

Historical Background:

Catastrophism versus Uniformitarianism

As an introduction, we first need to take a historical step back several hundred years in England. In the 1700s through the 1800s many British geologists were also clergymen. They did not see any conflict between geology and their Christian faith. They accepted a literal reading of the Bible and believed that G-d created everything in six days and that some time later He brought a worldwide deluge which, they suggested, subsequently determined the geology of the Earth. As an example, in 1698 Dr. John Woodward wrote a book entitled *An Essay toward a Natural History of the Earth...with an Account of the Universal Deluge and of the Effects that It Had upon the Earth*. This was followed by *Relics of the Flood*, the major work of Oxford professor of geology William Buckland (1784-1856). To quote from one of Professor Buckland's lectures, "...we find such undeniable proofs of a nicely balanced adaptation of means to ends, of wise foresight and benevolent intention and infinite power, that he must be blind indeed, who refuses to recognise in them proofs of the most exalted attributes of the Creator." Because in the 1820s its geologists used religion as the foundation of their science, this decade at Oxford is called the "diluvial decade."

Even before Buckland wrote his book, reactions against his and Woodward's views were being voiced. The most prominent critic was James Hutton (1726-1797). Hutton rejected the idea of a universal flood and suggested that the Earth had taken a very long time to develop. The famous

last line in a paper he published in 1785 maintains, "we find no vestige of a beginning, no prospect of an end."³ Thus, Hutton clearly put forth the notion of a very old Earth. As we shall see, this became the dominant paradigm for geology and even for biology. In fact, in geology textbooks Hutton is referred to as the father of modern geology.

The early geologists who advocated a universal flood to explain the geology of the Earth were called "catastrophists." Their view was that violent, catastrophic events in the past determined the geology of the Earth. Catastrophists were viewed as scientists who invoked supernatural causes, and catastrophic thinking was closely linked, in many people's minds, with biblical literalism. Although all catastrophists were not necessarily believers in biblical literalism, this notion was maintained in scientific circles for the better part of a century. Consequently, catastrophism was widely viewed as beyond the pale of acceptable science. In a book called *Principles of Geology* (1830-1833), Charles Lyell argued fervently against catastrophism, "...never was there a dogma more calculated to foster indolence...all theories are rejected which involve the assumption of sudden and violent catastrophies."⁴

Lyell advocated an alternative method for scientific inquiry that was later dubbed "uniformitarianism." Lyell insisted that only current observations would yield valid methods for studying the geologic past. In the words of one of his later commentators, "...Lyell argued that interpretation must proceed on the basis that causes had not varied in degree either; in short, the intensity of observable earthquakes, volcanoes, floods, and other geological agents should be the measure of their action in the past."⁵

Lyell's book was very influential. In fact, Charles Darwin himself said, "I always feel as if my books came half out of Lyell's brain...."⁶ Uniformitarianism became the paradigm for geology and for other sciences for the next hundred years. It is the basis for the belief that the Earth is very old.

A recent geology textbook phrased it this way: "The acceptance of uniformitarianism meant the acceptance of a very long history for Earth."⁷

Beginning about fifty years ago, chinks in the armor of uniformitarianism were found in the first of a series of scientific discoveries that finally led to the revival of catastrophism in modern science. Three of these discoveries will be discussed here.

1. Continental Drift

In a book published in 1915, *Die Verschiebung der Kontinente* (continental displacement), the German meteorologist Alfred Wegener proposed that all the continents originally had been connected and then moved apart. The early evidence to support this idea is the almost jigsaw fit of the continents, particularly South America with Africa (especially after the continental shelf is taken into account) and the similarity of rock formations and fossils on opposite continents thought to have been connected originally. Geologic theory considers the drifting apart of the continents to have taken place in stages: the Permian Period 233 million years ago, the Triassic Period 200 million years ago, the Jurassic Period 135 million years ago, and the Cretaceous Period 65 million years ago. These dates will be dealt with further on in this paper.

In suggesting such a scenario, Wegener committed two sins in the eyes of the professional geological community of his time. His first sin was that he was not a professional geologist, yet he dared to advance such a major geologic theory. His even greater sin was that such a notion smacked of catastrophism, which had been rejected by many serious geologists.

In particular, the American geologists were vehement in their opposition to his idea. Professor B. Willis of Yale proclaimed in 1949, "The theory is a fairy tale which should be discarded."⁸ Professor R.T. Chamberlain of the University of Chicago asked in 1926, "Wegener's hypothesis in general is the footloose type...Can we call Geology a science when there exists such difference of opinion on fundamental issues as to make it possible for such a theory as this run wild?"⁹

In a comprehensive book on this subject, Naomi Oreskes writes, "The theory of continental drift did not violate the laws of nature...but in Schuchert's view it did challenge, and seriously threaten the uniformitar-

ian principle that was at the root of his science..."¹⁰ (Charles Schuchert was a leading American geologist in the 1920s.)

Conclusive evidence for continental drift was found in the 1950s with the discovery of magnetic reversals and from this, indications of sea floor spreading. Today, also under the term "plate tectonics," it is the dominant theory behind all modern geology.

2. The Giant Meteor That Killed the Dinosaurs and, in Effect, the Theory of Evolution

A long-standing question among paleontologists, geologists, and other scientists is: What caused the sudden demise of the dinosaurs? Evolutionary theory would imply that they died by natural selection; somehow the dinosaurs were not fit to survive. If the dinosaurs died by natural selection, they would have died gradually, not abruptly. The fossil record evidence indicated, however, that the dinosaurs died suddenly. No dinosaur fossils are found above a certain thin clay layer called the K-T boundary. This suggests an abrupt extinction.

In 1980, a radical possibility was suggested, that a giant meteorite (also termed an asteroid) had struck the Earth, causing a dust cloud that obscured the sun for months and triggering massive earthquakes and tsunamis. As a result, all the dinosaurs and many other life forms died. This is, arguably, the ultimate catastrophic hypothesis. While extremely controversial, the possibility of this idea had to be taken seriously by the scientific community for two reasons. One was that the evidence for it could not be satisfactorily explained any other way, and the other was that Nobel laureate in physics Luis Alvarez was one of the team that suggested the theory.

