrance of a new period, died while all his ancestors from Noah onward were still living. Indeed Shem, Arphaxad, Selah and Eber must all have outlived not only Peleg, but all the generations following as far as and including Terah. The whole impression of the narrative in Abraham's days is that the Flood was an event long since past and that the actors in it had passed away ages before. And yet if a chronology is to be constructed out of this genealogy Noah was for fifty-eight years the contemporary of Abraham, and Shem actually survived him thirty-five years, provided 11.26 is to be taken in its natural sense, that Abraham was born in Terah's seventieth year. This conclusion is well-nigh incredible. The calculation which leads to such a result, must proceed upon a wrong assumption.

On these various grounds we conclude that the Scriptures furnish no data for a chronological computation prior to the life of Abraham; and that the Mosaic records do not fix and were not intended to fix the precise date either of the Flood or of the creation of the world.

Appendix 3: How Long Is the Sixth Day?

R. John Snow

The debate continues to brew in evangelical circles over the creation account in Genesis 1. Over the years, attempts to correlate alleged facts of science with the divine revelation have taken various forms. Relatively recently, however, the gap theory (held by DeHaan, Pink, Scofield and many other Christians) has been demonstrated to be unreliable in its exegetical basis, and most theologians have come to reject this view. Among those who hold to the inspiration of Scripture, the battle over the interpretation of Genesis I has tended to narrow down to the question of whether the days of God's creative activity were literal, twenty-four hour days or figurative days of greater length. Against those who hold the latter view, the charge has been made that the real motivation for such a view is the preconceived notion that scientific "facts" must be correct and the Bible made to fit, whereas if one considers just the Bible, only the literal-day view is possible.[1]

The thesis of this paper is that, aside from the external evidence of present-day scientific observations for determining age, there is adequate exegetical evidence to demonstrate that the days of Genesis 1 can be considered long indefinite periods. It is the feeling of the author that this is an area where the Christian needs to display openness, realizing that the intent of Genesis is theological and religious. To be dogmatic in the area of scientific correlation with the Scriptures can be dangerous, opening the door for repeating the errors of theology in the past.

Lessons from History

It is widely recognized that the word *yom* ("day"), as used in the Old Testament has a variety of meanings: a period of light (Gen. 1.5), 24 hours (Gen. 1.14b), or longer periods of time as in Genesis 2.4. Young says, "The length of days is not stated; what is important is that each of the days is a period of time which may legitimately be denominated *yom* ('day')."[2] This fact, then, opens the door for the possibility that the days of Genesis l represent any of the meanings listed above. The question is, of course, which one (or ones) are intended? Some feel that as yet we cannot know. Francis Schaeffer notes:

> In the light of the word as used in the Bible and the lack of finality of science concerning the problem of dating, in a sense there is no debate because there are no clearly defined terms upon which to debate.[3]

Schaeffer appears to be waiting upon science to determine which way the pendulum will swing. This approach is considered dangerous by others (for example, John C. Whitcomb, Jr., in *The Origin of the Solar System*) and therefore to be avoided.

Indeed, in some circles it seems to be evidence of spirituality to ignore scientific evidence that appears to contradict the "general impression" interpretation of Genesis l. However, such people should be careful or they may repeat the errors of history rather than learning from them. Galileo was denounced as a heretic for insisting on the Copernican theory of the solar system. Why? Because the Scriptures taught otherwise, according to the leading theologians of the day. Psalm 19 was quoted,[4] and the account of Joshua's long day,[5] as sure Scriptural proof that the earth was the center of the universe. A portion of a letter written by Cardinal Bellarmine reads as follows:

> I may add that the man who wrote "The earth abideth forever; the sun also riseth, and the sun goeth down, and hasteth to his place whence he arose," was Solomon, who not only spoke by divine inspiration but was wise and learned, above all others, in human sciences and in the knowledge of created things. As he had all this wisdom from God himself, it is not likely that he would have made a statement contrary to a truth, either proven or capable of proof. If you tell me that Solomon speaks according to appearances, inasmuch as though the sun seems to revolve, it is really the earth that does so . . . But as to the sun and the earth, a wise man has no need to correct his judgment for his experience tells him plainly that the earth is standing still and that his eyes are not deceived when they report that the sun, moon and stars are in motion.[6]

