Creationism's Geologic Time Scale

Should the scientific community continue to fight rear-guard skirmishes with creationists, or insist that "young-earthers" defend their model in toto?

Donald U. Wise

Creationism, the fundamentalist movement that rejects much of modern science because it conflicts with a strict literal interpretation of the Bible, especially the book of Genesis, has its philosophic roots in the Darwinian debates of the last century. Recently this movement has become a potent political force capable of challenging orthodox science in the arena of public opinion.

The earth sciences in particular face a newly focused assault from the fundamentalist camp. Until recently the claims made for "creation science" as an alternative to mainstream earth science consisted of a hodgepodge of geologic ideas floating loosely in time and space. Lately, its proponents have made more sophisticated attempts to square geologic evidence with scripture. A broad array of publications now supply alternative Bible-based earth histories. Using these materials as ammunition, creationists advocate laws requiring that any teaching of the scientific theory of evolution in the public schools be "balanced" by teaching of the "evidence against evolution."

Scientists have objected strenuously to such laws, since the evidence in question consists of untestable and pseudo-scientific interpretations derived by using the Bible as *the* primary scientific text. If enacted, such laws would have chilling effects both on science teaching and textbook content. As the Supreme Court has held, such laws would also violate the constitution by lending governmental support to a sectarian group's interpretation of the Bible.

In the last decade creationists have skirted federal courts by appealing to state legislatures and local school boards. In such venues the major scientific resources at hand are the local scientists, most of whom have only limited knowledge of the claims, methods and arguments of the creationists. The results have been predictable. Science is on the defensive, and creationists are gaining credibility in the court of public opinion.

When creationist rhetoric reached a boil in our community, I decided to take advantage of 40 years of geologic teaching and research and the local, self-proclaimed "largest creation science resource center east of the Mississippi" to formulate a composite creationist time frame of geologic events—"creation science's" answer to the geologic time scale on which students of geology are weaned. The result *(Figure 2)* highlights both the creationist arguments and those geologic facts most difficult for creationists to explain. It thereby provides the scientific community with access to many creationist positions.

As a strategy this article proposes that science should abandon its traditional and failing method of item-by-item rebuttal of creationist attacks. Instead, science should go on the offensive, using such a time scale to demand that creationists defend their total view of the geologic record and all their implausible and commonly ludicrous "scientific" interpretations.

The New Creationist Geologists

Scientific creationism, with its attempt to derive explanations for most of the geologic record from the Noachian flood, has suffered from a near-vacuum of well-educated geologists in the ranks of its proponents. The founders of the modern creationist movement included Ph.D. hydrologist Henry M. Morris and Ph.D. biologist Duane Gish. To lend credence to their cause, they recruited a number of young evangelical students to undertake graduate study in geology. Details of how those young evangelicals, one after another, deserted the creationist cause after exposure to graduate geologic education is amply detailed and documented in R. L. Numbers's 1993 book *The Creationists*.

A very few evangelicals did manage to survive graduate education in geology with their Biblical fundamentalist views of earth history intact. This younger group includes Steven Austin, John Morris and Kurt Wise (no relation to the author). They have now moved into primary roles of leadership and authorship in the movement and deserve individual note.

Steven Austin earned a Ph.D. in coal geology from the Pennsylvania State University in 1979. During his Penn State time he also wrote cre-

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ationist articles under the pseudonym of Stuart Nevins. Currently he is chair of the Department of Geology at the Institute for Creation Research (ICR) in southern California and is a major contributor to their in-house publications and articles on geology. His *Grand Canyon: Monument to Catastrophe* (Austin 1994) is a slick full-color volume designed both as a guide for fundamentalist field trips into the canyon and as a potential text for fundamentalist college-level geology courses. In these publications his scientific philosophy is never in doubt. In *Grand Canyon* he explains: "The real battle in regard to understanding the Grand Canyon is founded not just upon Creation and Noah's Flood versus evolution, but upon Christianity versus humanism." (Austin 1994)

John Morris, Henry's son, earned a Ph.D. in geological engineering from the University of Oklahoma and taught there for several years. In 1984 he moved to the ICR, which now lists him as president. He has led several expeditions in search of Noah's ark and has worked on the alleged coexistence of human and dinosaur tracks in the Paluxy River bed of Texas. His book, *The Young Earth*, consists of fundamentalist Sunday school themes and highly slanted geologic interpretations followed by 70 pages of overhead-projector masters designed to "be shared with your church or Bible study groups." With his father he has written: "The data of geology, in our view, should be interpreted in light of the Scripture, rather than distorting Scripture to accommodate current geological philosophy." (Morris and Morris 1989)

Kurt Wise graduated from the University of Chicago with honors in geophysical sciences before going on to earn his Ph.D. at Harvard under Stephen Jay Gould by working on details of mollusk classification. Wise has been the focus of a number of articles in the popular press and currently teaches at fundamentalist William Jennings Bryan College in Tennessee. He told a writer for *Harper's Magazine* in 1996: "I intend to replace the evolutionary tree with the creationist orchard, separately created, separately planted by God."

The rising influence in ICR circles of the likes of Austin, Morris and Wise has at least modernized the level of geologic debate. Although they are highly selective in their choice of which geologic data to present, their level of sophistication contrasts sharply with that of older creationists, who provided very few links to generally accepted geologic and paleontologic observations.

Critical reading of creationist literature is not easy even for a scientist with extensive geologic training. Particular care is required to detect how parts of the geologic record are cleverly distorted or ignored or how obscure literature citations or in-house creationist studies are expanded into general principles. Time and again, I found myself confusing pre- and post-