The theory of Alvarez et alia¹¹ was that the meteorite was massive, 100-1000 billion tons in weight and ten kilometers in diameter. It struck the Earth at a speed of 30,000 miles per hour. This is twenty times the speed of a bullet fired from a rifle. Its impact was equal to *five billion atomic bombs*. The impact produced earthquakes of the magnitude of 13 on the Richter scale, i.e., about 3000 times stronger than that which caused the recent tsu-

nami in Southeast Asia (9.3 on the Richter scale). As a result, virtually all the animals (in particular the dinosaurs) and many plants on Earth were wiped out.

A lingering question on Alvarez's Asteroid Impact Theory was the location of the crater that should have been formed. Strong evidence was finally found for the crater site in the Yucatan Peninsula. Also, evidence of tsunamis at that time was found. This evidence resulted in a wide acceptance of this catastrophist idea.

The world renowned geologist Kenneth Hsu wrote a book on Alvarez's Asteroid Impact Theory and suggested that not only were the dinosaurs killed by the giant meteorites, but also the theory of evolution. "It is time to awaken to the absurdity of the idea of natural selection."¹²

1. Catastrophic Flooding in the Channeled Scablands

There is an area in southeastern Washington state in the United States called the Channeled Scablands. It is characterized by very hard basalt rock. Carved throughout the basalt are channels and canyons. Roughly rectangular in cross-section, the canyons have steep, stepped sides. Uniformitarianism would imply rounded, gradually sloping sides—the opposite of what is observed. The Oregon bank of the Columbia River that flows between the states of Oregon and Washington is characterized by very high basalt rocks.

An explanation for the formation of the Channeled Scablands was proposed in 1929 by J. Harlan Bretz, a geologist at the University of Chicago. He suggested that they were formed by sudden catastrophic flooding over a short period of time. The waters were released from a giant inland body of water, Lake Missoula in Montana, that was held in place by ice dams. The dams gave way, and the water crossed the entire state of Idaho, flowing all the way to the Pacific Ocean. Five hundred cubic miles of water moved westward at sixty miles per hour, "in a torrent flowing with ten times the volume of all the rivers on earth...."¹³ The flood carved out channels and canyons and formed waterfalls many times larger than Niagara Falls. Water a thousand feet deep moving with the speed and force of

a fire hose formed the Grand Coulee, a gorge twenty-five miles long and nine miles wide. It also formed the gravel delta now underlying the city of Portland, Oregon.

This explanation for the formation of the Channeled Scablands was initially rejected as a catastrophist notion. Several decades after Bretz had proposed this idea, evidence from aerial photographs was found that strongly supported it. These observations convinced the geology community, and in 1979, at age 96, Bretz was awarded the Penrose medal—the highest award given to an American geologist. The telegram from the prize committee to Bretz closed dramatically with the words “we are all catastrophists now.”

These three examples clearly show that there has been a revival of catastrophism in modern science. The relevance of the above background on uniformitarianism and catastrophism for the dating methods discussed in the next section is that the uniformitarian assumption is a common thread running through all the dating methods.

Dating Methods

The major methods for dating terrestrial objects fall into four categories. The last three methods use radioactivity. They are listed in order of decreasing accuracy and also in terms of their applicability:

1. Tree rings—both live and dead wood
2. Carbon 14—objects that had once been alive, such as wood, bone, and shells
3. Potassium-argon—rocks and adjacent fossils
4. Uranium-lead—the oldest rocks and inferring the age of the world

1. Tree-Ring Dating

Certain species of trees, particularly oaks and evergreens, such as most pines and sequoias, produce what is characterized as an annual growth ring. Under suitable climatic conditions similar to our own (i.e., the uniformitarian assumption), a single ring per year is produced.

This method does not work for tropical trees. Moreover, there is a species of pine, *pinus radiata*, which can produce five rings per year. Even on

species that are used for dating, there can be extra and missing rings.

The technical term for tree-ring dating is dendrochronology. If one looks in a textbook or on web sites on the subject, an idealized picture will be seen to illustrate how the method is deployed. The textbook examples show well-defined ring patterns of, for example, a living tree. These patterns are placed against an old piece of wood for a comparison. If the match is considered satisfactory, then the older piece of wood is dated back, so to speak. In actual fact, samples taken from both living trees and dead wood, when matched and overlapped, are considered to progressively extend back into prehistoric times. In actual practice, though, samples rarely have well defined patterns of rings that are easily matched from one piece of wood to another. Instead, statistical methods are used to try to determine the best possible matches, and the validity of the statistics used in such an analysis is often questioned.¹⁴ For the older chronologies, there can be considerable dispute within the literature about the interpretation of some of the reported measurements.¹⁴

The rings are often very small and are counted under a microscope. According to dendrochronology, the bristlecone pine, found in the White Mountains of the California High Sierras, is the oldest life form on Earth. Interestingly, the oldest living tree that has been dated is about 5000 years old. Rings are about $\frac{1}{100}$ of an inch wide.

Using the method described above, dead trees found in the California High Sierras are dated to 8000 years ago. The trunk of a bristlecone pine can reach up to thirty-nine inches in diameter, so it is clear that there is very little growth from year to year.¹⁵ Similar methods are used for dating live and dead oaks in Europe. There are European oaks that have been dated to about 13,000 years ago.

The validity of various dating methods is often determined by checking whether the different methods agree. Dendrochronology of bristlecone pine and European oaks has been checked against carbon 14 measurements. The results are discussed in the section on carbon 14 below.

2, 3, and 4. Dating by Radioactivity

Some atoms are radioactive and others are stable. An initial or *pure* radioactive atom can decay into a different atom, called a *daughter*. The decay is characterized by a half-life—the period of time in which half the parent atoms decay into daughter atoms. As examples, the half-life of radioactive carbon, carbon 14, is 5730 years; and of radioactive potassium potassium 40, is 1.25 billion years.

If one measures the amount of parent and daughter atoms remaining in a particular sample, and then, *using an extrapolation based on the assumptions listed below*, the radioactivity can be exploited as a type of clock and used to deduce how old the particular item is. The validity of the results is dependent on the degree to which these assumptions are satisfied.