I wonder if many evangelical scholars of today would not have agreed with the Cardinal had they lived in that day, only to suffer the embarrassment of having to revise their hermeneutic later in the light of scientific fact. Galileo in his letter to Castelli (December 13, 1613) very succinctly says:

> Scripture deals with natural matters in such a cursory and allusive way that it looks as though it wanted to remind us that its business is not about them but about the soul and that, as concerns nature, it is willing to adjust its language to the simple minds of the people.[7]

Similar problems in the Bible/science debate arose when Columbus presented his views regarding a spherical earth:

> Columbus was assailed with citations from the Bible and New Testament: The Book of Genesis, the Psalms of David, the Prophets, the Epistles and the Gospels. To these were added the expositions of various saints and commentators: St. Chrysostom, St. Augustine, St. Jerome, St. Gregory, St. Basil, St. Ambrose and Lactantius, a redoubtable champion of the faith.[8]

Why do I mention these historical notes? To point out the real blunders theologians can make (1) by not considering various possibilities of interpretation, and (2) when facts of nature become reasonably certain, not being willing to adopt that interpretation which fits all the truth.

The Events of Day Six

Much of what has been written in favor of literal creative days is limited to Genesis 1 and its use of the numerical adjective, the phrase "evening and morning," and other similar considerations.[9] However, there has been little consideration given to the "close-up view" of creation presented in chapter two of Genesis, which particularly describes the events of day six.

Several events are recorded in Genesis 2 as occurring on day six. The following is a list of these events with appropriate comments in regard to time indications:

(1) "God *formed* man of the dust of the ground, breathed into his nostrils the breath of life, and he became a living soul" (v. 7). An instantaneous act does not seem to be implied here, but rather an action that consumes some time. The first verb used, *yatsar*, means to "mold" or "form." "It is the word that specifically describes the activity of the potter (Jer. 18.2ff)."[10]

(2) God *planted* a garden (v. 8). The notion of planting also suggests activity which involves time. The details are not described, but if an instantaneous act was intended, Moses certainly had vocabulary available (for example, *bara'*, "create") to so indicate. Wild vegetation today is often planted by birds,

wind and other natural phenomena. I suggest that God in his providence worked through such means to produce the beautiful garden as a special place for the man whom he had formed. Verse 9a further expands the notion of time as it says, "God *made to grow* every tree that is pleasant to the sight." The process of growth too was involved in producing this garden in which man would dwell.

(3) God *placed* man in the garden. Perhaps some time was involved here, also, but it would be difficult to suggest a time span or even the process of transportation. Certainly I would agree it is possible that "At the word of the Lord he may have been removed thither."[11]

(4) God said, "I *will make* him a help fit for him" (v. 18b). The future is used, denoting time subsequent to God's pronouncement. This span of time seems to cover the next three events.

(5) All the cattle, birds of the sky and every beast of the field were brought to Adam for naming (vv. 19-20). Certainly some time is involved in this activity. If every one of the approximately 15,000 living species of such animals[12] (not to mention those now extinct) were brought to Adam to be named, it would have taken ten hours if he spent only two seconds on each. Of course, it may be debated whether all present species existed at that time, a point not to be dealt with here, but we must also realize that this "naming" event could not have been a quick, cursory activity and still fit either God's intended result for this event or the proper significance of "naming."

> Ancient thought attached much greater importance to the names than we do. Words were more than a means of communication and the use of appropriate names was anything but arbitrary. Naming an animal properly indicated that one had understood and characterized its properties, that one had established a relationship with it and one's rule over it.[13]

To limit Adam to such a short time as the literal-day interpretation requires is not at all in keeping with this concept of naming.

(6) God caused Adam to go into a deep sleep, and he slept (v. 21). An interval is indicated during which Adam slept so that God could perform an operation. No doubt, the deep sleep was induced so that Adam would not suffer pain, and then so the healing process could take place as directed by God.

(7) God *built* a woman (v. 22b). The word "build" "applies to the fashioning of a structure of some importance; it involves constructive effort."[14] The time indication is evident even though God uses supernatural processes to complete this remarkable act.