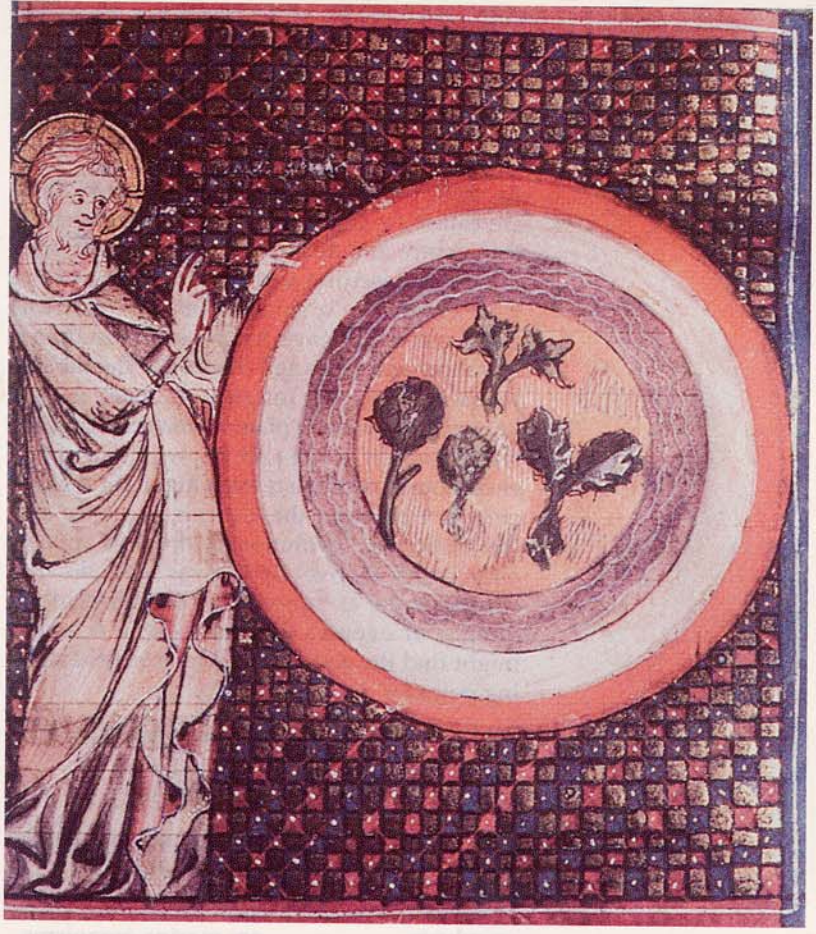


Figure 1. In the Biblical story of creation, a favorite subject of medieval artists, God created the earth's crust and plants the third day, having already made light and dark, waters below and waters above. Today fundamentalist Christians involved in the creationist movement insist that the story told in Genesis be considered a scientific text and that their alternative views arising from Bible-based "creation science" be presented in public schools as evidence against the evolutionary view of earth history. The author notes that as confrontations between creationists and scientists take place in many communities, many scientists are ill-prepared to respond to tactics that place them on the defensive. Creationists, he argues, should be required to defend their extraordinary claims and explain the fantastic model of earth history that they put forth as science. (From the 14th-century *Bible Historiale* of France, by permission of the Bibliothèque Interuniversitaire Montpellier).

flood events or mixing creation week events with flood events. But thanks to the younger generation, there is now enough detail in recent creationist literature to correlate between their "young earth" and the "old earth" or standard geologic time scales, even though the challenge is complicated by widely differing dates, events and models suggested by various creationist authors.

The following discussion explains the creationist time scale as I have managed to compile it. History suggests that detailed explanations and rebuttals of many items on this time scale will come from creationists. Scientists seeking more detail might look at T. H. Heaton's article, "A Young Grand Canyon?" in *The Skeptical Inquirer* (Heaton 1995), C. G. Weber's 1980 paper "The Fatal Flaws of Flood Geology" in *Creation/Evolution*, or D. A. Young's two fine books

(1977, 1982), which upset creationists enough to elicit answers to his points on a one-by-one basis (Morris and Morris 1989) and an entire book of rebuttals (Gish 1993).

Creation Week

As most people are aware, many creationists are called "young earth" proponents because they accept and defend the Genesis time scale of events, asserting that the universe and life were created in a single week and that this event could not have happened more than a few thousand years ago *(Figure 2)*. The Biblical sequence of events for creation week is well known and includes phenomena requiring the suspension of almost all known laws of science. Some creationists even highlight the discrepancy between the Genesis sequence and the traditional "evolutionary order of appearance." John Morris (1994) gives the following comparisons as *support* for the Biblical sequence of events. Alternatively, a scientist might find the juxtaposition an excellent starting point for debate.

Biblical Order	Evolutionary Order
Earth before sun and stars	Sun and stars before earth
Land plants before sun	Sun before land plants
First life forms are plants	First life forms are marine organisms
Fruit trees before fish	Fish before fruit trees
Fish before insects	Insects before fish
Birds before land reptiles	Reptiles before birds

The precise date of creation week in years varies among creationists. A good discussion of the history of this question starting with the Bishop of Ussher (1650) is given by W. R. Brice (1982). Henry Morris (1993) suggests that creation took place about 6,000 years ago and that the elapsed time from creation to the Noachian flood was 1,656 years. This means that the flood took place about 2350 B.C., a time somewhat after the start of recorded human history. John Morris (1994) notes that some uncertainties exist between the length of the Biblical time and the historical record but adds, "I suspect it is the secular chronology which needs revision."

Pre-Flood Earth History

Creationist pre-flood geology and biology span the period of roughly 1,500 years between creation week and the global flood that was survived only by the inhabitants of the ark. Henry Morris (1978) proposes that during this time lunar craters were formed as collateral damage in cosmic battles between Satan's angels and those of the Archangel Michael. Creationists also allege that the thin coating of dust on the moon and in its craters indicates that both moon and earth are very young. Such arguments continue to be made despite a recent technical paper by two creationists (Snelling and Rush 1993) who review the subject and conclude:

> It thus appears that the amount of meteoritic dust and meteorite debris in the lunar regolith and surface dust layer, even taking into account the postulated early intense bombardment, does not contradict the evolutionists' multi-billion year time scale (while not proving it). Unfortunately, counter responses by creationists have so far failed because of spurious arguments or faulty calculations. Thus, until new evidence is forthcoming, creationists should not continue to use the dust on the moon as evidence against an old age for the moon and solar system.

Meanwhile, back on earth, creationist time continues in the Garden of Eden, where all animals including dinosaurs started out as vegetarians, an interpretation based on Biblical statements of the absence of death in Eden prior to the apple incident (Gish 1992). Evidence most commonly cited for the coexistence of people and dinosaurs prior to the flood consists of intermingled footprints of dinosaurs and supposed human beings in bedrock exposed in and along the Paluxy River of central Texas. The creationist interpretation of these tracks is that they include human footprints created in early phases of the Noachian flood just before these evil people and dinosaurs were engulfed.

G. J. Kuban, a religious man scrupulous about the scientific details of these footprints, reports (1986) visiting the Paluxy site in the company of a number of creationists, including John Morris. Kuban's extensive documentation of the tracks includes stain markings of obviously nonhuman, three-clawed toes as integral parts of the "man-tracks." He notes later correspondence with John Morris in which Morris agrees that all the Taylor Site tracks (the best of the sites) were probably dinosaurian. In the same issue of *Origins Research*, Morris (1986) makes a half-hearted retraction.

Kuban felt it necessary to draw the lines between science and religion carefully. In a statement following the article cited above, he wrote:

> I am a Christian and believe in a Creator, but prefer not to be labeled a "Creationist" or an "Evolutionist," since I do not fully identify with all the tenets that are often assumed to typify each camp.... Although my findings are not favorable to the "man track" claims, the objective of my research has not been to attack Creationism, but to carefully investigate and document what actually exists on the Paluxy sites alleged to contain human footprints.... When the full evidence is brought to light, it is evident that all the Taylor Site tracks are dinosaurian.