Assumptions for Radioactive Dating Methods

- *Closed system*: Nothing goes in or out of the object being dated.
- For potassium-argon, and uranium-lead there is *no daughter atom present initially*. For carbon 14, the ratio of parent to daughter is assumed to be known at the outset.
- *Conditions were sufficiently uniform* throughout the age of the object dated so that an extrapolation can be made.

We can now take a more detailed look at some of the radioactive dating methods with particular regard to the assumptions listed above. In previous papers in *B'Or Ha'Torah*,¹⁶ we have already discussed the lack of satisfying closed system behavior and the difficulties of knowing the initial conditions that influenced the objects that are dated. We shall now summarize these discussions and consider a comparison of all these dating methods within the broader context of this paper. Issues warranting further discussion will be raised.

An interesting aspect of all the radioactive dating methods is the difference between the analytical measurements used and the quality of the samples chosen. The analytical methods are quite sophisticated and therefore can result in impressive precision. *Precision* here means that the measurements themselves on a particular sample are very reproducible. The objects to be dated, on the other hand, can and often do exhibit considerable variation in their properties. The result is that the *accuracy* of a date is dependent on the quality of the sample. Researchers tend to stress

the precision of their techniques, but the key numbers are to be found in how accurate their conclusions are.

Carbon 14 Dating

Carbon 14 is formed through the action of energetic cosmic rays on nitrogen 14 in the outer atmosphere of the Earth. The carbon 14 forms carbon dioxide (CO_2), and enters the Earth's atmosphere and mixes with CO_2 formed from ordinary, non-radioactive carbon—carbon 12. Plants absorb this CO_2 , and, as long as they are alive, the ratio of carbon 14 to carbon 12 within the plants is constant. A key assumption that is particular to this dating method is that the carbon 12 and carbon 14 ratio in the atmosphere at the time the plant dies is known. When a plant dies, it no longer absorbs CO_2 and whatever carbon 14 was present in the plant now begins to decay radioactively. Measuring the ratio of carbon 14 to carbon 12 in the dead plant later on is thought to enable a calculation of its "age."

Another key assumption is that the only source of carbon 12 in the plant is from the CO_2 that was absorbed while it was alive. It is now known that serious problems with interpreting such ages can occur if there are dissolved carbonates present in the ambient (either currently or formerly aqueous) where the sample to be dated is found. The dissolved carbonates can result in the uptake of large amounts of carbon 12 and therefore make it appear that the object to be dated is much older than it really is. Carbon 12 uptake is a serious violation of a closed system.

This problem of dissolved carbonates is recognized by workers in the field, and chemical techniques have been developed to allow for appropriate corrections here, but whether the corrections are adequate for subsequent reliable dates is debatable. (See my paper on hominid evolution in this volume for the implications of this possibility.)

The basic uniformitarian assumption underlying carbon 14 dating is that the ratio of carbon 12 to carbon 14 in the atmosphere at the time the plant died is the same as at the time that the plant is dated. In fact, it is now known that a number of factors can affect this ratio. This is discussed in the paper on carbon 14 dating, in volume 2 of *B'Or Ha'Itonah*.

Correlations and Calibration

As a check on their accuracy, the dating techniques are compared one with another in those cases in which there is sufficient overlap of applicable time frames. One of the best known examples of this is the effort to find a correlation between tree-ring dating and carbon 14 dating. The actual measurement technique for carbon 14 is quite sensitive, and individual tree rings can be measured for their carbon 14 content. An early result¹⁷ is shown in the graph below, where the vertical scale is the radiocarbon age in years before the present and the horizontal scale is the tree-ring age.

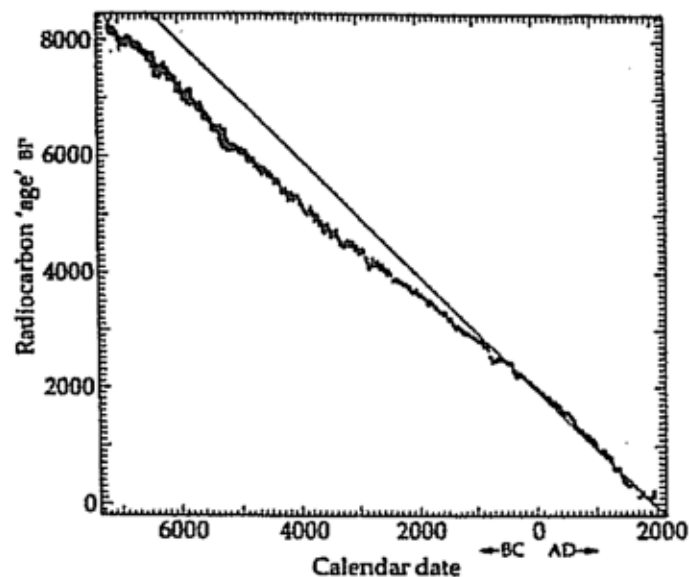


Figure 1. Comparison of the carbon 14 age (vertical scale) versus the tree-ring age (horizontal scale) for the past 7000 years based on Irish oak (*Quercus* sp.). Graph adapted from Sheridan Bowman, *Radiocarbon Dating* (London: The Trustees of the British Museum, British Museum Publications, Ltd., 1990) p. 18.

If the two methods agreed, all the data that is represented by the wiggly line would match up with the straight line on the graph. Instead, there is a disparity of about 600 years—5700 years ago—with the disparity beginning about 3200 years ago. So, even in this case, using the most accurate of the dating methods (dendrochronology) to establish a correlation with the next most accurate method (carbon 14), there is a disparity. To quote Michael Baillie, an authority on tree-ring dating, “One irony is that dendrochronology, aimed at the calibration of the radiocarbon timescale,

has tended to expose the limitations of radiocarbon dating."¹⁸ This disparity is often attributed to a violation of the assumption that the carbon 12 to carbon 14 ratio in the atmosphere has been consistent throughout the history of the tree being measured. That is to say, it is recognized that a simplistic application of uniformitarianism is not warranted here. All this has not discouraged scientists from trying to work out agreed-upon calibration curves. A recent article in *Science* discusses this and the ensuing controversies surrounding such activity.¹⁹

Radioactive Rock Dating

All the radioactive rock dating methods have one characteristic in common. The majority of the rocks that are thought to be dated with the highest level of confidence are assumed to have been formed originally in a molten state and, as they cooled, crystallized into a solid state. Their "age" is generally assumed to start when they became a solid crystal. One could think of this in the same way that water (in the molten or liquid state) is allowed to cool until it crystallizes into ice (a solid state). The formation of the majority of the minerals that are dated, then, is really a crystal growth process and should be subject to the same principles that govern crystal growth.