It is only natural to ask, How much time transpired as these events took place? Can 24 hours be enough? This author feels that it is difficult to conceive of these events occurring in such a short interval without resorting not only to supernatural acts but also to additional explanations such as Adam's superior intelligence to enable him to name the animals so quickly. But the Scriptures nowhere suggest that such additional assumptions are to be made.

It is apparent from the text that Adam and Eve were last in the creative acts of day six and that all the time-consuming events just mentioned are related to Adam. So if the literal-day view is held, Adam does not even have 24 hours to become an accomplished zoologist and to recognize that he is missing something—a wife!

The Term Happa'am

Another time-indicator in Genesis 2, suggesting that day six is longer than 24 hours and warranting more detailed consideration, is *happa'am* (root *pa'am*) which appears in verse 23. The root form has many meanings ("best," "foot," "anvil," "occurrence") and is used 118 times in the Old Testament. However, when it is used with the article it takes on a time connotation and is translated by Brown, Driver and Briggs as "now at length."[15]

The translation of Genesis 2.23a is given below for three selected versions, with *happa'am* emphasized:

> And the man said, this is *now* bone of my bones.... (NASB)
>
> Then the man said, This at last is bone of my bones.... (RSV)
>
> And the man said: This now at length is bone of my bones.... (Leupold)[16]

Leupold, commenting on his translation above, says,

> That a being of this sort had been looked for with anticipation appears from the word happa'am "now at length."[17]

Another commentator says,

> Adam recognized in her the desired companion, welcomed her joyfully as his bride and expressed his joy in a poetic exclamation. The words "this is now" reflect his pleasant surprise as he saw in the woman the fulfillment of his heart's desire.[18]

Lange says,

> In contrast with the long missing of his help, he finds at last his desire realized.[19]

The question that naturally comes to mind is, How could Adam generate this great desire in such a short time, if the literal-day view is correct? To develop such a longing, that is, to know that one is missing something such as human companionship, does not generally become a psychological reality until a time has passed substantially greater than allowable with a literal-day interpretation. God induced this desire by having Adam observe the animals, and in the process of time this desire and knowledge of his lack came (v. 20). "The words 'This is now bone . . .' are expressive of joyous astonishment at the suitable helpmeet..."[20] This exclamation springs from a desire for human companionship greater than could develop in only a few hours. It is to be noted that "the creation of animals does not alleviate man's need for a *real* partner. They do not overcome man's basic loneliness. For that reason God creates the woman."[21]

Now the above interpretation is not only supported by the consideration of the time necessary to develop such desire or emotion, but it is also substantiated by the very usage of the word *happa'am* elsewhere. The evaluation of the references which follow will bear this out:

Genesis 29.34-35: The context of this passage deals with Leah, who had been given over to Jacob as his wife by the crafty devices of Laban (vv. 24-25). Jacob loved not Leah, but rather Rachel. Leah, being unloved, became despondent and sought Jacob's love through child-bearing. After having borne a third son to him, she says, "Now (*happa'm*) this time will my husband become attached to me . . ." (29.34b).

That is to say, after such a long time and three children, my husband will surely find favor with me. The emotional time-content is quite evident in this passage.

Genesis 30.20: The context here is again that of Leah and her relationship to Jacob. Having three sons did not change his relationship to her, so she continues to bear children by him. After son number six, she still greatly desires to win his favor and exclaims: "Now (*happa'am*) will my husband dwell with me" (30.20b). Again the word *happa'm* denotes a substantial time-period.

Genesis 46.30: This verse falls within the life of Joseph, when Jacob is finally reunited with his favorite son. His great remorse over Joseph's alleged death remains with him from the time his sons relate the sad story (Gen. 37.34). The many years that elapse between the events of chapters 37 and 46 give rise to the expression of 46.30b: "Now (*happa'm*) let me die, since I have seen thy face...."

Judge*s 15.3:* Samson had been deceived by his Philistine bride to tell her the riddle of the honey and the lion, causing him to lose both a wager and a triumph over the Philistine oppressors. Samson angrily departs before the marriage is consummated, only to return later and find that his wife had been given to another. As a result he becomes really angry, and exclaims, "Now (*happa'm*) shall I be more blameless..." (15.3). The passage suggests that Samson has been seeking revenge for some time, and now at last he feels justified in doing so (which he immediately does).

