A Christian Response to Radiometric Dating

Dr Tasman B. Walker

For more than ten years now, Dr Roger C. Wiens, a physicist who obtained his bachelor's degree at Wheaton College, an evangelical Christian college, has published a detailed paper on the web entitled Radiometric Dating: A Christian Perspective. In it he says that radiometric dating is absolutely reliable and that the earth is definitely millions of years old. His paper has been extensively downloaded and quoted.

He says that Christians should accept an old age for the earth and harmonize it with their 'faith'. His article is often cited within Christian circles.[1] Interestingly, it is also cited by secularists and skeptics, seemingly to convince Christians to accept that the earth is billions of years old.[2]

Here Dr Tasman B. Walker addresses Wiens's paper and shows why the claims he makes are not correct. Beginning on the next page, Dr Wiens's paper is reproduced in red, and the point-by-point response by Dr Walker is interspersed in black and indented as per normal email fashion.

Dr. Walker has a B.Sc. (Hons) majoring in Earth Science and a Ph.D. in Mechanical Engineering. He was employed in the electricity industry in Australia for 25 years in the planning, design and operation of many different kinds of power stations. He has been involved with the geology of coal mines and researched the geochemistry of a layered igneous intrusion, including its isotopic relationships. He has published in the *Journal of Creation*, *Creation* magazine and the International Conference of Creationism and is now a speaker and researcher with Creation Ministries International in Brisbane, Australia.

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[1] For example, Wiens paper is made available on the website of the American Scientific Affiliation, a 'fellowship of Christians in science', and by Reasons to Believe, the interdenominational Christian organization of Dr Hugh Ross which argues that 'progressive' creation over millions of years is consistent with the Bible.

[2] For example, in the Department of Geology of Colby College, a liberal arts college, Maine, and the Talk Origins website, a site that is aggressively anti-creation and anti-Christian.

Radiometric Dating
A Christian Perspective

Dr. Roger C. Wiens

Dr. Wiens has a PhD in Physics, with a minor in Geology. His PhD thesis was on isotope ratios in meteorites, including surface exposure dating. He was employed at Caltech's Division of Geological & Planetary Sciences at the time of writing the first edition. He is presently employed in the Space & Atmospheric Sciences Group at the Los Alamos National Laboratory.

> The subtitle 'A Christian Perspective' makes it clear that this paper is intended for Christians. The paper aims to persuade them that the world is billions of years old, contrary to the plain teaching of Scripture. Someone cheekily said a more appropriate subtitle would be, 'A Pseudo-Christian Uniformitarian Propaganda sheet'. Although Wiens appears to have impressive credentials we must check all claims (including mine) against the Scriptures: 'test everything' (1 Thessalonians 5:21). Like the Bereans, who 'examined the Scriptures every day to see if what Paul said was true' (Acts 17:11), the authority for the Christian is the Word of God, because we know that His word is true.

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> Unfortunately this paper does not address the results of the groundbreaking Radioisotopes and the Age of the Earth (RATE) creationist research initiative, published in 2005.[3]

Radiometric dating--the process of determining the age of rocks from the decay of their radioactive elements--has been in widespread use for over half a century. There are over forty such techniques, each using a different radioactive element or a different way of measuring them.

> That a method has a long history, is popular, and gives a consistent story is no guarantee that it is true. Similar claims were made for spontaneous generation and phlogiston.

It has become increasingly clear that these radiometric dating techniques agree with each other and as a whole, present a coherent picture in which the Earth was created a very long time ago.

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[3] Vardiman, L. *et al*. (Eds.), *Radioisotopes and the Age of the Earth Vol. II*, ICR, El Cajon, CA, CRS, Chino Valley, AZ, 2005; and DeYoung, D., *Thousands … Not Billions*, Master Books, Green Forest, AR, 2005.

That is, millions of years ago. But it is clear from Scripture that God created the earth by His word in six-days about 6,000 years ago. Which is true? Like many Christians today, Wiens accepts that the earth is billions of years old, but in this article he does not discuss the problems that idea creates for the integrity of the Bible.

There have been many attempts by many people to reinterpret the Scriptures to incorporate eons of time into the Bible, but no method works (which is why there are so many). Every compromise position undermines the authority of Scripture and damages the biblical world view. Like a blow to the heart, millions of years destroy the Gospel by placing the fossil record, with its death and suffering, before sin entered the world through Adam and Eve. Thus, the issue is crucial for the Christian (indeed for all people, because the Bible is true and its message has consequences for everyone).

Further evidence comes from the complete agreement between radiometric dates and other dating methods such as counting tree rings or glacier ice core layers.

The methods are made to agree because they are calibrated and compared with each other.

Many Christians have been led to distrust radiometric dating and are completely unaware of the great number of laboratory measurements that have shown these methods to be consistent.

Actually, the RATE research, which Wiens has not mentioned, shows the methods are consistently *inconsistent*. The most reliable technique ('mineral isochrons') applied *in a single rock* sample to four different sets of radioactive elements and their daughters gives four quite different dates. Being from a single rock, all the dates should be the same. But the dates differ by far more than the measurement error, in several cases by up to a factor of two or three. Furthermore, the pattern of differences is consistently inconsistent. For example, beta-decaying elements (emitting an electron) always give lower 'ages' than alpha-decaying (emitting a helium nucleus) elements.[4] So the claim of 'consistency' is not correct.

Many are also unaware that Bible-believing Christians are among those actively involved in radiometric dating.

Any Christian who considers that the Bible is reliable would distrust claims of millions of years. Even if we do not understand the science, our confidence in the

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[4] Snelling, A.A., Isochron discordances and the role of inheritance and mixing if radioisotopes in the mantle and crust; in: Vardiman, L. *et al*. (Eds.), *Radioisotopes and the Age of the Earth Vol. II*, ICR, El Cajon, CA, CRS, Chino Valley, AZ, pp. 393–524, 2005. See also Snelling, A.A., Radioisotope dating of rocks in the Grand Canyon, *Creation* **27**(3):44–49, 2005.

Word would make us realize that something is wrong. So, if another Christian who worked in the area said ‘Trust me’, we should still be uneasy about accepting ideas that so plainly contradict Scripture.

This paper describes in relatively simple terms how a number of the dating techniques work, how accurately the half-lives of the radioactive elements and the rock dates themselves are known, and how dates are checked with one another.

He *does* describe the methods simply, but he does not explain the effects of the assumptions behind the methods, or how the results are handled in practice. In a nutshell: it is impossible to make scientific measurements in the past; thus none of the methods measure age; every date is based on assumptions about the past; radioactive dating is not the primary method that geologists use to determine the age of a rock; all radioactive dates are interpreted to harmonize with the geological interpretations from the field.

In the process the paper refutes a number of misconceptions prevalent among Christians today. This paper is available on the web via the American Scientific Affiliation and related sites to promote greater understanding and wisdom on this issue, particularly within the Christian community.

Although the paper is published on the website of ASA, an association of Christian scientists, we should not accept claims that contradict the Bible. Especially we need to be aware that ASA is committed to interpreting scientific data in terms of a billion-year-old earth.

Radiometric Dating
A Christian Perspective
Dr. Roger C. Wiens

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Introduction

Arguments over the age of the Earth have sometimes been divisive for people who regard the Bible as God's word.