Synthetic crystals play a major role in our technological civilization. Silicon crystals, for example, are the basis for transistors and solar cells. Growing silicon crystals is a major industry in itself. A significant part of present-day science dealing with crystals is the study of their defects. A perfect crystal is an idealization that does not occur in any observed materials. Instead, there are defects such as impurities, missing or extra atoms, and grain boundaries. Defects are particularly pervasive in crystalline substances found in rocks, far more than in any of the synthetically grown crystals. In general, defects can easily dominate the properties of these materials. Such defects and the overall crystallization process play a major role in assessing the validity of radioactive rock dating.

Potassium-Argon Dating and Defects in Rocks

Certain minerals, particularly micas, have a small amount of radioactive potassium in them. Potassium is a metal, the radioactive form of which is called potassium 40. Potassium 40 decays by radioactivity into argon 40, which is an inert gas. Assuming a closed system, by measuring the amount of potassium 40 and argon 40, the time from solidification (i.e., the "age") can be determined. An earlier paper on potassium-argon dating in *B'Or Ha'Torah* 15 pointed out how defects could totally vitiate any possibility of a closed system.¹⁶

As was pointed out in the earlier article on potassium-argon dating, Brent Dalrymple, a leading researcher in radioactive dating and, incidentally, a very active supporter of evolution in the debates ongoing in the US, has likened the argon that is formed in a mica mineral to that of a bird in a cage. In actual fact, though, argon is *not* like a bird in a cage. Actual rocks have many defects, and there are many studies in the literature documenting how the argon moves in and out very rapidly due to these defects. Other violations of closed system behavior are that excess argon can form in rock when it initially crystallizes, even when there should not be any argon present. Exposure to hot water (hydrothermal effects) can change both the potassium 40 and argon 40 concentrations in a mineral.

Uranium-Lead Dating and Defects in Rocks

There are some minerals, particularly zircon (zirconium silicate), that contain a small amount of radioactive uranium. This uranium, through a series of radioactive decays, ultimately results in radioactive lead. Assuming a closed system by measuring the amount of uranium and lead in the zircon, the "age" of the zircon can be deduced from when it first crystallized. For uranium-lead there are similar possibilities for violations of a closed system behavior as for potassium argon. In particular, a likely cause of the escape of lead—a major problem for this dating method—is connected with the presence of defects in the zircon crystals.

Zircons are favored for this work because in theory the crystal structure of this substance more closely approximates a closed system. However, in

practice, the zircon crystals are microscopic in size and subject to the same problems that arise from defects in crystals.

A typical zircon crystal used for dating is only about two-thousandths of an inch long. Much larger zircons can be grown in a laboratory and are used as fake diamonds in jewelry.

Researchers claim to have discovered the “oldest rock in the world” in a rock formation in Western Australia.²⁰ Their work attracted considerable publicity, including an article in *Scientific American*. They obtained their results by using a very sensitive instrument widely used by materials scientists—a so-called ion microprobe. This instrument was used to measure the amount of a particular form of uranium and a particular form of lead at very small locations on a slice of the zircon crystal. From the concentration of these two materials, the age of the zircon is inferred at various locations on the sample surface.

Do the “ages” found in a zircon sample make sense scientifically? When the ages are quoted over a distance on the zircon crystal of about $\frac{1}{1000}$ of an inch, the ages vary by almost one hundred million years. Assuming no lead loss, this would imply that the zircon crystal grew at a rate of about one atomic layer every two to three thousand years. There is no evidence based on known cooling rates of crystals grown in the laboratory of such a phenomenally slow crystal growth.

The authors of a study on this do not discuss the possibility of such a low crystal growth rate. Instead, they they simply state that “the interpretation of disparate ages from a single grain is a problem for all ion microprobe studies of U-Pb ages in zircons...For this study, we favor Pb loss to explain variable ages within individual zircons.”²⁰ Thus, a key issue in this kind of work is variability within a single crystal and loss of lead (Pb).

In general, however, geologists do speak of various rock formations taking tens of millions of years to form. This would still imply extraordinarily slow crystal growth processes, unlike anything known to modern day science. If this is so, this represents an interesting violation of the general uniformitarian principle.

An even greater source of error in zircon dating, is the fact that the

radioactive decay chain that proceeds from uranium to lead also involves some highly energetic by-products that can literally knock the atoms around inside the crystal, much like billiard balls hitting each other. When this occurs, the outer appearance of the crystal can still manifest crystallographic faces except that the inner part of the material is no longer crystalline, but rather amorphous. Amorphous can be understood here as meaning highly defective. As is well known, an amorphous material is the very antithesis of a closed system, since atoms such as lead could easily move in or out. A description of a very recent study in *Nature*²¹ discusses this issue and points out that significant changes in the physical properties of zircon can be the result. For example, the density could decrease by 17 percent.

Another issue is that of the possibility of lead and uranium leaching due to hydrothermal effects. There are studies that indicate strong hydrothermal effects at temperatures as low as 200° C, particularly in zircon that are amorphous.²²

Summary and Conclusions

All the major terrestrial dating methods rely on the uniformitarian principle. They do so despite the fact that catastrophism is now an accepted part of modern science. The revival of catastrophism has not been taken seriously enough to serve as the grounds for reevaluating terrestrial dates or for adjusting or discarding the current dating methods. I have not found any studies that attempt to pursue any of these three objectives.