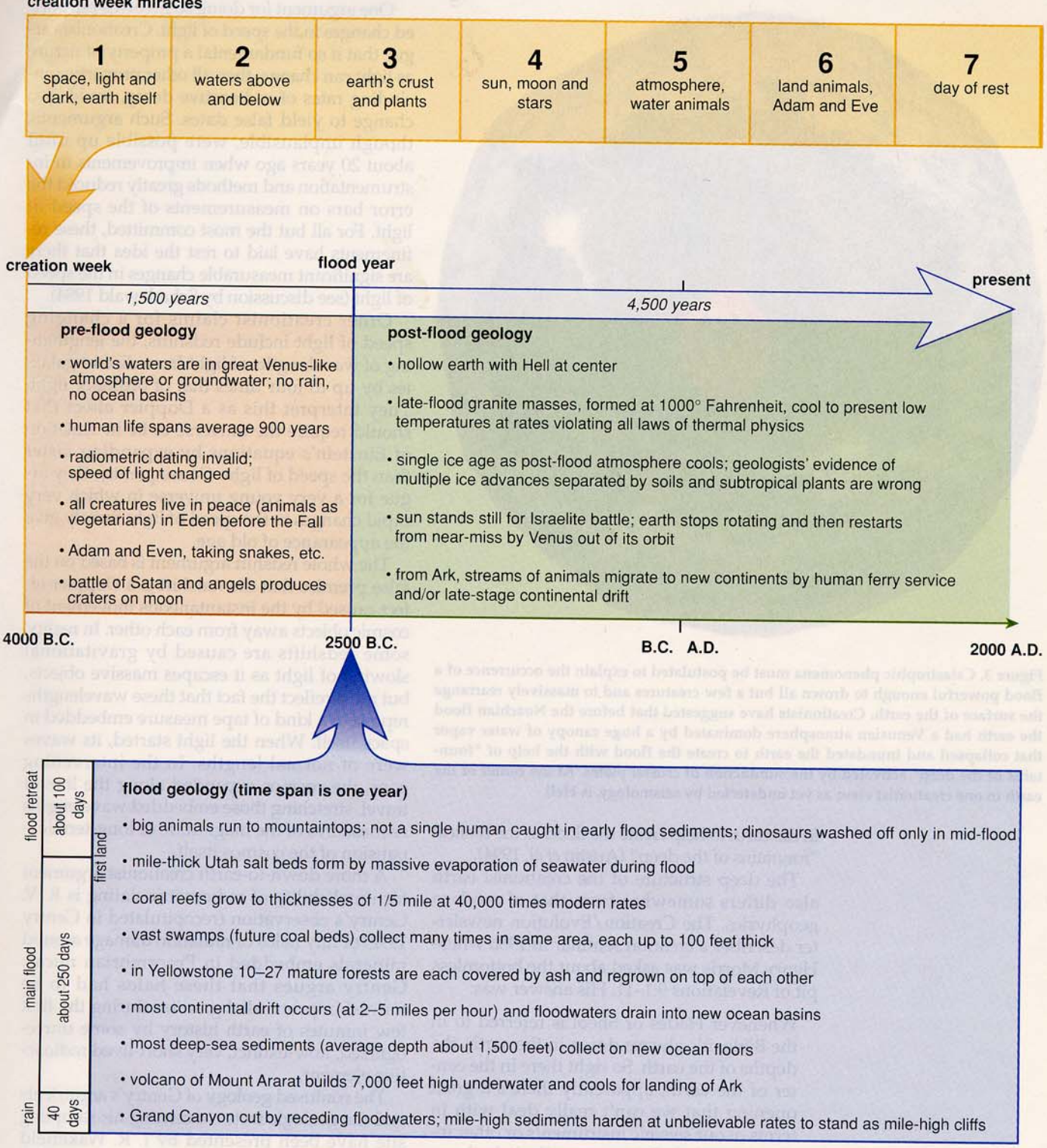


Figure 2. Unlike the 4.5-billion-year-old geologic time scale that has been developed through a century and a half of scientific research, creationism's geologic time scale compresses the history of the universe into about 6,000 years, requiring that radiometric dating be discredited and that many of the steps in the formation of the earth were so accelerated that millions of years of geologic change were accomplished in a few days or weeks. The entire fossil record of the earth is explained as having been deposited during the year of the Noachian flood 4,500 years ago.

As for the flood itself, creationist models for the source of the waters stem from the writings of Isaac Newton Vail, who refined over a 30-year period the "annular theory" (Vail 1912), in which the early earth had a series of Saturn-like aqueous rings, the collapse of which caused successive cataclysms to bury organisms and create fossils. The collapse of the last ring caused the Noachian flood. Subsequently, most writings propose only one great canopy, which collapsed to create the flood (Dillow 1981). Alternative creationist models store most of these waters with-

Figure 3. Catastrophic phenomena must be postulated to explain the occurrence of a flood powerful enough to drown all but a few creatures and to massively rearrange the surface of the earth. Creationists have suggested that before the Noachian flood the earth had a Venusian atmosphere dominated by a huge canopy of water vapor that collapsed and inundated the earth to create the flood with the help of "fountains of the deep" activated by the subduction of crustal plates. At the center of the earth in one creationist view, as yet undetected by seismology, is Hell.

in the earth to help create the flood as the Biblical "fountains of the deep" (Austin *et al.* 1994).

The deep structure of the creationist earth also differs somewhat from that of modern geophysics. The Creation/Evolution newsletter describes a creation seminar in 1986 where Henry Morris was asked about the bottomless pit of Revelations 9:1–11. His answer was:

> Whenever Hades or Sheol is referred to in the Bible, it's always down in the earth, the depths of the earth. So right there in the center of the earth, apparently there's a great opening that we can't really deal with in terms of our seismic instruments or other instrumentation. But apparently it is there. You can take the Bible to mean what it says.

Radiometric Dating

Modern geologists routinely date progressive evolution of the earth and its changing life forms by calculating ages of mineral samples containing concentrations of various radioisotopes and daughter products having known rates of decay. If "young earth" models have any hope of viability, creationists must somehow discredit almost all these methods of mineral dating.

One argument for doing so involves purported changes in the speed of light. Creationists argue that if so fundamental a property of nature as light can change, then all other properties, including rates of radioactive decay, could also change to yield false dates. Such arguments, though implausible, were possible up until about 20 years ago when improvements in instrumentation and methods greatly reduced the error bars on measurements of the speed of light. For all but the most committed, these refinements have laid to rest the idea that there are significant measurable changes in the speed of light (see discussion by Schadewald 1984).

Other creationist claims for a changing speed of light include redshifts, the lengthening of wavelengths of light from distant galaxies by up to four times that of ordinary light. They interpret this as a Doppler effect that should require the universe to be in violation of Einstein's equations by expanding faster than the speed of light. Consequently, they argue for a very young universe in which very rapid changes in the speed of light merely give the appearance of old age.

The whole redshift argument is based on the false premise that the redshift is a Doppler effect caused by the instantaneous movement of cosmic objects away from each other. In reality, some redshifts are caused by gravitational slowing of light as it escapes massive objects, but most reflect the fact that these wavelengths represent a kind of tape measure embedded in space itself. When the light started, its waves were of normal lengths. In the intervening eons, the cosmos expanded along the line of travel, stretching those embedded wavelengths as measures of the magnitude of long-term expansion of the cosmos itself.

A more down-to-earth creationist argument for unreliability of radiometric dating is R. V. Gentry's observation (recapitulated in Gentry 1992) of tiny halos of radiation damage around minerals embedded in Precambrian micas. Gentry argues that these halos had to be formed in primordial granites during the first few minutes of earth history by some unrecognized, now-extinct, very short-lived radioactive element.

The confused geology of Gentry's arguments and the geologic facts concerning his sampling site have been presented by J. R. Wakefield (1988). Wakefield points out that various kinds of halos of radiation damage around certain minerals in micas are common and that Gentry's samples came from dikes that cut Precambrian sedimentary rocks. Thus, field relations prove that his samples are younger than the sedimentary deposits and therefore cannot be of primordial origin.

Creationists commonly cite the "helium problem" as evidence for a young atmosphere that contradicts radiometric dates (Vardiman 1986

and J. Morris 1994). Scientists generally recognize that the rate of production of helium from the earth's crust and mantle exceeds by a factor of 2 to 5 the Jeans rate of strictly *thermal* escape from the upper atmosphere Harper and Jacobsen 1996). If these were the only factors in earth's helium balance, the creationists' claims of an atmosphere with a maximum age of only 2 million years might have some merit (J. Morris 1994).