> Division is nothing new for the Christian church because always there have been people who seek to teach ideas that are contrary to sound doctrine. Paul warned against those who teach 'contrary to the teaching you have learned' (Romans 16:17). Jude made it clear that division in the church is caused by those who scoff at God's word. Peter says the scoffers deliberately forget Creation and the Flood (2 Peter 3:3–7). Wiens's associate Hugh Ross teaches an outwardly naturalistic 'creation' and denies that the Genesis Flood was world-wide.
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> So the issue is not 'division' but who is teaching sound doctrine. Wiens implies here that those who insist on a young earth are being divisive, but it is the young-earth creationists who take Creation and the Flood seriously. Nowhere in his paper does Wiens discuss what the Bible says about the age of the earth, yet he calls this view a Christian view. For a Christian the Scripture is our highest authority and our source of unity. In fact all people need to take heed of the Scriptures because they speak the truth.

Even though the Earth's age is never mentioned in the Bible, it is an issue because those who take a strictly literal view of the early chapters of Genesis can calculate an approximate date for the creation by adding up the life-spans of the people mentioned in the genealogies. Assuming a strictly literal interpretation of the week of creation, even if some of the generations were left out of the genealogies, the Earth would be less than ten thousand years old.

> True, the age of the earth is not mentioned specifically in the Bible, but that does not mean we cannot confidently determine the earth's age from Scripture, or that it is an unimportant issue. The Bible does not specifically mention the Trinity, Original Sin or the Virginal Conception but no one would suggest these doctrines are not clearly set out in Scripture, or that they are unimportant.
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> Notice where he lays the blame: 'those who take a strictly literal view of the early chapters of Genesis'. In other words, if the literalists would interpret Genesis differently the divisions would pass.
>
> But the age of the earth is logically deduced from the Bible, as Wiens acknowledges. Biblical literalists have not invented a new interpretation of the Bible. The young-earth position has been the orthodox position for Christians for 1,800 years. It is the long-age interpretation of Scripture that represents a departure from orthodoxy.
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> The secular writer Jack Repcheck in his biography of James Hutton, the Scottish geologist who invented geological time, recognized this: 'The Scottish

Presbyterian Church, the English Anglican Church, the Lutheran Church and the Catholic Church—indeed, all Christian churches, their clergies, and their followers—believed that the earth was not even 6,000 years old. This belief was a tenet based on rigorous analysis of the Bible and other holy scriptures. It was not just the devout who embraced this belief; most men of science agreed that the earth was young.'[5]

It was only with the rise of uniformitarian geology in the late 1700s, promoted, not primarily by Christians but by Bible rejecting deists, that this became an issue in the church. Note too that the long age for the earth did not arise with the advent of radiometric dating but with Hutton's new geologic philosophy. Radiometric dating was not invented until 100 years later, and it has been developed in a way that it supports the uniformitarian philosophy.

Radiometric dating techniques indicate that the Earth is thousands of times older than that--approximately four and a half billion years old.

There we have it. A literal reading of the Bible yields an age for the earth of around 6,000 years (Wiens says less than 10,000, but that is a rounded number) whereas radioactive dating says the earth is 4.5 billion years old. That is why the age of the earth is important. If we can't literally accept what the Bible says about the age of the earth, then why should we literally accept what the Bible says about anything? No wonder the age of the earth is such an issue for those who oppose Christian values in the West. And Wiens wants Christians to concede the issue without any resistance.

Many Christians accept this and interpret the Genesis account in less scientifically literal ways.

'Everyone is doing it' is no justification for Christians accepting any unbiblical doctrine, including the biblical age for the earth. We need to have biblical reasons.

If we can accept Genesis, which is so plainly historical narrative, as 'less scientifically literal', then where do we stop? If we say that Bible believing Christians can accept that 4,500,000,000 years is consistent with the biblical 6,000 years then why should we be rigid about those passages which speak against homosexual behaviour, or adultery, or polygamy, or immorality, or lying, or murder?

However, some Christians suggest that the geologic dating techniques are unreliable, that they are wrongly interpreted, or that they are confusing at best. Unfortunately, much of the literature available to Christians has been either inaccurate or difficult to understand, so that confusion over dating techniques continues.

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[5] Repcheck, J., *The Man Who Found Time: James Hutton and the Discovery of the Earth's Antiquity*, Perseus Publishing, Cambridge, MA, p. 14, 2003.

When it comes to literature that explains how radioactive dating works and how reliable it is, Christians have access to the same material as the rest of the community, including encyclopedias, museum exhibits, media articles, television documentaries and school text books. What Wiens is referring to here is the literature written specifically for Christians explaining why we do not have to believe the ages that are quoted for radioactive methods and how they are based on unprovable assumptions. Christians naturally are interested in such literature because they can plainly see that the long ages contradict the Bible.

The next few pages cover a broad overview of radiometric dating techniques, show a few examples, and discuss the degree to which the various dating systems agree with each other. The goal is to promote greater understanding on this issue, particularly for the Christian community.

Wiens says he wants to 'promote greater understanding on this issue, particularly for the Christian community,' but it seems his goal is rather to promote the long-age position. He does not discuss the pros and cons of radiometric dating but only presents material that could overwhelm with science. Some of the information provided, though, is incorrect, and he does not explain how dates are interpreted in a way that makes it impossible to falsify the dating technique.

Many people have been led to be skeptical of dating without knowing much about it.

Sometimes we don't need to understand everything about an issue before we realize it has problems. The Bible presents the truth, so if we have a good knowledge of the biblical worldview we will have powerful insights into any new philosophies or teachings we encounter, and realize when something is wrong. Psalm 119:99 says we will have more insight than our teachers when we meditate on God's word.

For example, most people don't realize that carbon dating is only rarely used on rocks.

Correct, many people don't realize this. But many people don't realize either that carbon-14 provides powerful evidence for a young earth. He does not mention this. For example, in the RATE results that Wiens ignores, carbon-14 has been found in diamonds that were supposedly more than a billion years old, indicating that they can only be thousands of years old.[6] And every time carbon-14 dating has been applied to rocks that do contain carbon, such as limestone, the resulting ages are always *thousands* of years, not the hundreds of millions obtained by other radioactivity dating techniques on the same rocks. These glaring, thousand-fold, differences are hugely outside the possible measurement errors of the different techniques. So again, Wiens's claim of 'consistency' runs aground on the facts.

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[6] Sarfati, J., Diamonds: a creationist's best friend, *Creation* **28**(4):26–27, 2006; <www.creationontheweb.com/content/view/4650>.

God has called us to be "wise as serpents" (Matt. 10:16) even in this scientific age.

> Yes, especially when confronted with new ideas. As the Bible says, we need to be alert for those who distort the truth: 'Even from your own number men will arise and distort the truth in order to draw away disciples after them' (Acts 20:30).

In spite of this, differences still occur within the church. A disagreement over the age of the Earth is relatively minor in the whole scope of Christianity;

> If the age of the earth is such a minor issue, why has Wiens written such a long paper on the topic? Why is the age such a focus of attacks from anti-Christian websites?

it is more important to agree on the Rock of Ages than on the age of rocks. But because God has also called us to wisdom, this issue is worthy of study.