Judges 16.18: Delilah has schemed long and hard to learn the source of Samson's strength. Finally Samson succumbs to the pressure and gives in to her. Then she says to the soldiers outside, "Come up this once (*happa'm*) for he hath shown me" (16.18b). Emotion is expressed as the result of a time-consuming series of events.

Exodus 9.27: After a long series of plagues Pharaoh appears to be softening with regard to the release of the Israelites. He finally exclaims, "I have sinned this time (*happa'm*) . . ." (9.27b), or as Brown, Driver and Briggs render it, "Now at length I have sinned."[22] Here the word takes on a definite time reference, spanning the period of the plagues.

The word *happa'm* is also used in Genesis 18.32, Exodus 10.17, Judges 6.39 and 16.28. In these passages it occurs with the adverb *'ak* and is translated "only this once."[23] In each case it is used to terminate a time period of some length. Only in one case, Genesis 18.32, where Abraham intercedes for Sodom that God would withhold his judgment, is this period shorter than a few weeks, and here the strong emotional climax may build quickly because Abraham is bargaining with God.

From all these uses of *happa'm*, we see that it functions as a terminating expression for an emotional build-up which has been developing within a person over an extended time. In all six cases without the adverb, and in all but one with it, this time involves weeks and sometimes years, during which the desire or emotion rises to a climax.

John Calvin notes:

> In using the expression *happa'm*, Adam indicates that something had been wanting to him; as if he had said, "Now at length I have obtained a suitable companion, who is part of the substance of my flesh, and in whom I behold, as it were, another self."24

Even though the length of time that passed from God's bringing the animals before Adam to be named until Adam awoke from his deep sleep is not specified, it seems unreasonable, impractical and exegetically unwarranted to insist that this interval be limited to only a few hours. Gleason Archer expresses the time factors of day six by noting:

> 1. Adam was given the responsibility of tending the Garden of Eden for some length of time until God observed him to be lonely.
>
> 2. God then granted him the fellowship of all the beasts and animals of the earth, giving them all names.
>
> 3. Loneliness is still apparent—so God fashions a wife— by a rib taken from deep sleep.[25]

Archer then goes on to ask if all the above events occurred in 24 hours, concluding: "Obviously the 'days' of chapter 1 are intended to represent stages of unspecified length, not literal 24-hour days."[26]

Conclusion

God's activity in bringing the earth into existence with all its intricate detail and physical properties is so astounding that God has told us ultimately it is "through faith we understand that the worlds were framed by the word of God, so that the things which are seen were not made of the things which do appear" (Heb. 11.3). Hence as science seeks to discover the secrets of the formation of the eons[27] (which seems to be a legitimate enterprise in view of Gen. 1.28 and Ps. 19.1), there is still the necessity of faith. This cannot be avoided. Faith must be the ultimate touchstone of Christian inquiry into the matter of creation and origins. Yet as the facts of language and nature are discovered, it is important to remember a principle given by Charles Hodge: "If the ordinary sense brings the Mosaic account into conflict with facts, and another sense would avoid such conflict, then it is obligatory on us to adopt the other."[28] It is the "ordinary sense" of Genesis 1 that is usually argued in favor of a 24-hour-day view of creation week. It has been shown in this paper that "another sense" is a legitimate understanding for day six. May it not also be the proper understanding of the other days also?

In light of the fact that there are evidences in support of both sides of the "day" question, may the saints be diligent in searching the Scriptures and in recognizing those areas which are unknown. And may they be willing to submit to the teaching of God as he chooses to reveal these things, whether through a Galileo or a theologian, testing each teaching whether it be of God.

Notes for Appendixes

Notes for Appendix 1

Reprinted, with author's corrections, from the *Journal of the American Scientific Affiliation*, vol. 27, no. 4, 145-152 (1975) by permission. Copyright 1975 by American Scientific Affiliation. The author of this appendix has since completed two books related to these matters: *God's Time-Records in Ancient Sediments* (1977), and *Neglect of Geologic Data: Sedimentary Strata Compared with Young-Earth Creationist Writings* (1987), containing numerous examples, with illustrations and further explanations, of most of the sections appearing in this Appendix. These books may be ordered from IBRI, PO Box 423, Hatfield, PA 19440. See their website at www.ibri.org.