However, a number of nonthermal processes are capable of accounting for steady-state atmospheric compositions of earth, Venus, and Mars, as outlined by B. C. Shizgal and G. C. Arkos (1996). These include exothermic exchanges of helium and nitrogen ions that can boost helium ions to escape velocity, as well as the solar wind, which sweeps helium ions outward along high-latitude open magnetic field lines. The helium problem remains under active investigation, but its scientific understanding has gone far beyond the simple thermal-escape models still cited by creationists.

Another common creationist argument for the "unreliability" of radiometric dates is Austin's (1994) dating of the Uinkaret lava flows of the Grand Canyon region. It is generally recognized that some of these flows were so young that they cascaded over the canyon edges and dammed huge lakes within it. Austin cites a number of different analyses of these lavas that can be used to calculate a wide range of radiometric model ages, some older than the earth itself. He concludes by asking, "Has any Grand Canyon rock ever been successfully dated?"

There are many methods of deriving radiometric dates, some widely recognized as being far more accurate than others; the range of ages Austin cites merely shows the lack of precision among the cruder methods. For the most part, Austin used a ham-handed approach by dating whole rocks rather than individual minerals or parts of individual mineral grains. He then set up a straw man by culling other dates from the literature for comparison to complain about the wide spread of the results. In fact, Wenrich, Billingsley and Blackerby (1995) derived quite precise dates from these Uinkaret volcanics. Using some of the best potassium-argon methods, they found a regional pattern of younger and younger dates moving eastward with time to reach the youngest Grand Canyon volcanoes only 10,000 years ago, a date in good accord with erosional history.

Creationist claims about radiometric dates and their linkage to the supposedly unreliable fossil record fail to point out the rarity of locations where rocks with well-controlled fossil dates are closely associated with proper mineral material for very precise radiometric dates. A few hundred of these well-dated localities represent the primary control points on which the entire dating system of the geologic column is based.

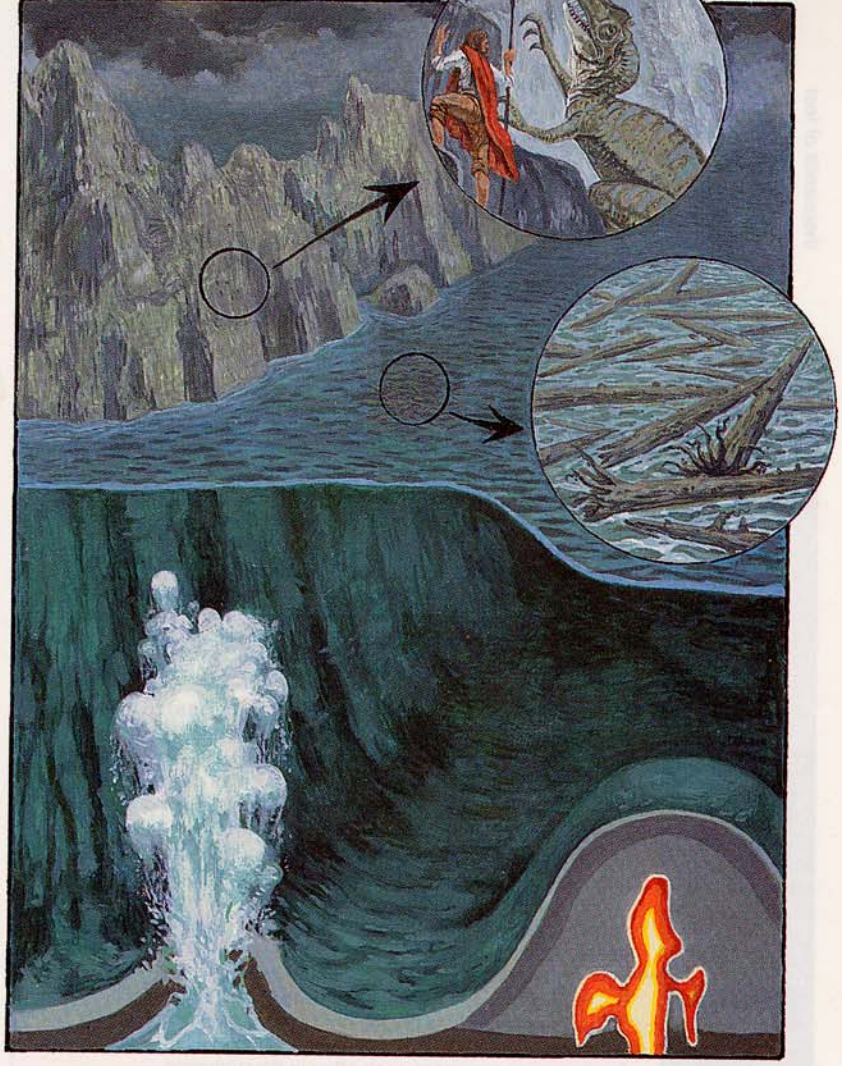
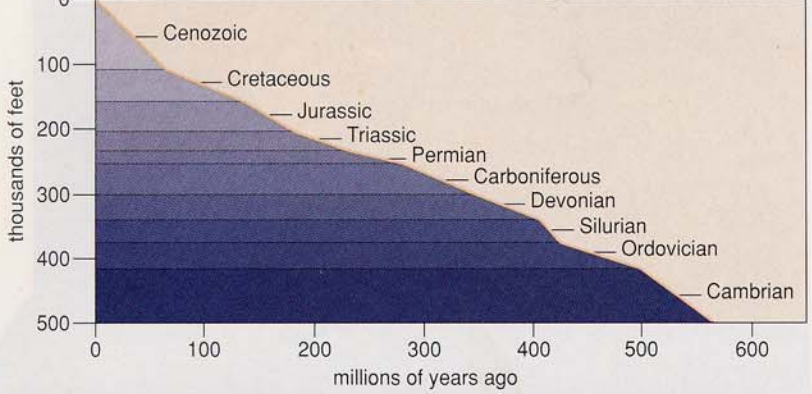


Figure 4. "Creation science" explains the fossil record and deposits of petroleum, natural gas and coal as products of the flood year. Larger land animals, it is argued, ran to the mountaintops *(upper inset)*, explaining why they appear in upper fossil strata; meanwhile massive mats of vegetation formed *(lower inset)*, later to become coal beds. The volcano that is now Mount Ararat rose rapidly *(bottom right)* beneath the deluge and just as rapidly cooled to provide a place for Noah's ark to later be grounded. According to this view, human beings and dinosaurs co-existed before the flood. At lower left, water spews from one of the biblical "fountains of the deep."