> The fact is that the age of the earth is crucial to the integrity of the Christian worldview. Once we accept long ages the biblical picture of the Rock of Ages unravels. The Bible says that God created a good world, but if the world is millions of years old then the fossils would mean that God created a world using disease, bloodshed and suffering. The Bible says that death is the consequence of mankind's sin, but if the world is millions of years old then death was here long before man sinned and has nothing to do with sin. The age of the earth is foundational to the Christian worldview.

Overview

> Here begins a long and detailed tutorial. Don't be awed into trusting radioactivity dating without question by the length and detail of this description. Nothing of what is outlined here is a surprise to creation scientists who have studied these techniques for years. Most important, Wiens neglects to point out the weaknesses of the methods.

Rocks are made up of many individual crystals, and each crystal is usually made up of at least several different chemical elements such as iron, magnesium, silicon, etc. Most of the elements in nature are stable and do not change. However, some elements are not completely stable in their natural state. Some of the atoms eventually change from one element to another by a process called radioactive decay. If there are a lot of atoms of the original element, called the parent element, the atoms decay to another element, called the daughter element, at a predictable rate. The passage of time can be charted by the reduction in the number of parent atoms, and the increase in the number of daughter atoms.

> The word 'charted' is misleading. I've worked in power stations and they have charts that continually record the temperatures and pressures of the turbines. By inspecting these long charts we could see what happened to the machines in the past. The use of the word 'chart' here is inappropriate because there is no recording of how the isotopes changed in a rock in the past. All we have is a measurement of the isotopes in the rock at one point in time—the present.

Radiometric dating can be compared to an hourglass. When the glass is turned over, sand runs from the top to the bottom. Radioactive atoms are like individual grains of sand—radioactive decays are like the falling of grains from the top to the bottom of the glass. You cannot predict exactly when any one particular grain will get to the bottom, but you can predict from one time to the next how long the whole pile of sand takes to fall. Once all of the sand has fallen out of the top, the hourglass will no longer keep time unless it is turned over again. Similarly, when all the atoms of the radioactive element are gone, the rock will no longer keep time (unless it receives a new batch of radioactive atoms).

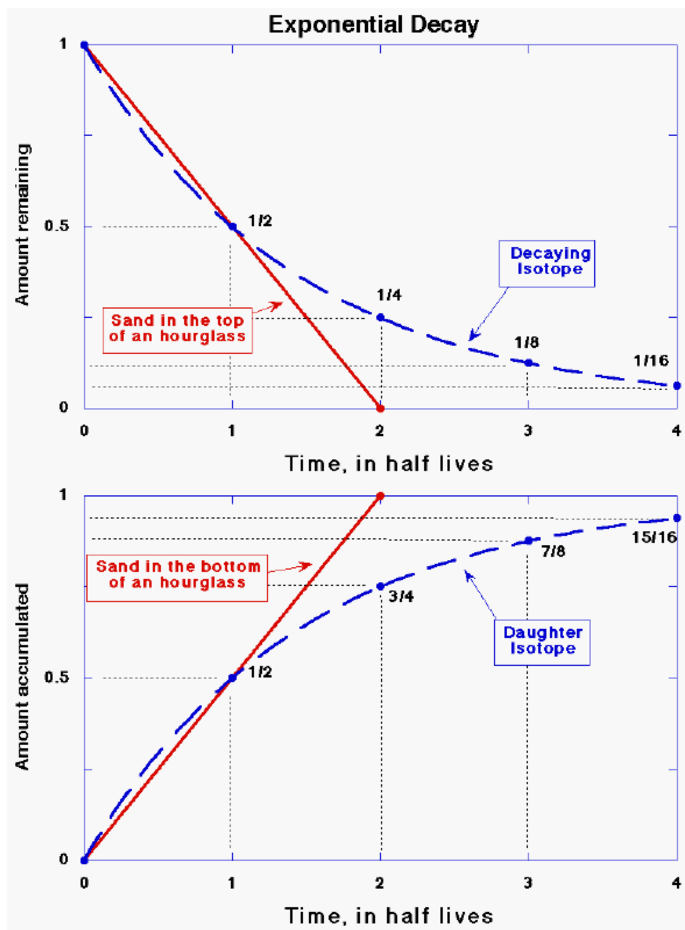

Figure 1. The rate of loss of sand from the top of an hourglass compared to the exponential type of decay of radioactive elements. Most processes we are familiar with are linear, like sand in the hourglass. In exponential decay the amount of material decreases by half during each half-life. After two half-lives only one fourth is left, after three half-lives only an eighth is left, etc. As shown in the bottom panel, the daughter element or isotope amount increases rapidly at first and more slowly with each succeeding half-life.

> The hourglass is a common analogy for radiometric dating, but I think it gives more of an impression of the way they would *like* it to work, rather than the way it *really* works.

Unlike the hourglass, where the amount of sand falling is constant right up until the end, the number of decays from a fixed number of radioactive atoms decreases as there are fewer atoms left to decay (see Figure 1). If it takes a certain length of time for half of the atoms to decay, it will take the same amount of time for half of the remaining atoms, or a fourth of the original total, to decay. In the next interval, with only a fourth remaining, only one eighth of the original total will decay. By the time ten of these intervals, or half-lives, has passed, less than one thousandth of the original number of radioactive atoms is left. The equation for the fraction of parent atoms left is very simple. The type of equation is exponential, and is related to equations describing other well known phenomena such as population growth. No deviations have yet been found from this equation for radioactive decay.

Also unlike the hourglass, there is no way to change the rate at which radioactive atoms decay in rocks. If you shake the hourglass, twirl it, or put it in a rapidly accelerating vehicle, the time it takes the sand to fall will change. But the radioactive atoms used in dating techniques have been subjected to heat, cold, pressure, vacuum, acceleration, and strong chemical reactions to the extent that would be experienced by rocks or magma in the mantle, crust, or surface of the Earth or other planets without any significant change in their decay rate.[7]

> One survey of the scientific literature refers to more than two dozen experiments where changes in decay rates were reported.[8] Laboratory experiments have quantified, for certain radioactive decay processes, how much the rate is affected by the chemical and physical conditions, but the changes observed are small.[9]
>
> More importantly, it has been demonstrated in the laboratory that under certain conditions the radioactive decay rate can be accelerated a *billion* fold.[10] Furthermore, a group of seven creationist research scientists, called the RATE group,[11] has identified examples that point toward accelerated nuclear decay.[12] They have also developed a theoretical basis for how accelerated decay could occur.[13] And finally, since we cannot travel into the past we cannot know all the different conditions that have existed on Earth and to which rocks may have been subject. So, the emphatic statement that decay rates are absolutely constant over all time is a belief, not a fact.

An hourglass will tell time correctly only if it is completely sealed. If it has a hole allowing the sand grains to escape out the side instead of going through the neck, it will give the wrong time interval. Similarly, a rock that is to be dated must be sealed against

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[7] In only a couple of special cases have any decay rates been observed to vary, and none of these special cases apply to the dating of rocks as discussed here. These exceptions are discussed later.

[8] Hahn, H.-P., Born, H.-J. and Kim, J.I., Survey on the rate perturbation of nuclear decay, *Radiochimica Acta* **23**:23–37, 1976.