The demise of the dinosaurs is an example of an issue that requires reevaluation. Modern science says that the dinosaurs disappeared 65 million years ago. If all the upheavals suggested by Alvarez occurred, the many—if not all—of the rocks on the surface of the Earth had to have been affected. The 2004 disaster of a giant tsunami and earthquake in the Far East is an interesting case in point. The effects under sea were such that pieces of rock a mile long were moved seven miles at speeds of 100 miles per hour. Scientists have estimated that the island of Sumatra moved out to two meters and the north pole of the Earth shifted about an inch.²³ The forces suggested by the meteor impact that killed off the dinosaurs were

orders of magnitude greater than what occurred in Thailand and neighboring countries, and yet there do not seem to be any studies on how this could have reset all the radioactive clocks. Very extensive hydrothermal effects were also a likely outcome of the meteorite impact. As discussed above and in the earlier paper on potassium-argon dating, hydrothermal effects can result in a resetting of the radioactive clocks.

Scientists would answer that there have been innumerable measurements of dates and that there is consistency among these dates, particularly from different radioactive dating methods. As a consequence, there is good reason to believe in their validity.

However, in this paper we have argued that a catastrophic event such as the meteor impact described by Alvarez could have altered all the rocks on the surface of the Earth so that they would now appear to give consistent dates. While such an assertion cannot be made more quantitative at this time, it is planned to develop a future model that could demonstrate this.

If some of the above arguments for a reevaluation of all the major terrestrial dating methods are valid, why are so few people willing to address these questions? One possible answer is a sociological and political one. The fierce debate still raging on Intelligent Design and whether it should be taught as science is the successor to the earlier debate described in this article between the catastrophists and the uniformitarians. As a result, scientists view any questioning of the age of the world as an admission that the other side in the debate might be right. Any possible debate on this kind of subject tends to be more political than scientific. In this case, dogmatism is not the exclusive property of the religious believers but can be found in abundance among those who believe that they are defending science. Kenneth Hsu²⁴ makes this point very clearly.

Notes

- ¹ Talmud *Rosh Ha'Shanah* 11a.
- ² Cited by A. Hallam, *Great Geological Controversies* (Oxford University Press, 1986) p. 41.
- ³ *Ibid.*, pp. 33-34.
- ⁴ Charles Lyell, *Principles of Geology*, (1930-1933; repr., London: Penguin Classics, 1997) p. 352.
- ⁵ *Ibid.*, introduction by James A. Secord, ed., p. xvii.
- ⁶ Cited in G. Himmelfarb, *Darwin and the Darwinian Revolution* (New York: W.W. Norton, 1968) p. 97.
- ⁷ E.J. Tarbuck and F.K. Lutgens, *Earth Science*, 10th ed. (Prentice Hall, 2003) p. 288.
- ⁸ Paraphrased in Hallam, pp. 135-136.
- ⁹ Paraphrased in W. Sullivan, *Continents in Motion* (New York: McGraw Hill, 1974) p. 11.
- ¹⁰ Cited in Naomi Oreskes, *The Rejection of Continental Drift* (New York: Oxford University Press, 1999) p. 207.
- ¹¹ Walter Alvarez, *T. Rex and the Crater of Doom* (New York: Vintage Books, 1998). An excellent reference for the story of this discovery, told by the son of Luis Alvarez who was also one of the key players.
- ¹² Kenneth Hsu, *The Great Dying* (New York: Ballantine Books, 1986) p. 277.
- ¹³ U.S. Department of the Interior. National Park Service, www.cn.nps.gov/history/online_books/geology/publications/inf/72-2/Sec5.htm.
- ¹⁴ M.G.L. Baillie, *A Slice through Time* (London and New York: Routledge, 1995) p. 20.
- ¹⁵ S. Bowman, *Radiocarbon Dating* (London: British Museum Publications, 1990) p. 17.
- ¹⁶ Yaacov Hanoka, "Torah, Science and Carbon 14," *B'Or Ha'Torah*, vol. 2 (1982) pp. 33-38; "Radioactive Rock Dating and the Age of the Earth," *B'Or Ha'Torah*, vol. 15 (2005) pp. 27-33.
- ¹⁷ Bowman, p. 18.
- ¹⁸ Baillie, p. 11.
- ¹⁹ *Science*, vol. 313 (15 Sep 2006) pp. 1560-1563.
- ²⁰ John Valley, University of Wisconsin, www.geology.wisc.edu/zircon/earliestpiece/earliest.html. See also A.J. Cavosie et al., "Internal Zoning and U-Th-Pb Chemistry of Jack Hills Detrital Zircon," *Precambrian Research*, vol. 135 (2004) pp. 251-279.
- ²¹ *Nature*, vol. 445 (2007) pp. 161-162.
- ²² T. Geisler et al, *Chemical Geology*, vol. 191, no. 1-3 (Nov. 2002) pp.141-154; and, T. Geisler, et al., *Mineralogical Magazine*, 67, no. 3 (June 2003) pp. 485-508.
- ²³ Jim Loney, "Asian Quake Moved Islands, Shortened Days," (Reuters) 9 Feb 2005, www.abc.net.au/science/news/space/SpaceRepublish_1299077.htm.
- ²⁴ Hsu, p. 277-281.

Excerpts from the Question and Answer Session with the panelists of the panel
"How Should We Teach the Origin and Diversity of the Species?"