Where such ideal conditions exist, the same horizons yield the same precise dates even if the locations are continents apart. For instance, Bowring *et al.* (1993) used the finest uranium-lead methods to date zircons associated with the base of the Cambrian in Siberia at 543.9 (± 0.2) million years, whereas in southern Africa, J. P. Grotzinger and his colleagues (1995) found a number of ash beds spanning the same fossil range, yielding dates from 545 to 539 (± 1) million years. In the Rocky Mountain region, about 20 Cretaceous (140–65 million years old) ash beds are interlayered with well-known fossil-bearing sequences recognized both here and in Europe. Precision dating by J. D. Obradovich (1993) of these ash beds differing by only 0.5 million to 1 million years confirmed the same 1, 2, 3... sequence as that derived both from fossils and field relationships.



present	
Cenozoic	Ice cores in Greenland and Antarctica collect winter/summer couplets that can be counted back at least 30,000 years.
	Reef limestones grow 2,550 feet thick on Bikini Atoll. Maximum recorded vertical growth of any known reef: 0.27 inch/year. Minimum time to grow Bikini reef at this rate: 110,000 years.
	Yellowstone ash buries forest, develops soil, grows new mature forest. Process is repeated 10–27 times.
	Green River Lakes of Wyoming collect 2,000 feet (5 million years) of paper-thin summer/winter couplets.
65 million years	
Cretaceous	Chalk cliffs of Dover grow 1,000 feet thick as calcareous organisms live, die and settle in deep seas covering Europe.
Jurassic	In Zion National Park sweeping cross-bedded sand-dune deposits of Navajo Formation collect up to 1,500 feet thick.
Triassic	Newark Basin of New Jersey collects lake beds in sedimentary cycles linked to cycles of earth's orbit over 20 million years.
250 million years	
Permian	Salado Formation of West Texas collects 1,000 feet of marine salt beds in backwater lagoons and tidal flats.
Carboniferous	Coal swamps grow atop each other in West Virginia and Pennsylvania—commonly a dozen deep at any location.
	Rundle Limestone of Canadian Rockies collects as a 1,000-foot-thick debris mass made mostly of crinoids (calcareous "sea lilies") that grew on the seafloor.
Devonian	Leduc reefs of the Canadian Plains grown in place and cement their own debris to form patch reefs up to 1,000 feet thick.
Silurian	Michigan Basin evaporation in semi-closed basin collects successive salt beds to total thickness of 2,000 feet.
Ordovician	Subtropical fauna in Africa gives way to glacial deposits and then has time to return to subtropical conditions.
Cambrian	Burgess Shale of British Columbia and related formations record progressive replacement of early fauna by fauna having well-preserved hard parts, including current major animal phyla.
540 million years	
Precambrian	Belt Series of Montana and British Columbia collects to 30,000 feet of mostly shallow water sediments as shoreline slowly sank beneath them.

Figure 5. Flood geology must explain a massive geologic record as a single year's events. The maximum known thicknesses of sedimentary rocks of a given age are plotted at top to derive their maximum rate of deposition during geologic periods, according to radiometric dating (graph adapted from Hudson 1964). In the chart are listed some selected features in each geologic time segment that creationist models require to have been formed within part of the year of the Noachian flood, most in a few weeks. Standard geologic interpretations require any single one of them to occupy more than the total 6,000 years of earth history allowed by creationists.

Fossil Stratigraphy, Corals and Limestones

Since the beginning of fossil-hunting, the earth's rock layers have yielded a record of life with a consistent pattern: more and more complex life forms appear at progressively higher and newer levels. Creationists argue that this progression shows that during the flood, higher-order animals ran to the mountaintops to be washed off and buried last, a "mechanism" originally proposed by George McCready Price (1923).

Recent refinements of this mammals-to-the-mountains model have included the notion that rising waters engulfed first the shoreline plant and animal communities and then more complex upland flora and fauna. This argument neglects to discuss why burial sequences for fish, marine reptiles and marine mammals followed the same pattern of increasing complexity, when these groups should have been relatively unaffected by rising waters. In addition, a pre-flood human race without a single individual dumb enough to be trapped on some isolated mountaintop by early stages of rising waters would seem to be a miracle in its own right.

Above all, the creationist model requires the fossil record to be a somewhat haphazard jumble of odds and ends dumped by the flood, recording only a generalized sequence of simple to complex life. Creationists allege that academics consistently warp and misinterpret the stratigraphic/paleontologic evidence in an attempt to defend cherished but untenable beliefs about science's particular version of evolution and the geologic record. One might expand such charges of bias to include the oil industry, a group of the most hard-headed realists known, who constantly test geologic and paleontologic predictions with drillings currently at a worldwide rate of about a meter per second and who, after a century's experience, continue to delude themselves by pouring untold billions of dollars into such exploration.

The thick sedimentary formations that cover large portions of the interior of North America to average depths of about a kilometer pose especially difficult problems for the "young earthers." Large percentages of these deposits consist of former calcareous muds and fossil debris created by lime-secreting organisms. Production of such volumes during a single "flood year" would surely require Herculean activity on the part of those organisms. For instance, in the Grand Canyon region the Redwall and Kaibab limestone formations are each about 150 meters thick. If deposition was spread uniformly through the entire flood year, these two units would require organisms to have produced carbonate mud deposits at the unbelievable rate of 80 centimeters per day.

Recently young-earth proponents have used a new twist—rapid tectonic movement—to obviate the required excessive growth rates for limestones during the flood year (Austin *et al.*

1994). In this view, for about 1,500 years between Eden and the flood, extremely abundant carbonates were produced by vibrant biological activity in the postulated extremely high carbon dioxide pressure of those times. Thick carbonate muds collected in those early ocean basins, only to be hurled onto the continents by violent runaway subduction during the flood as plates moved at speeds of 1–10 kilometers per hour, depending on the model. Conceivably this process might yield the volume of carbonate sediments on the continents, though hardly the delicate and orderly succession of fossiliferous limestone and other formations typical of the continental interior, of the Grand Canyon and elsewhere.

As for coral reefs, Morris and Morris (1989) argue correctly but somewhat disingenuously for an absence of great coral reefs in the past. They cite the claim of S. E. Nevins (Austin's 1975 pseudonym) that some of the greatest of these, Capitan and the Permian reef complex of west Texas, comprise mostly transported fossil-bearing lime muds rather than coral. Geologists have long recognized that these particular formations are banks of carbonate debris, cemented in place into reeflike masses by algae, sponges and bryozoa, many still preserved in their growth positions. Other deposits such as the oil-bearing Leduc reefs near Edmonton, Canada, were true isolated patch reefs, cementing self-generated debris into isolated wave-resistant masses to thickness of 300 meters. To most geologists these are definitions of reefs whether they comprise 100 percent coral or not. In the case of the Leduc reefs, the one-year flood model requires an average vertical growth rate of 0.8 meter per day or 3.5 centimeters per hour, a rate 40,000 times the maximum ever recorded for any modern reef surface (Chave *et al.* 1972).

Coal, Salt and Deep Oceanic Sediments

Coal beds represent compaction of organic materials to 5 to 10 percent of their original thickness. Hence a typical coal bed might represent the slow accumulation of 20–30 meters of original swamp material and require a considerable time span to form. Austin did his doctoral dissertation (1979) on a single coal bed in Kentucky that might have formed very quickly. He argues that relationships in that bed suggest formation as a kind of logjam or mat of floating vegetation. Subsequently, creationists have added the interpretation that such floating vegetational rafts in Noah's flood were responsible for almost all coal beds (Major 1990), a common creationist approach of extrapolating from local example to the entire geologic record.

For some small coal beds, origin as vegetational mats is a generally accepted mechanism. For others, such as the Pittsburgh and Kittaning coals of Pennsylvania and West Virginia, the total area was on the order of 20,000 square kilometers, with systematic lateral changes and continuous upward transition from underlying sands and lake beds into the swamp deposits). The difficulty of collecting such a huge but orderly logjam as well as providing mechanisms for its survival and ultimate burial beneath the tumultuous seas of the Biblical flood is not addressed by creationists.