[9] Huh, C.-A., Dependence of the decay rate of ^{7}Be on chemical forms, *Earth and Planetary Science Letters* **171**:325–328, 1999.

[10] Woodmorappe, J., Billion-fold acceleration of radioactivity demonstrated in laboratory, *Journal of Creation* **15**(2):4–6, 2001.

[11] RATE stands for **R**adioactivity and the **A**ge of **T**he Earth.

[12] Snelling, A.A., Radioisotope dating of rocks in the Grand Canyon, *Creation* **27**(3):44–49, 2005.

[13] Chaffin, E.F., Accelerated decay: theoretical considerations; in: Vardiman, L. *et al.* (Eds.), *Radioisotopes and the Age of the Earth Vol. II*, ICR, El Cajon, CA, CRS, Chino Valley, AZ, pp. 525–586, 2005.

loss or addition of either the radioactive daughter or parent. If it has lost some of the daughter element, it will give an inaccurately young age.

> This highlights the problem with the hour glass analogy. Instead of sand flowing through the hour glass, a better analogy would be of one sponge sitting on another sponge, both in the open weather. Instead of sand we would have water trickling down. I suggest sponges because rocks are renowned for behaving as open systems, and it is impossible to know how they behaved in the past because we were not there to see.

As will be discussed later, most dating techniques have very good ways of telling if such a loss has occurred, in which case the date is thrown out (and so is the rock!).

> In other words, unless, like the hour glass, the rock being dated behaved as a closed system the dating results are rubbish. Wiens says there are good ways of telling if the assumption of a closed system is violated. But, how can we know if we can't go back in time to see? The fact is that we can't. It is only when the results seem strange that geologists will say that the rock behaved as an open system. If they don't look strange they assume the result is okay, at least for the moment. But there are more problems:

An hourglass measures how much time has passed since it was turned over. (Actually it tells when a specific amount of time, e.g., 2 minutes, an hour, etc., has passed, so the analogy is not quite perfect.) Radiometric dating of rocks also tells how much time has passed since some event occurred. For igneous rocks the event is usually its cooling and hardening from magma or lava. For some other materials, the event is the end of a metamorphic heating event (in which the rock gets baked underground at generally over a thousand degrees Fahrenheit), the uncovering of a surface by the scraping action of a glacier, the chipping of a meteorite off of an asteroid, or the length of time a plant or animal has been dead.

> The first problem is that we do not know how much of each isotope was in the rock in the beginning. That's because we cannot travel into the past to make measurements. An hour glass is useful because we saw it turned over *and* we observed that the bottom glass was empty. But with a rock how can we *know* how much of each isotope was present when it formed. We can't.
>
> The next problem is that we don't know what has happened to the rock during its 'lifetime'. An hour glass is only useful if it is not disturbed. But after rocks crystallize from molten magma, they can be heated and cooled; they can be affected by metamorphic events and groundwater.
>
> This means that, on its own, a radioactive 'date' is meaningless. That is why every radioactive date has to be interpreted before anyone can say what it relates to. A geologist would never collect a rock and send if off for radioactive dating on its own. The result would mean nothing.

What happens is that the geologist will carefully record exactly where he collected the rock. He explores the geology of the area so he can understand the geological history and where his particular sample fits into the sequence of geological events. He checks out the ages other geologists have assigned to the different rocks in the region. He studies samples of his rock under the microscope looking for clues of how it crystallized, whether it was later heated, deformed, altered or weathered.

Then, when the laboratory sends him the date for his rock, he can decide if the date refers to the time the rock crystallized or when it cooled. Or perhaps the date refers to the time when the rock was heated or deformed or altered, or somewhere between two of these. Or maybe the date refers to an earlier time, a time when the magma melted before the rock even formed. So the geologist has a lot of options he can choose from as he develops a story to explain the meaning of the date for his rock.

And even after the geologist has interpreted his date and published in a journal, another geologist may later decide that there is a problem with that interpretation, and say the date should be disregarded or reinterpreted.

So radiometric dating is not as objective as Weins implies in his overview.

The Radiometric Clocks

There are now well over forty different radiometric dating techniques, each based on a different radioactive isotope.[14] A partial list of the parent and daughter isotopes and the decay half-lives is given in Table I. Notice the large range in the half-lives.

Table I Some Naturally-Occurring Radioactive Isotopes and Their Half-Lives

Radioactive Isotope (Parent)	Product (Daughter)	Half-Life (Years)
Samarium-147	Neodymium-143	106 billion
Rubidium-87	Strontium-87	48.8 billion
Rhenium-187	Osmium-187	42 billion
Lutetium-176	Hafnium-176	38 billion
Thorium-232	Lead-208	14 billion
Uranium-238	Lead-206	4.5 billion
Potassium-40	Argon-40	1.26 billion
Uranium-235	Lead-207	0.7 billion
Beryllium-10	Boron-10	1.52 million
Chlorine-36	Argon-36	300,000
Carbon-14	Nitrogen-14	5715
Uranium-234	Thorium-230	248,000
Thorium-230	Radium-226	75,400

Most half-lives taken from Holden, N.E. (1990) Pure Appl. Chem. 62, 941-958.

[14] The term isotope subdivides elements into groups of atoms that have the same atomic weight. For example carbon has isotopes of weight 12, 13, and 14 times the mass of a nucleon, referred to as carbon-12, carbon-13, or carbon-14 (abbreviated as ^{12}C, ^{13}C, ^{14}C). It is only the carbon-14 isotope that is radioactive. This will be discussed further in a later section.

Yes, there are many different radiometric dating methods in use today, giving the impression that the methods work reliably. Otherwise, why would people spend time and resources on them? It simply proves that the methods are useful, not that the 'dates' they produce are the true ages. There are a number of explanations why the methods could still be useful even though they do not measure age, including the possibility of accelerated decay, the order in which material erupted from within the earth and the rate of change rate of geological processes with time.

Isotopes with long half-lives decay very slowly, and so are useful for dating correspondingly ancient events. Isotopes with shorter half-lives cannot date very ancient events because all of the atoms of the parent isotope would have already decayed away, like an hourglass left sitting with all the sand at the bottom. Isotopes with relatively short half-lives are useful for dating correspondingly shorter intervals, and can usually do so with greater accuracy, just as you would use a stopwatch rather than a grandfather clock to time a 100 meter dash. On the other hand, you would use a calendar, not a clock, to record time intervals of several weeks or more.

A calendar is only useful when we know the starting date.

It is correct that different half-lives mean that some isotopes are more suited for certain ages than others. But can you see the problem this causes? It means that a researcher's prior beliefs about the age he expects will influence his choice of method. He won't waste his time and research money on tests that would give the 'wrong' age, but select the method that most closely matches the age he anticipates. This also reduces the chance he will obtain a conflicting result on his sample.