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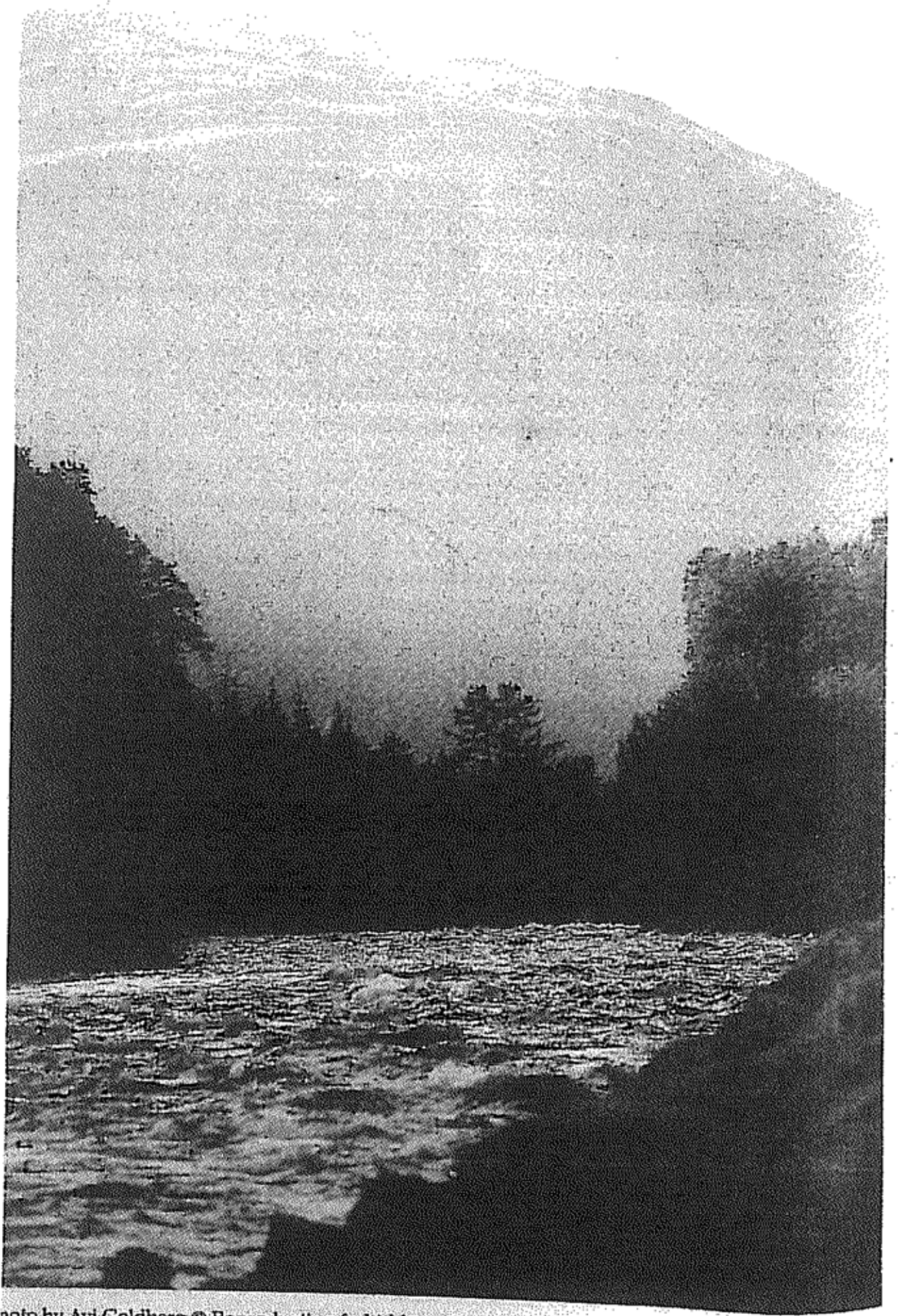


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Norway

Continental Drift, Asteroid Impacts, and the Flood

Yaacov Hanoka, PhD

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The leading paradigm in modern geology is continental drift and plate tectonics. The surface of the Earth is viewed as being a series of plates that move relative to one another. At one time all connected together, the continents are now separated and still slightly moving as part of this plate movement. Paleontologists today widely accept the Alvarez theory of a massive asteroid impact to explain the sudden demise of dinosaurs as well as numerous other fauna and flora. The mass of such an asteroid has been estimated as up to 10^{13} kilograms. There is now strong evidence that the location of the impact crater is the Yucatan Peninsula.

Investigation of Torah commentary on the Flood suggests some of these recent findings in geology and paleontology. A midrash in Genesis Rabba clearly states that the continents were connected prior to the Flood, and later commentaries assert that the seasons of the year began only after the Flood. The Talmud *Rosh Hashana* elaborates on possible extraterrestrial causes (i.e., asteroids) of the Flood.

Taking these Torah sources along with the conclusions of some of these scientific find-

ings, it is possible to construct a broad qualitative model that potentially could explain a wide diversity of phenomena, for example, why the Yucatan Peninsula is the location of the impact crater and how the 23.5 degree tilt of the Earth's axis relative to the plane of the ecliptic may have come about. The model can explain the major distributions of microtektites throughout the world. If verified by some of its predictions, this model could clearly have very significant implications for the Torah/science interplay. Given the validity of the model, the issue of reconciling radioactive rock dating with the chronology of the Torah needs to be addressed, and some approaches to this will be presented.

Dr. Yaacov Hanoka has a PhD in solid state physics and has worked on solar cells for the past twenty-five years. He has fifty publications and twenty-one patents in this field. He is a founder and vice president of Evergreen Solar. He and his wife Bina have five children, three of whom work in Habad Houses in the USA. Active in programs for Jewish college students, Dr. Hanoka writes and lectures on Torah and science. hanoka@evergreensolar.com

A Flood of Ideas

The Talmud¹ describes one of the actions of G-d in bringing about the Flood in the time of Noah. It says, "...He took two stars from Kima and brought a flood upon the world." According to Rashi and Tosafot, Kima refers to the tail of Aries. Thus we have an indication of an extraterrestrial source which helped bring about the Flood. Note also two stars are mentioned. The Midrash² says, furthermore, that the constellations did not "function" during the Flood. This hints of major extraterrestrial changes at that time.

The Midrash tells us of upheavals on Earth as a result of the Flood. Prior to the Flood there was constant springtime with no change of seasons. People had to cultivate their fields only once in forty years. The Midrash furthermore tells us that before the Flood the continents were all connected, so that a person

uld go from one "end" of the Earth to the other "end" without encountering an ocean. By this account, the separation of the continents took place as a result of the Flood. Since the seasons are due to the 23.5 degree tilt of the axis of the Earth relative to the plane of the ecliptic (the apparent annual path of the sun in the heavens), several of the later Torah commentators attribute the occurrence of this tilt to the Flood.³

In sum, the Flood represents an event of massive, almost unimaginable global consequences. The continents were separated, the Earth's axis was tilted, non-terrestrial influences were in play, and much of the geology of the Earth as we now know it was formed.⁴

Fast-Forward to the Present

We now change gears and consider some recent ideas from geology, astronomy, and paleontology.