Thick salt beds formed by the evaporation of seawater comprise another problem for creationists. Young-earth geologists interpret almost all classic stratigraphic units as deposits produced during the flood year: Hence, interbedded salt formations must have formed as part of those events. Some of the more extensive salt formations within the U.S. are in the Paradox Basin of Utah, where they reach a depositional thickness of 1.5 kilometers with at least 29 separate cycles of salt deposition (Hite 1960). To deposit just these beds in a single year would require salt to have formed at a minimum rate of 4 meters per day or 17 centimeters per hour, presumably by evaporation while the flood was in progress.

For such deposits, creationists use an ostrich approach. The chemical balance of salt in the ocean is discussed by Austin and Humphreys (1991) and John Morris (1994) with brief paragraphs on each of 11 ways that salt can be added and seven ways it can be removed. The fourth of these removal methods is halite (salt) deposition, which takes place

> as a result of river water evaporation, not sea water. Actually the ocean would need to be 20 times more concentrated in salt for deposition to occur. This happens infrequently in trapped pools but such deposits redissolve easily. This output is trivial. The volume of salt water evaporated in trapped lagoons and not redissolved is not significant.

Morris and Morris (1989) cite the extreme minority view of V. I. Sozansky (1973) that great salt deposits are products of the degasification of the earth's interior brought up along faults by juvenile waters derived from volcanic rocks. Nowhere in the Morris and Morris publication is mention given of the enormous halite deposits common at many times in the geologic record nor of their generally accepted origin by continuous evaporation of seawater flowing into semi-restricted basins in arid regions.

Finally, typical deep-ocean floors are covered by about 800 meters of sediments (Worzel 1974). The present rates of accumulation of these deep-water sediments in the North Pacific are 0.2, 0.02, 0.005, and 0.001 millimeter/year respectively for muds, calcareous ooze, siliceous ooze and red clay (Berger 1974). Assuming an average deposition rate of 0.01 millimeter/year, the 800-meter accumulation would require 80 million years, a quite reasonable geologic age for

typical ocean basins. "Young earth" models would require most of this accumulation to take place late in the flood year, a minimum rate of 2 meters/day or 80 million times present rates. Alternatively, most of the deposition might have been in the subsequent 4,500 years, an average of about 20 centimeters/year or only 17,000 times present rates. The very delicate layering and fine grain size characteristic of these oozes and muds argue strongly against such wholesale dumping rates. In addition, this model requires that somehow such catastrophic rates ceased once modern measurements became possible.

Plate Tectonics

Surprisingly, most modern creationists accept some variations of plate tectonics. In one creationist model Henry Morris (1993) proposes that during later parts of the flood, opening of ocean basins provided a means for draining waters from the continents. If this opening took place during the last half of the flood year, the east coast of the U.S. moved to its present distance 5,500 kilometers from Africa at an opening rate for the Atlantic of 30 kilometers/day or more than one kilometer per hour.

An alternative creationist mechanism proposed by J. R. Baumgardner (1990) and by Austin, Baumgardner, Kurt Wise and others (1994) suggests that following earth-core formation, convection and frictional heating by the slowly moving downgoing slabs of oceanic crust reduced the viscosity of the earth's mantle by a "factor of a billion" (from rock to Jell-o). The result was a runaway convection system with tectonic plates moving at "meters per second" (2 meters per second = 4.4 miles per hour), allowing deep mantle plumes to spew forth steam as the Biblical "fountains of the deep," condensation of which caused the flood.

The thermal problems of this model are mind-boggling. At the start, gravitational energy released by core formation would raise the entire globe's average temperature by 2,500 degrees Celsius (Birch 1965). To this, the model requires adding frictional heating from the proposed runaway subduction as well as the massive heat of condensation of the collapsing vapor canopy. Even more surface heat was added as brand new basaltic ocean floors, with minimum melting temperatures of 1,000 degrees Celsius, were spewed out over two-thirds of the earth's surface beneath miraculously nonboiling flood waters. Finally this cumulative massive thermal pulse had to dissipate in a few thousand years by unstated processes to leave most of the earth's surface devoid of hot springs or any evidence of abnormally high heat flow. The authors apologize that their model is still in the "formative stages and thus is incomplete."

In the area of plate tectonics the creationist views contradict an enormous body of new data. The last 30 to 40 years have seen plate tectonics grow from an intriguing theory loosely supported by some data from a few subdisciplines of geology into a revolutionary paradigm supported by massive interlocking data arrays from the entire spectrum of the geosciences. Detailed plate motion directions and velocities with their passenger continents (DeMets *et al.* 1990) have been derived from combinations of geophysics, deep sea drilling, seafloor magnetic anomalies, and land based structural, geophysical, and sedimentological studies, the whole cemented by a time framework based on stratigraphic, paleontologic and radiometric time scales.

Recent satellite-based Global Positioning System measurements show a 95 percent correlation of present motions and rates with those interpreted from the plate-tectonic record (Larson, Freymueller and Philipsen 1997). Only the Pacific and Nazca plate interpretations needed some minor readjustment to fit the data. Because correlations with long-term velocity determinations must involve some span of geologic time, an average of 3.16 million years for the Larson *et al.* data, these measurements represent an additional test and validation of radiometric and paleontologic dating methods.

Mount Ararat

Because Noah's ark in the Biblical story ultimately grounded on Mount Ararat in modern Turkey, this area has received close attention by creationists. The top two kilometers of Mt. Ararat's 5.2-kilometer height is a volcano built over deformed sedimentary rocks. Consequently, the creationists' model requires that the entire volcanic growth took place very late in the flood year. This volcano had to violate all laws of thermal physics in order to cool completely in a few months in time for the ark to land on it.

Claims of the discovery of Noah's ark in the Mt. Ararat region continue to abound. These claims are reviewed by one of the few persons recently allowed into that region of Turkey (Collins and Fasold 1996). The "ark" claimed to be found by some is shown to be nothing more than a canoe-shaped fold of erosionally resistant rocks, a common structure in most mountain systems. Recently, other scientists have found geologic evidence that could provide a more reasonable source for the Biblical flood story. Seismic and drill-core data (Ryan *et al.* 1997) indicate that until recently the Black Sea basin contained a freshwater lake surrounded by vast areas of potential farmland. As polar ice caps melted, rising ocean waters finally topped the sill at the Dardenelles and poured into the Black Sea basin at about 5100 B.C. The resulting floodwaters, of truly Biblical proportions, rose at rates of decimeters/day to cover permanently 100,000 square kilometers of agricultural lands. This may well be the source of