For example, most geologists would consider it a waste of money to use carbon-14 on a sample they knew was more than 50,000 years old. But when a creationist geologist tested wood from rocks that were supposedly about 200 million years old he found significant concentrations of carbon-14—direct evidence that the wood was young.[15]

The half-lives have all been measured directly either by using a radiation detector to count the number of atoms decaying in a given amount of time from a known amount of the parent material, or by measuring the ratio of daughter to parent atoms in a sample that originally consisted completely of parent atoms. Work on radiometric dating first started shortly after the turn of the 20th century, but progress was relatively slow before the late forties. However, by now we have had over fifty years to measure and re-measure the half-lives for many of the dating techniques. Very precise counting of the decay events or the daughter atoms can be done, so while the number of, say, rhenium-187 atoms decaying in 50 years is a very small fraction of the total, the resulting osmium-187 atoms can be very precisely counted. For example, recall that only one gram of material contains over 10^{21} (1 with 21 zeros behind) atoms. Even if only one trillionth of the atoms decay in

[15] Snelling, A.A., Geological conflict: young radiocarbon date for ancient fossil wood challenges fossil dating, *Creation* **22**(2):44–47, March 2000.

one year, this is still millions of decays, each of which can be counted by a radiation detector!

> Half-life measurements are an example of good experimental science, where the measurements are made in the present, and they can be repeated and checked again and again.
>
> But the measurements are not without problems because it is not always easy to count decays. With rhenium-187 the end point energy of the beta spectrum is only about 2.5 keV which makes it difficult to determine the half life by direct counting. One estimate was even obtained by measuring iron meteorites and accepting their age was 4.5 billion years based on radioactive dating by a different method. Likewise, the half-life of lutetium-176 was determined from measurements on meteorites of supposedly known age. These cases clearly involve circular reasoning.
>
> On the other hand, one estimate of the half-life of rubidium-87 involved measuring daughter products directly, but this technique is unusual. It takes over ten years before significant quantities of daughter isotope are produced.
>
> Because the value of the half-life has such an effect on the calculated date, the actual half-life numbers used in radiometric dating work, as well as some significant isotopic ratios, are now agreed by an international committee for the most-utilized methods.

The uncertainties on the half-lives given in the table are all very small. All of the half-lives are known to better than about two percent except for rhenium (5%), lutetium (3%), and beryllium (3%). There is no evidence of any of the half-lives changing over time. In fact, as discussed below, they have been observed to *not* change at all over hundreds of thousands of years.

> Yes, the uncertainties in measured half-lives are small, and the measurements can be regularly repeated. However, the assertion that half lives remain constant for millions of years is an assumption, and it is open to serious question.[16]

Examples of Dating Methods for Igneous Rocks

Now let's look at how the actual dating methods work.

> Having explained the general theory of radiometric dating, Wiens says he will turn to its practice, but he ends up describing more theory, the theory behind some of the different isotopic methods. He still skirts the basic problem of timing something.

[16] Vardiman, L. *et al.* (Eds.), *Radioisotopes and the Age of the Earth Vol. II*, ICR, El Cajon, CA, CRS, Chino Valley, AZ, 2005.

To know how long something takes we have to establish that *two* events happened at the *same* time, and we need to establish that *twice*: once at the beginning and once at the end.

Think of an Olympic race. When the starting gun sounds the runners sprint from their blocks *and* the official begins his stop watch. Both events must happen simultaneously. At the end, the winner crosses the line *and* the official stops his watch. Again, both events must happen together. The official reads the time for the race from his stop watch.

How does this apply to dating rocks?

Igneous rocks are good candidates for dating. Recall that for igneous rocks the event being dated is when the rock was formed from magma or lava. When the molten material cools and hardens, the atoms are no longer free to move about. Daughter atoms that result from radioactive decays occurring after the rock cools are frozen in the place where they were made within the rock. These atoms are like the sand grains accumulating in the bottom of the hourglass.

Determining the age of a rock is a two-step process. First one needs to measure the number of daughter atoms and the number of remaining parent atoms and calculate the ratio between them. Then the half-life is used to calculate the time it took to produce that ratio of parent atoms to daughter atoms.

With a rock we can easily establish the *isotopes* in the rock *now*, thus we have the final condition. We can measure isotopes in igneous, metamorphic and even sedimentary rocks. But what was the *initial* condition? Wiens says that in igneous rocks the beginning event was when the rock hardened. Why?

Remember, we were not there and we did not see it happen. We can only imagine a model in our head. So let's imagine a large volume of molten rock deep under the earth, containing all sorts of elements: iron, potassium, silicon, uranium, argon, hydrogen, magnesium, etc. Even while it is liquid, radioactive isotopes will decay producing daughter isotopes and these will be able to move in the liquid to a certain extent. But when the magma solidifies it is assumed that the rock becomes a closed system and all subsequent changes between the parent and daughter are locked inside the solid rock.

So can we calculate the age of the rock? No, because we don't know how much of the daughter isotope was in the rock when it solidified. So how can we calculate a date? We would have to *assume* how much daughter element was in the rock when it formed. This is the fatal flaw of radiometric dating, and Wiens brushes it off as a 'complication'.

Radioactive dating is not usually used to determine the age of sedimentary rocks because (except for a few specific situations) we can't imagine how to determine a meaningful starting event.

However, there is one complication. One cannot always assume that there were no daughter atoms to begin with.

Exactly. Imagine that you find a stop watch lying on the track. You pick it up, see that it is running, and you *accurately* read the time. What does that time mean? You don't have any idea because you don't know who started the watch or when.

It turns out that there are some cases where one can make that assumption quite reliably. But in most cases the initial amount of the daughter product must be accurately determined. Most of the time one can use the different amounts of parent and daughter present in different minerals within the rock to tell how much daughter was originally present. Each dating mechanism deals with this problem in its own way. Some types of dating work better in some rocks; others are better in other rocks, depending on the rock composition and its age. Let's examine some of the different dating mechanisms now.

In fact, the initial conditions cannot be measured; they have to be assumed. Geologists don't like to assume the amount of daughter directly (perhaps that sounds like cheating), but they often do, and they call it a 'model' age. Geologists prefer to make *indirect* assumptions. They may assume that different minerals in the rock originally had the same isotopic ratios to start with. Or that different rock samples had the same ratio. As Wiens says, each dating method uses different kinds of assumptions to get around this problem for radiometric dating—the deadly problem caused by the fact that we cannot make measurements in the past.

Potassium-Argon.

Potassium is an abundant element in the Earth's crust**.** One isotope, potassium-40, is radioactive and decays to two different daughter products, calcium-40 and argon-40, by two different decay methods**.** This is not a problem because the production ratio of these two daughter products is precisely known, and is always constant: 11.2% becomes argon-40 and 88.8% becomes calcium-40**.**

This branching ratio can be precisely measured in the present (experimental science), but can we guarantee it has *always* been the same in *every* situation in the past?

It is possible to date some rocks by the potassium-calcium method, but this is not often done because it is hard to determine how much calcium was initially present**.** Argon, on the other hand, is a gas**.** Whenever rock is melted to become magma or lava, the argon tends to escape**.** Once the molten material hardens, it begins to trap the new argon produced since the hardening took place**.** In this way the potassium-argon clock is clearly reset when an igneous rock is formed.

> The attraction of the potassium-argon method lies in the fact that the daughter element, argon, is an inert gas, so it is assumed that all argon gas escapes from the molten rock while it is liquid. Thus it is assumed that any argon-40 measured within the rock has been produced by the radioactive decay of potassium-40 since the time the rock solidified. This situation allows geologists to envisage an initial 'event'. The radioactive hour glass seals and starts running when the rock solidifies.