First, let us discuss the catastrophic demise of the dinosaurs. There is now almost universally accepted evidence, particularly from the fossil record, that not only the dinosaurs, but also most animals and many plants died out suddenly and catastrophically. The explanation given for the "great dying," as it was termed by the geologist Kenneth Hsü,⁵ is that a huge asteroid struck the Earth.⁶ The impact produced a dust cloud that covered the Earth and blocked the sun, causing total darkness for several months. There were earthquakes calculated to have been one hundred thousand times more powerful than anything witnessed in recorded history, and enormous tsunamis (seismic sea waves) possibly several kilometers high were produced. The asteroid is believed to have been as massive as a thousand billion tons and ten kilometers in diameter. It would have struck the Earth with a force equal to ten thousand times that of the entire world nuclear arsenal. The initial hole it would have created would have been forty kilometers deep. The outer layer or crust of the Earth has continental thickness varying from about ten to seventy-two kilometers and oceanic depth ranging from five to eleven kilometers. Thus, the asteroid easily could have penetrated the outer crust of the Earth.

It is now generally accepted that the site of this impact was the Yucatan Peninsula. The Chicxulub Crater (its local Mayan name) there has been dubbed the "crater of doom."⁷ A key piece of the puzzle that led to the discovery of the Chicxulub Crater was the prevalence of microtektites in the area surrounding the impact site. Microtektites are glassy rounded solids about one millimeter in size. They can be formed only under the condition of enormous and rapid pressure and heat due to an impact of an extraterrestrial body on the Earth's surface. Examination of the known distribution of microtektites throughout the world, as illustrated in figure 1, reveals an interesting pattern.

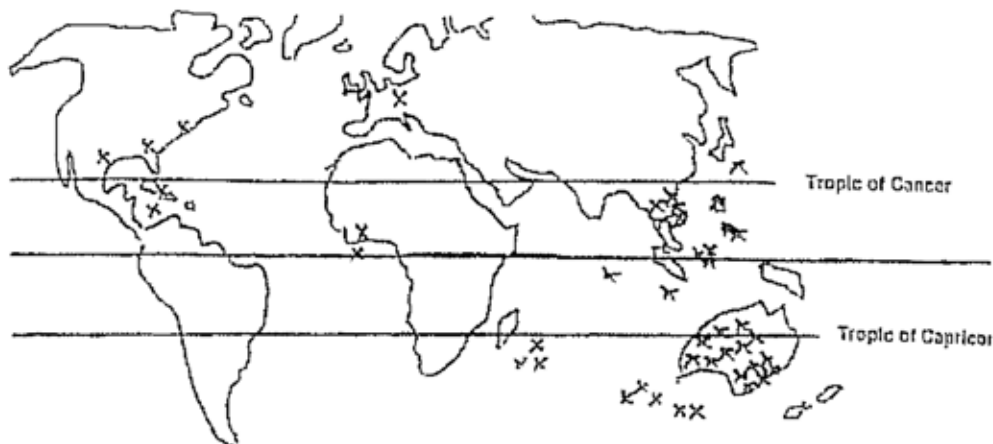


Figure 1. Microtektite distribution in the world. The equator and the tropics of Cancer and Capricorn are also indicated.

To understand the full import of figure 1, first of all bear in mind that these microtektites can travel thousands of miles after they are formed in the atmosphere following an impact. Secondly, based on their assumed trajectories and since the Earth is rotating relatively rapidly below them, their distribution tends to be skewed towards the east. This distribution suggests that such microtektites could have been ejected from two main central locations: one is the Yucatan Peninsula and the other is the Indian Ocean, west of Australia. The former is very close to the tropic of Cancer, 23.5 degree north latitude, and the latter is close to the tropic of Capricorn, 23.5 degree south latitude. The location of each of these impact sites corresponds exactly to the 23.5 degree tilt of the Earth's axis.

Terra Firma Slips Away

We turn now to some recent geologic theories regarding the continents.



Figure 2. The continents prior to their breakup

The current paradigm underlying virtually all of contemporary geologic thinking is continental drift, and more generally, *plate tectonics*. This theory says that all the continents were once connected and that they moved or "drifted" apart to form our present-day continents separated by oceans. Figure 2 shows one view of how the continents were connected prior to their separation. The term plate tectonics is used because, as a result of the concept of continental movement, the surface of the Earth's outer crust of rock is pictured as made of huge, slowly moving plates. The intersection of these plates is considered responsible for such events as earthquakes and volcanoes, as is seen along the Ring of Fire—the western coasts of South and North America all the way over to Japan and south to Hawaii.

As an interesting aside, continental drift is an excellent example of the difficulties in changing scientific paradigms. The theory was not accepted by most of the geology community in the first half of the twentieth century. The resistance was not based only on scientific merit. Continental drift suggests a catastrophic change, which was anathema to orthodox geologists for decades, rather than a uniformitarian or gradual change.

Evidence that helped to sway the opponents of continental drift theory was obtained from careful studies of the remnant magnetic orientation of rocks under the oceans. The rocks clearly showed that the magnetic field of the Earth had reversed itself many times throughout its history. This led to the idea—now a fundamental part of plate tectonics theory—that new molten rock is continually forming and solidifying under the ocean. As this rock solidifies, the magnetic minerals within take on the present orientation of the Earth's magnetic field. The continual formation of this "new" rock under the oceans then forces the continents to move. As Hsü has pointed out, the Earth's core, with its molten iron and nickel, can act like a dynamo.⁷ Calculations have indicated that turbulence that can result in a "certain critical configuration" can bring about a reversal.

It has been suggested⁸ that massive impacts due to events like asteroids striking the Earth and producing far-flung microtektites are likely associated with or even responsible for reversals in the Earth's magnetic field, so that what originally pointed north, now points south.

The Model

With all of the above as background, we can construct a scenario of what happened during the Flood.

The Torah describes several different stages regarding the Flood. First it rained for forty days and nights, and also the subterranean water was released. Finally, apparently towards the latter part of this forty-day period, the waters covered even the mountains. This was followed by a period of 150 days when the water was still covering the earth, and then a still longer period before the water receded and Noah emerged from the Ark with his family and animals. The entire process took twelve months.