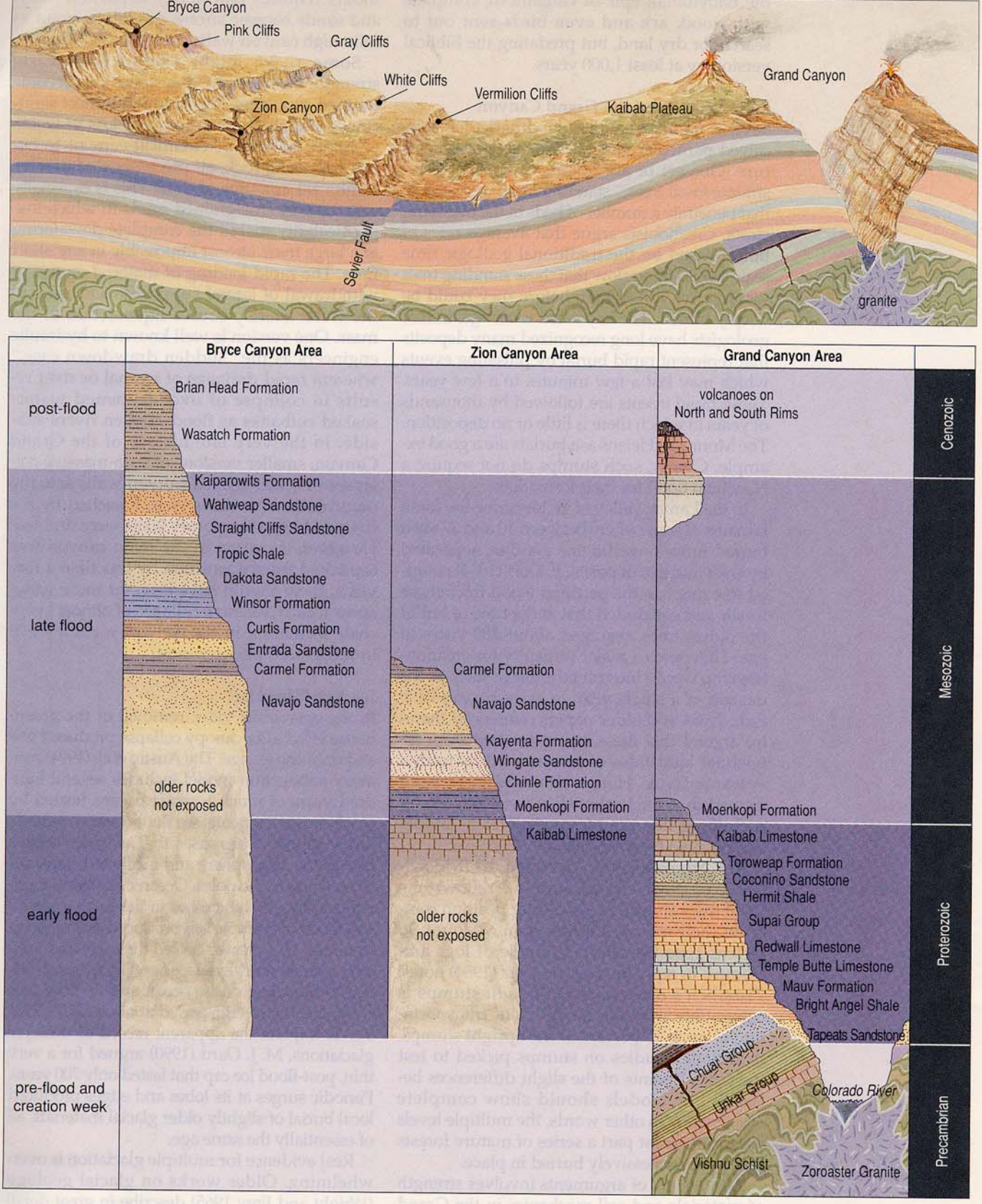


Figure 6. Grand Canyon geology—the sweeping history of earth told in rock that has inspired generations of geologists—has recently been rewritten by creationists. In the alternative view the canyon was not formed by layers of sedimentation atop ancient metamorphic rock deposited over millions of years, followed by volcanic flows into the canyon and the downcutting action of the powerful Colorado River. Some 500 million years of the canyon's history are explained in this view *(labels at left)* as taking place during the Noachian flood year, a feat that would require massive layers of wet sediments to be deposited and harden at astounding rates over the course of weeks, leaving them solid enough to be incised into mile-high cliffs by receding floodwaters. (Creationist ages, *left*, after Austin 1994, with basic geology after Coney 1975.)

the Babylonian epic of Gilgamesh, complete with flood, ark and even birds sent out to search for dry land, but predating the Biblical version by at least 1,000 years.

Yellowstone and the Grand Canyon

Several familiar national landmarks have received particular attention in creationist literature. One set of arguments concerns "polystratate fossil trees," standing fossil tree stumps that penetrate a number of beds in the overlying strata. Creationists argue that average rates of burial based on the traditional geologic time scale would be so slow that these standing trees would have rotted long before they could be deeply buried. The key word is *average*, in that geologists have long recognized many deposits that represent rapid burial by pulsating events which may last a few minutes to a few years. These rapid events are followed by thousands of years in which there is little or no deposition. The Mount St. Helens ash burials are a good example. Clearly, such stumps do not require a Noachian flood for their formation.

In the Lamar Valley of Yellowstone the fossil remains of somewhere between 10 and 27 such buried forests overlie one another, separated by river and ash deposits. E. Dorf (1964) counted tree rings on the petrified wood from these fossils and concluded that at the time of burial the oldest trees averaged about 200 years in age. This poses a major difficulty for creationists who would interpret the entire stack as the deposit of a single year. In early papers W. J. Fritz (1984 and older papers referenced therein) argued that these layers resulted from sequential landslides of forested debris from a volcanic flank. Hence all could have been formed in a single short-lived volcanic event, something like the Mount St. Helens model widely cited by creationists.

R. F. Yuretich (1984) examined the field evidence to show that most of the Yellowstone fossil trees are still in a standing position rooted in their own soil rather than a Mount St. Helens-type transported jumble of logs and stumps. In reply to Yuretich, Fritz (1984) notes: "Yuretich's observation of *in situ* stumps is compatible with my model ... of transportation of up to 15 percent of the upright stumps. Additional studies on stumps picked to test the critical points of the slight differences between our models should show complete agreement." In other words, the multiple levels are for the most part a series of mature forests that were successively buried in place.

Another set of arguments involves strength of materials and soil mechanics in the Grand Canyon region. In Austin's model (1994), sedimentary rocks of the Grand Canyon were all deposited during the early part of the flood year *(Figure 5)*, later to be incised by receding waters to form the present canyon. Thus, the model requires that newly deposited muds and sands became strong enough to stand as mile-high canyon walls within a few years.

Some rocks might exhibit such early strength; for example, limestones can become lithified soon after deposition. But most sandstones and shales require major loss of water, compaction and/or chemical cement to become a strong rock, all processes that involve significant amounts of time. This is especially true for very fine-grained muds in which low permeability makes the complete dewatering of a large mass almost impossible in any short time. The rapid loading of material on top or withdrawal of lateral support to squeeze out the water merely causes liquefaction of the mass. One version is well known to hydraulic engineers as the "sudden drawdown case," wherein rapid drainage of a canal or river results in collapse of oversteepened water-soaked cutbanks as flood-swollen rivers subside. In the very late history of the Grand Canyon, smaller versions of such massive collapses of water-soaked canyon walls actually occurred as lava dams were breached by the river and huge temporary lakes were drained. However, if cutting of the main canyon was separated from deposition by less than a few years, there should have been far more widespread, early, massive collapse of almost every shale formation in the canyon, a completely unrecognized phenomenon.