In its simplest form, the geologist simply needs to measure the relative amounts of potassium-40 and argon-40 to date the rock**.** The age is given by a relatively simple equation:

$$t = h \times \ln[1 + (\text{argon-40})/(0.112 \times (\text{potassium-40}))]/\ln(2)$$

where *t* is the time in years, *h* is the half-life, also in years, and *ln* is the natural logarithm**.**

> Yes, it is a simple calculation. And the method has been widely used for decades. But the calculated age is only as valid if the assumptions about the past are correct.

However, in reality there is often a small amount of argon remaining in a rock when it hardens**.** This is usually trapped in the form of very tiny air bubbles in the rock**.** One percent of the air we breathe is argon**.** Any extra argon from air bubbles may need to be taken into account if it is significant relative to the amount of radiogenic argon (that is, argon produced by radioactive decays)**.** This would most likely be the case in either young rocks that have not had time to produce much radiogenic argon, or in rocks that are low in the parent potassium**.** One must have a way to determine how much air-argon is in the rock**.** This is rather easily done because air-argon has a couple of other isotopes, the most abundant of which is argon- 36**.** The ratio of argon-40 to argon-36 in air is well known, at 295**.** Thus, if one measures argon-36 as well as argon-40, one can calculate and subtract off the air-argon-40 to get an accurate age.

> This correction for the amount of atmospheric argon in the rock when it formed (again based on assumptions) is typically small. The big question is whether the rock contained other argon-40 when it solidified. If it did, the calculated age would be far too old. A related question is whether the rock was subsequently disturbed and lost argon. If so, the age would be too young. How can we know?

One of the best ways of showing that an age-date is correct is to confirm it with one or more different dating method(s). Although potassium-argon is one of the simplest dating methods, there are still *some* cases where it does not agree with other methods**.**

Why do we have to confirm that our date is correct? If the method is reliable why can't we just trust it? Because no dating method can be trusted on its own, as Wiens acknowledges here. We always have to check our results with other dates. But what happens if the results conflict? It's simple; we change our story about the past. Wiens explains how they change the story.

Some young-Earth proponents recently reported that rocks were dated by the potassium-argon method to be a several million years old when they are really only a few years old. But the potassium-argon method, with its long half-life, was never intended to date rocks only 25 years old. These people have only succeeded in correctly showing that one can fool a single radiometric dating method when one uses it improperly. The false radiometric ages of several million years are due to parentless argon, as described here, and first reported in the literature some fifty years ago. Note that it would be extremely unlikely for another dating method to agree on these bogus ages. Getting agreement between more than one dating method is a recommended practice.

In view of the problems Wiens describes in the main text, it is surprising that he so scathingly attacks these dating results published by young-earth creationists—work which simply confirms his discussion about parentless argon. He is referring to a test where creationists analyzed basalt rock which formed about 25 years ago, yet the laboratory analysis gave ages of millions of years. Wiens admonishes that the potassium-argon method should never have been used on 25-year-old rocks, but in so doing he confirms the creationist's point. If you have to *know* the age of a rock before you can confidently use the method, then of what value is it?

When this does happen, it is usually because the gas within bubbles in the rock is from deep underground rather than from the air**.** This gas can have a higher concentration of argon-40 escaping from the melting of older rocks**.** This is called *parentless* argon-40 because its parent potassium is not in the rock being dated, and is also not from the air**.** In these slightly unusual cases, the date given by the normal potassium-argon method is too old**.** However, scientists in the mid-1960s came up with a way around this problem, the argon-argon method, discussed in the next section.

Notice that Weins does *not* say the geologists change their assumptions, but that is what they are doing. See what is happening. He is developing a *new* story about the past, different from the original story that explained how potassium-argon dating works. Ask yourself which of the details of this story have been observed.

Notice the story is about older rocks, melted rocks, solidified rocks and argon gas. It explains what each of these were doing deep inside the earth millions of years ago. The story explains that the behaviour of 'parentless argon' (it even has a name, although some call it 'excess argon') made the age too old. Too old compared with what? With the true age of the rock. But wasn't that what we were trying to measure?

The problem is that although radiogenic argon and parentless argon have different names they are exactly the same isotope—argon-40. It is impossible to distinguish between them experimentally. So, how do we work out how much parentless argon we have? We can only calculate the amount of excess argon if we know the true age of the rock. But wasn't that what we were trying to measure? Wiens does not mention this problem.

What happens when the age is too *young*? In this case the method is again salvaged by changing assumptions about the past. Often a heating event is invoked to liberate the argon from the solid rock, although other assumptions are made as well. (Wiens discusses this case in the following section on Argon-Argon dating.)

Argon-Argon. Even though it has been around for nearly half a century, the argon-argon method is seldom discussed by groups critical of dating methods**.** This method uses exactly the same parent and daughter isotopes as the potassium-argon method**.** In effect, it is a different way of telling time from the same clock**.** Instead of simply comparing the total potassium with the non-air argon in the rock, this method has a way of telling exactly what and how much argon is directly related to the potassium in the rock.

This description of argon-argon dating gives the impression that the method overcomes all the problems of the potassium-argon method, but that is not the case as we will see. And it is wrong to imply that creationists have no answer for this method, because the problems have been discussed in a number of places.[17,18]

As Wiens explains, the method is essentially the same as the potassium-argon method. The difference is that it uses an ingenious laboratory technique to measure the parent potassium isotope. First, the sample is placed in a nuclear reactor to change some of its potassium-39 into argon-39. Then the sample is placed in a mass spectrometer and heated. The gas driven off is analyzed for argon-39 (representing the parent) and argon-40 (the daughter). Because it's a reincarnation of the potassium-argon method it has all the same shortcomings.

In the argon-argon method the rock is placed near the center of a nuclear reactor for a period of hours**.** A nuclear reactor emits a very large number of neutrons, which are capable of changing a small amount of the potassium-39 into argon-39**.** Argon-39 is not found in nature because it has only a 269-year half-life. (This half-life doesn't affect the argon-argon dating method as long as the measurements are made within about five years

[17] Woodmorappe, J., Chapter 7: The 40Ar/39Ar method and its imagined diagnostic properties, *The Mythology of Modern Dating Methods*, Institute of Creation Research, El Cajon, CA, pp. 72–79, 1999.
[18] Snelling, A.A., 'Excess argon': The 'Archilles' Heel' of potassium-argon and argon-argon 'dating' of volcanic rocks, *Impact* **307**, 1999.

of the neutron dose). The rock is then heated in a furnace to release both the argon-40 and the argon-39 (representing the potassium) for analysis. The heating is done at incrementally higher temperatures and at each step the ratio of argon-40 to argon-39 is measured. If the argon-40 is from decay of potassium within the rock, it will come out at the same temperatures as the potassium-derived argon-39 and *in a constant proportion*. On the other hand, if there is some excess argon-40 in the rock it will cause a different ratio of argon-40 to argon-39 for some or many of the heating steps, so the different heating steps will not agree with each other.