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Notes for Appendix 2

[1]Reprinted, with headings added, from *Bibliotheca Sacra*, 47 (1890). 285-303. Scripture references are KJV.

[2]W. H. Green, *The Pentateuch Vindicated from the Aspersions of Bishop Colenso* (1863), p. 128n.

[3]He is called in I Chronicles 24:20 a son of Amram, the ancestor of Moses; for Shubael and Shebuel are in all probability mere orthographic variations of the same name.

[4]In Ruth 4:17 Ruth's child is called "a son born to Naomi," who was Ruth's mother-in-law and not even an ancestor of the child in the strict sense. Zerubbabel is called familiarly the son of Shealtiel (Ezr. 3:2, Hag. 1:1), and is so stated to be in the genealogies of both Matthew 1:12 and Luke 3:27, though in reality he was his nephew (I Chron. 3:17-19). That descent as reckoned in genealogies is not always that of actual parentage appears from the comparison of the ancestry of our Lord as given by Matthew and by Luke.

[5]The number varies in different manuscripts.

Notes for Appendix 3

[1]Alva J. McClain, *Christian Theology: God and the World*, with revisions by John C. Whitcomb, Jr. and Charles R. Smith (Winona Lake, IN: Grace Theological Seminary, n.d.), p. 29.

[2]Edward J. Young, "The Days of Genesis," *The Westminster Theological Journal* 25 (1963), 170.

[3]Francis A. Schaeffer, *Genesis in Space and Time* (Downers Grove, IL: InterVarsity Press, 1972), p. 57.

[4]Georgio DeSantillana, *The Crime of Galileo* (Chicago: University of Chicago Press, 1955), p. 54.

[5]James Broderick, *Galileo: The Man, His Works, His Misfortunes* (New York: Harper & Row, 1964), p. 87.

[6]DeSantillana, *Crime of Galileo*, p. 100.

[7]Ibid., p. 41.

[8]Charles Duff, *The Truth about Columbus and the Discovery of America* (London: Jarrolds Publishers, 1936), p. 49.

[9]McClain, *Christian Theology*, p. 20.

[10]H. C. Leupold, *Exposition of Genesis* (Grand Rapids: Baker Book House, 1942) 1:115.

[11]Ibid., p. 118.

[12]Lord Rothschild, *A Classification of Living Animals* (New York: John Wiley and Sons, 1961), pp. 45.

[13]Aldert Van Der Ziel, *Genesis and Scientific Inquiry* (Minneapolis: T. S. Denison and Co., Inc., 1965), p. 59

[14]Leupold, *Exposition of Genesis*, 1:135.

[15]Francis Brown, S. R. Driver and Charles A. Briggs, *A Hebrew and English Lexicon of the Old Testament* (Oxford: Clarendon Press, 1907), p. 822.

[16]Leupold, *Exposition of Genesis*, 1:135.

[17]Ibid., p.136.

[18]Francis D. Nichol, ed., *The Seventh-Day Adventist Bible Commentary* (Washington, DC: Review and Herald Publishing Assoc., 1953), 1:227.

[19]John P. Lange, *Commentary on the Holy Scriptures: Genesis* (Grand Rapids: Zondervan Publishing House, 1971), p. 209.

[20]C. F. Keil and F. Delitzsch, *Biblical Commentary on the Old Testament* (Grand Rapids: William B. Eerdmanns Publishing Co., 1951), 1, 90.

[21]Van Der Ziel, *Genesis and Scientific Inquiry*, p. 59.

[22]Brown, Driver and Briggs, *Lexicon*, p. 822.

[23]Ibid.

[24]John Calvin, *Commentaries on the Book of Genesis* (Grand Rapids: William B. Eerdmanns Publishing Co., 1948), 1:135.

[25]Gleason L. Archer, *A Survey of Old Testament Introduction* (Chicago: Moody Press, 1964), p.176.

[26]Ibid.

[27]R. C. H. Lenski, *The Interpretation of the Epistle to the Hebrews and the Epistle of James* (Minneapolis: Augsburg Publishing House, 1966), p. 380.

[28]Charles Hodge, *Systematic Theology*, (New York: Charles Scribner and Co., 1872), 1:571.

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