Ice Age (Singular)

In the creationist view, removal of the greenhouse effect after canopy collapse produced one and only one ice age. The Austin *et al.* (1994) runaway subduction model includes several hundred years of much warmer oceans heated by newly formed igneous sea floors over two-thirds of the globe. It proposes that warmer oceans heated the atmosphere and facilitated transport of moisture to the poles. Oceanic heat was counteracted by great increases in the earth's albedo as a result of volcanic ash produced during flood tectonics. This change cooled the earth and initiated a single short-lived ice age. Once the ash settled and cooling of the ocean and its floor was complete, the ice age ended at about 2000–2500 B.C. To explain the apparent record of multiple glaciations, M. J. Oard (1990) argued for a very thin, post-flood ice cap that lasted only 700 years. Periodic surges at its lobes and edges produced local burial of slightly older glacial materials, all of essentially the same age.

Real evidence for multiple glaciation is overwhelming. Older works on glacial geology (Wright and Frey 1965) describe in great detail arguments for four major ice ages in the last two million or so years. This evidence includes well-developed soil horizons and subtropical vegetation overrun by succeeding ice advances. More recent works (Dawson 1992, Anderson

and Borns 1994) support these observations and further separate the glacial stages into about ten different advances. In addition, they give evidence of several other very much older glacial epochs, including one in Africa as well as some Precambrian ones, which in creationist terms should have been in the warm "pre-flood" environment of Eden.

Probably the best argument for the magnitude of ice-age time is the record from long cores taken through the ice caps of Greenland and Antarctica. Gish's incorrect statement (1992) that an armored dinosaur had been found in the ice of Antarctica only confuses the issue: In reality the fossil was found in Mesozoic *rocks* of the Santa Marta formation of Antarctica (Weishampel 1990).

In the ice cores, summer and winter bands can be counted back, year by year, at least 30,000 years (Anderson and Borns 1994) with overall core lengths indicating total time spans of several hundred thousand years. Younger dates derived by counting the annual layers in the cores can in turn be correlated with C^{14} (carbon-14 radiometric) dates from the CO_2 contained in entrapped air bubbles, with C^{14} dates from tree rings that can be counted and correlated back 12,000 years, with annual sediment layers from glacial lakes, with dates from the pollen records of climatic change in Europe and America and with radiometric dates and rate of sedimentation dates on deep-sea cores.

Most of these dates can in turn be stitched together and mutually supported by paleomagnetic dates from other areas and other dating techniques (summaries by Anderson and Borns 1994). As new evidence is gained and dating techniques are refined, all these lines of converging evidence show increasingly good correlations with the Malenkovich climatic cycles. These cycles are based on the celestial mechanics associated with long-term changes in the ellipticity of the earth's orbit and changes in the tilt of its axis, and provide an additional set of time links to modern astronomic measurements. It requires an extreme leap of faith to argue in the face of such massive and interlocking evidence that the Ice Ages occurred only in the last few thousand years, at a time when written history existed in other parts of the globe.

Cooling Rates

In addition to those models discussed above that involve preposterous rates of global and sea floor cooling, there is the problem of rapid cooling of the high-temperature granite masses that now comprise tens of thousands of cubic kilometers in the cores of almost all great mountain systems. Creationist models require these bodies to have cooled completely since 2500 B.C. by mechanisms recorded neither by general history nor the Bible. Furthermore, these unknown mechanisms must be so efficient that only a few hot springs remain in most areas of the globe. Even though the laws of cooling and heat transfer are well established with their values and applications to geologic examples provided in many geophysics texts, to date I have found no attempts by creationists to apply these thermal constraints in any detail to their models.

Figure 7. Creationists offer a cartooned view of science that is often hard to address in public debate. Creationism itself, meanwhile, has tempted a few cartoonists to take up their pens. John Holden, a paleontologist by training (and co-author with R. S. Dietz of a cartoon commentary, *Creation/Evolution Satiricon*), has pondered the implications of Henry Morris's explanation of lunar craters as the result of cosmic battles between Satan's angels and those of the Archangel Michael.

Additional cooling constraints reside in various mineral types associated with these large granite bodies. The minerals formed at different temperatures and were able to trap daughter products of radioactive decay within them, starting at different cooling temperatures. Radiometric dating of when these different minerals passed through their retention temperatures allows the determination of cooling rates within the granite bodies. W. S. Pitcher (1993) provides a summary of such measurements, which range from 30 to 250 degrees Celsius per million years, depending on size of body and depth of burial. These values, in good accord with typical laws of thermal physics for cooling bodies, further strengthen the case for accuracy of radiometric dating.

The Earth Stands Still

Many Biblical tales pose special problems for those who would attempt scientific explanations. One is the story (Joshua 10, 12–13) of Joshua keeping the sun from setting while the Israelites took vengeance on the Canaanite kings. This was an event that supposedly occurred in the last few thousand years in the creationist era of relatively normal science, a time when recorded history existed. Stopping and starting the earth's rotation should have been accompanied by unbelievably massive earthquakes and giant tidal waves, phenomena not recorded by other societies, nor in the geologic record of such young deposits. However, Henry Morris, in the *Defender's Study Bible* (1995), says:

> Since the earth rotates on its axis, the sun could only be made to "stand still" relative to earth by stopping earth's rotation.... This was surely a unique miracle, but not beyond the capabilities of the Creator of the sun and moon and planets. He started their motions, has maintained them through the ages, and is able to change them at will.

As a "scientific" explanation for this tale, I. Velikovsky (1950) proposed that a few thousand years ago a comet, later to become the planet Venus, was ejected from Jupiter to do a near-miss of the earth, stopping the earth's rotation and the sun's apparent motion. Velikovsky has been so thoroughly debated and refuted that restating all the faulty arguments and questionable data seems pointless. D. Morrison and C. R. Chapman (1990) list many of these. Velikovsy's mechanism, bad as it might be, at least pretends to be science. Morris's explanation is clearly religious and beyond such pretense.

Conclusions

Only now is the scientific community coming to recognize that although battles in the last decade to keep creationist pseudo-science out of public-school science classrooms may have been won in the courts, the war itself is in serious danger of being lost in the court of public opinion. L. Kraus (1996) may have made the best statement in a *New York Times* Op-Ed piece: "The increasingly blatant nature of the nonsense uttered with impunity in public discourse is chilling. Our democratic society is imperiled as much by this as any other single threat, regardless of whether the origins of the nonsense are religious fanaticism, simple ignorance or personal gain."

The creationist strategy has been to portray this debate as a choice between their cartoon of science or their particular brand of religion. As scientists, we must emphasize repeatedly that the argument against creationism is not against religion as such but rather against a fringe group's attempt to force the Bible into the public schools in the guise of a science textbook.

Creationists have always picked here and there at science trying to discredit the whole by casting doubt on some small piece, largely by misrepresenting the facts before scientifically unsophisticated audiences. Science has fallen into a trap by trying to argue about these individual pieces without forcing creationists to defend their "scientific" worldview. This has been particularly unfortunate in debates about biological evolution, in which scientific arguments fall prey to common public aversions to "monkey ancestors" and to the ease of confusing the public with complex and unfamiliar biologic processes.

The rock record may be a much easier point of attack. It offers a fairly straightforward outline of events and rates of change generally familiar to most Americans. The total creationist view of earth history should be exposed in full detail, and its proponents should be forced to defend it in public debate. Extraordinary claims require extraordinary levels of proof. The time has come to stop fighting defensive skirmishes and to start challenging creationists to defend *in toto* what they call science—humorous absurdities and all.

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