> The technique has many technical advantages over the potassium-argon method. First, there is the benefit that the parent and daughter isotope are measured at the same time, which is more convenient and enables more precise results (note precision is not the same as accuracy). Second, it is possible to analyze small samples, which means individual minerals can be tested. Third, the sample can be heated in small steps, driving off a little more gas each time, thus allowing multiple calculations of a sample's 'age'. Fourth, the process can be automated.
>
> What happens is that the machine is loaded with dozens of samples at once, but it analyses these one-by-one over a period of days or weeks. When it starts analyzing a sample, it will first heat it to the lowest step and record the gases liberated. After a few minutes it will heat the sample to the next step, and so on until all the steps are finished. A computer records the measurements and it also calculates the age result for each step. So, one tiny sample can yield ten or twenty 'age' calculations, instead of just one, and all this for very little extra time or effort.

Figure 2 is an example of a good argon-argon date. The fact that this plot is flat shows that essentially all of the argon-40 is from decay of potassium within the rock. The potassium-40 content of the sample is found by multiplying the argon-39 by a factor based on the neutron exposure in the reactor. When this is done, the plateau in the figure represents an age date

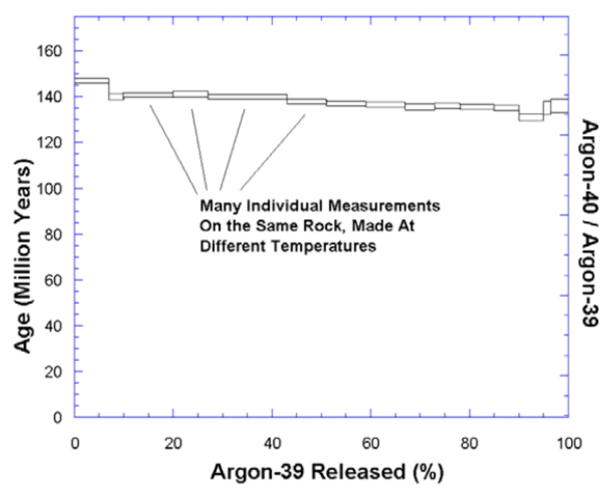

Figure 2. A typical argon-argon dating plot. Each small rectangle represents the apparent age given at one particular heating-step temperature. The top and bottom parts of the rectangles represent upper and lower limits for that particular determination. The age is based on the measured argon-40 / argon-39 ratio and the number of neutrons encountered in the reactor. The horizontal axis gives the amount of the total argon-39 released from the sample. A good argon-argon age determination will have a lot of heating steps which all agree with each other. The "plateau age" is the age given by the average of most of the steps, in this case nearly 140 million years. After S. Turner *et al.* (1994) *Earth and Planetary Science Letters, 121,* pp. 333-348.

based on the decay of potassium-40 to argon-40.

It is common to present all the ages for each sample graphically as shown in figure 2, a graph that is often called a 'spectrum'. In this case, fifteen separate age estimates are presented in the order in which they were analyzed. The vertical axis shows the age. The horizontal axis represents the percentage of gas liberated in each step. Each estimate is shown as a long rectangle. The length represents the percentage of gas liberated. Its width represents the estimated error. It is a remarkable technological feat.

Note the words 'good argon-argon date'. Now this is the interesting part. We are continually told, as Wiens has said already in this paper, that we know radioactive dating is valid because repeated dates agree with each other. In this example (of a good date!) we can see that each estimate is remarkably precise (the error is only about ± 1.0 million years). Yet the fifteen different estimates are not the same but vary from 131 million years to 147 million years. Does this disagreement cause geologists to question radiometric dating? Not at all. Belief in radiometric dating is so deeply entrenched that it is never doubted, not even in the subconscious. So, no matter what the results turn out to be, it is simply an issue of developing a story to explain them, and there are many factors that can be selected for every story, and the stories are very convincing.

You would appreciate that the argon-argon technique is more complicated than its potassium-argon relative. The older method is traditionally applied to *whole-rock samples*. In order to explain why different rocks give different ages we need to explain how isotopes behave when rocks solidify.

But the argon-argon method is applied to *individual minerals*. This means we need to explain why different minerals in the same rock give different results. Further, different heating steps on the same mineral give different 'ages', so we also need to explain what happens as the mineral is progressively heated. There is also a question about what happens when the sample is put in the nuclear reactor (isotopes can be dislodged from the mineral lattice affecting the age results, a process called 'recoil'). Consequently, there are many more factors that we can choose to include in our story to explain the results.

The advantage of having so many different measurements on the same sample enables the researcher to check whether the data is internally consistent. For example, if most of the heating steps yield the same age the spectra will look like a long flat plateau. This internal consistency is interpreted as a valid 'date'.

There are occasions when the argon-argon dating method does not give an age even if there is sufficient potassium in the sample and the rock was old enough to date. This most often occurs if the rock experienced a high temperature (usually a thousand degrees Fahrenheit or more) at some point since its formation. If that occurs, some of the argon gas moves around, and the analysis does not give a smooth plateau across the extraction temperature steps. An example of an argon-argon analysis that did not yield an age date is shown in Figure 3. Notice that there is no good plateau in this plot. In some instances there will actually be two plateaus, one representing the formation age, and another representing the time at which the heating episode occurred. But in most cases where the system has been disturbed, there simply is no date given.

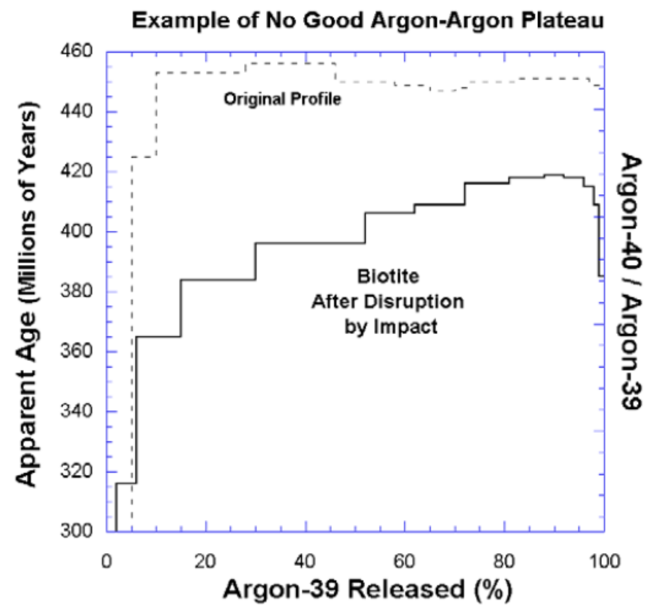

Figure 3. An argon-argon plot that gives no date. Note that the apparent age is different for each temperature step so there is no plateau. This sample was struck with a pressure of 420,000 atmospheres to simulate a meteorite impact--an extremely rare event on Earth. The impact heated the rock and caused its argon to be rearranged, so it could not give an argon-argon date. Before it was smashed the rock gave an age of around 450 million years, as shown by the dotted line. After A. Deutsch and U. Schaerer (1994) *Meteoritics, 29*, pp. 301-322.

When the age spectrum is curved the individual heating steps clearly disagree with each other; it's internally inconsistent. If the curve is upwards like an arch (as in Wiens example, Figure 3) the sample is said to have suffered argon loss, probably in a heating event. The spectra may be curved the opposite way, like a U or a saddle, and this supposedly points to excess argon. The spectra can be curved in other ways too, but always a curve means that the step ages disagree and no meaningful age can be determined for the sample.