Sometime in the period while the Ark was floating, probably near the end

of the forty-day interval, two giant asteroids (the two "stars" from the Kima constellation) struck the Earth simultaneously. They struck at the positions of the tropic of Cancer in the Yucatan Peninsula and the tropic of Capricorn in the Indian Ocean west of Australia. The double impact then produced sufficient force to literally crack the continents apart and set them moving away from each other at rather high speeds. The speeds had to be on the order of fifteen kilometers per twenty-four hours. As a further consequence of this, the division of the oceans as we now know them came about. Recall that the estimated depth of the impact at Chicxulub was, in several instances, deeper than the thickness of the Earth's crust, so this one asteroid literally penetrated the Earth's crust to the molten rock underneath the crust and then helped to initiate the movement of the continents as they "slid" over this underlying molten rock.

One of the asteroids hit what was then land, literally formed or carved out what is now the Gulf of Mexico, and formed the Yucatan Peninsula with its Chicxulub Crater. The second asteroid struck water in what we now call the Indian Ocean.

A question remains: How did the Earth become tilted on its rotation axis? Asteroid impacts, even given two of them, could not possess enough energy and force to produce such a tilt. A possible answer may be the changes mentioned by the Midrash: There might have been extraterrestrial forces at work. The fact that the impact sites occur at the same latitudes as the degree of the tilt of the Earth could possibly mean some relationship between them and the tilt, even if not a directly causative one.

As a further outcome of this double-asteroid impact, sufficient perturbation was produced in the Earth's molten metal core to cause the magnetic fields of the Earth to reverse them numerous times, probably over the 150-day period while the Earth was still covered by water.

Admittedly, this scenario is speculative and highly qualitative. However, as we have tried to show, it is striking how very much in accord it is both with Torah sources and contemporary scientific theories. Of course, the timescales show an enormous disparity. Geologic processes occurred supposedly over hundreds of millions of years; paleontologists claim that the dinosaurs disappeared sixty-five million years ago; whereas according to Torah chronology the Flood occurred about four thousand years ago.

An approach to this issue will be outlined in the following section.

Radioactive Rock Dating

Geologists date events in the Earth's history by the occurrence of certain fossil types believed characteristic of certain time periods and also by employing radioactive rock-dating techniques. The latter is more important for our purposes.

There are certain elements found in the Earth's crust that are radioactive. This means that part of this element will decay within a characteristic time period (called its *half-life*) into another element. By measuring the relative amounts of

the original element and the new element formed by the decay process, and assuming uniform conditions, it is possible to extrapolate and date the rock from the time of its formation. For example, in many basalts (a very hard rock formed by volcanic action) radioactive potassium metal decays into argon gas. By measuring the potassium-argon ratio in basalt rock samples and *assuming* that the decay took place in a so-called closed system, we can measure the age of the rock. *Assuming* is italicized here because this highlights an important aspect of all the radioactive rock-dating methods. A closed system means (1) that the initial starting concentrations of argon and potassium are inherent to the rock as it crystallizes from the molten state; (2) that the subsequent temperatures it is subjected to never rise above a few hundred degrees centigrade.

All the dating methods are based on what is called the uniformitarian assumption. Over the past one hundred and fifty years there has been a heated controversy among geologists between the uniformitarian view and the catastrophic approach. The uniformitarian view can be summarized by its claim that "the present is the key to the past." That is, only processes that we now observe, including their rates of action, are to be used to explain geologic features. Such a viewpoint does not admit catastrophic events such as massive floods, asteroid impacts, or rapid movement of the continents. The recent discoveries in geology discussed above clearly do not fit into the uniformitarian paradigm, and yet catastrophism now has a respectable place in the geologist's worldview. This acceptance is not as yet universal. In particular, the dating methods are still all based on uniformitarian principles.

Returning now to the example of potassium-argon dating, if at any time the rock had been subjected to high temperatures, the argon gas could have diffused out of the rock more rapidly than normal, and the remaining amount of argon would be much lower than usual. The rock would then measure much younger than it truly is. In the other direction, examples are cited in the literature in which recent volcanic rock, known to have been formed on the Hawaiian Islands in 1801, had potassium-argon ratios that indicated an age of up to three billion years.⁹ It has been found that in some cases potassium argon can give dates older than the purported geologic age of the Earth, about 4.8 billion years. The explanation here is that an external source of argon had found its way into the rock. In other words, this was not a closed system even at the outset.

Also, if the extensive volcanic activity suggested by the asteroid theory for the death of the dinosaurs did in fact occur, then much rock, which may seem much older to us, would have been molten and solidified at that time. The potassium-argon dating method could not tell us whether this was four thousand years ago or sixty-five million years ago because we have no way of knowing what the starting values of potassium and argon were, particularly given the cataclysmic conditions which must have surrounded their formation.

Potassium-argon is only one example of the methods used for radioactive rock dating, but this illustration should suggest the need for a fresh look at rock-dating methods in light of the discrepancies caused by catastrophic occurrences. The

tacit assumption of uniformitarianism in regard to rock dating, however, is so entrenched in the thinking of most geologists that, like continental drift, it will be difficult to displace. We suggest that a willingness to suspend belief in the validity of uniformitarianism would be fruitful. Such willingness could lead to an understanding of how the presumed geologic time scale of millions of years could be compressed into a period of a few months—the duration of the Flood.

Your Comments

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Notes

- ¹ Talmud *Brakhot* 58a and *Rosh Hashana* 11b and 12a.
- ² Genesis Rabba 34:13, cited by the commentary of Rabbi Samson Raphael Hirsch on Genesis 8:22.
- ³ Commentary of Malbim and Sforino on Genesis 8:22.
- ⁴ See, for example, the commentary of the Netsiv on Genesis 7:20.
- ⁵ Kenneth J. Hsu, *The Great Dying* (Ballantine Books, 1986).
- ⁶ For a detailed list of references see the notes in W. Alvarez, *T. Rex and the Crater of Doom* (New York: Vintage Books, a division of Random House, 1998). The original paper was published in 1980.
- ⁷ Hsu, *op. cit.*, p. 77.
- ⁸ Billy P. Glass and Bruce C. Heezen, "Tekites and Geomagnetic Reversals" in *Scientific American* (vol. 217, Jul. 1967) pp. 32-38.
- ⁹ J.G. Funkhouser and J.J. Naughton, "Radiogenic He and Ar in Ultramafic Inclusions from Hawaii" in *Journal of Geophysical Research* (vol. 73, Jul. 1968) p. 4606.