The important point to note is that, rather than giving wrong age dates, *this method simply does not give a date if the system has been disturbed*. This is also true of a number of other igneous rock dating methods, as we will describe below.

In other words, it is supposedly impossible for the argon-argon to give a wrong date. This was loudly claimed in the early days of the new technique, but as it has been more widely used it has been found that even when the age spectrum is flat the age can be geologically meaningless. John Woodmorappe cites a number of published examples of flat spectra that cannot be accepted as the age of the rock.[17] So, in the face of many geologically absurd results, geochronologists have been forced to retreat from their early claims for this method.

The existence of curved spectra is also bad news for the potassium-argon method which has been used for decades on whole-rock samples. The literature is full of dates determined by this method. But, who can say which of those dates, if tested using the argon-argon method, would be internally consistent and which would not. Until all those samples can be retested using the argon-argon method, no one could be confident about which published ages are valid, and which are not.

Rubidium-Strontium. In nearly all of the dating methods, except potassium-argon and the associated argon-argon method, there is always some amount of the daughter product already in the rock when it cools**.**

The same problem keeps returning. We can only make our scientific measurements in the present but to calculate time we need to know the value of parameters in past. And, as we have discussed above, the potassium-argon method is not an exception to this problem.

Using these methods is a little like trying to tell time from an hourglass that was turned over before all of the sand had fallen to the bottom**.** One can think of ways to correct for this in an hourglass: One could make a mark on the outside of the glass where the sand level started from and then repeat the interval with a stopwatch in the other hand to calibrate it**.** Or if one is clever she or he could examine the hourglass' shape and determine what fraction of all the sand was at the top to start with**.** By knowing how long it takes all of the sand to fall, one could determine how long the time interval was**.**

Let's think about this for a minute. His solution would only work if we *saw* the hour-glass turned over and *observed* how much sand was in it then. But if we did not see the glass turned over, how could we ever know how much sand was in the bottom? Thus, even if the hourglass were calibrated, his idea would not work.

But how *could* we calibrate the dating method? It's easy to calibrate an hourglass because we can repeat the experiment with the hourglass over and over. But we can't calibrate a rock sample that is supposedly millions of years old. How can we take that rock back through geological time and observe it change over millions of years? And what would we calibrate it against? We know a stop watch is accurate because it has been experimentally calibrated against a standard timekeeper. But what 'stop watch' do we have that has been calibrated over millions of years?

Similarly, there are good ways to tell quite precisely how much of the daughter product was already in the rock when it cooled and hardened.

This is a remarkable claim, one that is commonly made, but one which is not true. It would be better to say, 'Similarly, the problem with radiometric dating is that it can't be calibrated.'

In the rubidium-strontium method, rubidium- 87 decays with a half-life of 48.8 billion years to strontium-87. Strontium has several other isotopes that are stable and do not decay. The ratio of strontium-87 to one of the other stable isotopes, say strontium-86, increases over time as more rubidium-87 turns to strontium-87. But when the rock first cools, all parts of the rock have the same strontium-87/strontium-86 ratio because the isotopes were mixed in the magma. At the same time, some of the minerals in the rock have a higher rubidium/strontium ratio than others. Rubidium has a larger atomic diameter than strontium, so rubidium does not fit into the crystal structure of some minerals as well as others.

> Here Wiens describes rubidium-strontium dating, which he uses as an example of the isochron method—a method that can be used with *any* radioactive parent and daughter isotopes. The point about the isochron method, as he claims above, is that it supposedly avoids the need to make assumptions about the past.
>
> But did you notice his assumption about the past included in the above story? He says that when the rock cools all parts have the same ratio because the isotopes were mixed in the magma. How does he know that? And he makes the same assumption in the next paragraph when he says that at first all the minerals lie along a horizontal line. But no-one measured the isotopes in the minerals at the beginning. He then describes how the isotopes are assumed to change with time, and how the age is therefore calculated from the graph. But it is all based on assumptions.

Figure 4 is an important type of plot used in rubidium-strontium dating. It shows the strontium-87/strontium-86 ratio on the vertical axis and the rubidium-87/strontium-86 ratio on the horizontal axis, that is, it plots a ratio of the daughter isotope against a ratio of the parent isotope. At first, all the minerals lie along a horizontal line of constant strontium- 87/strontium-86 ratio but with varying rubidium/strontium. As the rock starts to age, rubidium gets converted to strontium. The amount of strontium added to each mineral is proportional to the amount of rubidium present. This change is shown by the dashed arrows, the lengths of which are proportional to the rubidium/strontium ratio. The dashed arrows are slanted because the rubidium/strontium ratio is decreasing in proportion to the increase in strontium-87/strontium-86. The solid line drawn through the samples will thus progressively rotate from the horizontal to steeper and steeper slopes.

All lines drawn through the data points at any later time will intersect the horizontal line (constant strontium-87/strontium-86 ratio) at the same point in the lower left-hand corner. This point, where rubidium-87/strontium-86 = 0 tells the original strontium-87/strontium-86 ratio. From that we can determine the original daughter strontium-87 in each mineral, which is just what we need to know to determine the correct age.

It also turns out that the slope of the line is proportional to the age of the rock. The older the rock, the steeper the line will be. If the slope of the line is m and the half-life is h, the age t (in years) is given by the equation

$$t = h \times \ln(m+1)/\ln(2)$$

For a system with a very long half-life like rubidium-strontium, the actual numerical value of the slope will always be quite small. To give an example for the above equation, if the slope of a line in a plot similar to Fig. 4 is m = 0.05110 (strontium isotope ratios are usually measured very accurately--to about one part in ten thousand), we can substitute in the half-life (48.8 billion years) and solve as follows:

$t = (48.8) \times \ln(1.05110)/\ln(2)$
so $t = 3.51$ billion years.

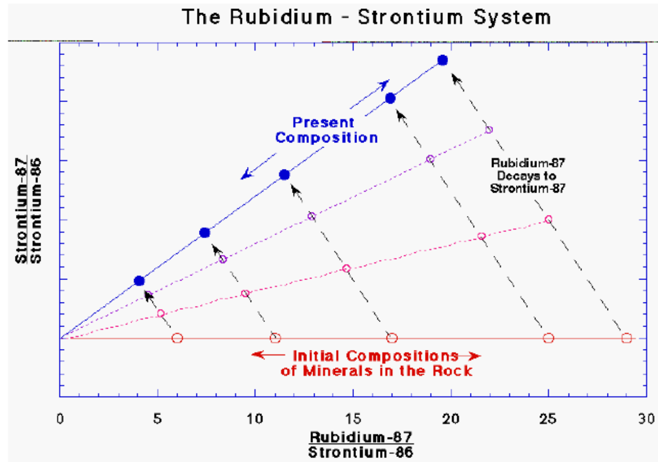

Figure 4. A rubidium-strontium three-isotope plot. When a rock cools, all its minerals have the same ratio of strontium-87 to strontium-86, though they have varying amounts of rubidium. As the rock ages, the rubidium decreases by changing to strontium-87, as shown by the dotted arrows. Minerals with more rubidium gain more strontium-87, while those with less rubidium do not change as much. Notice that at any given time, the minerals all line up—a check to ensure that the system has not been disturbed.

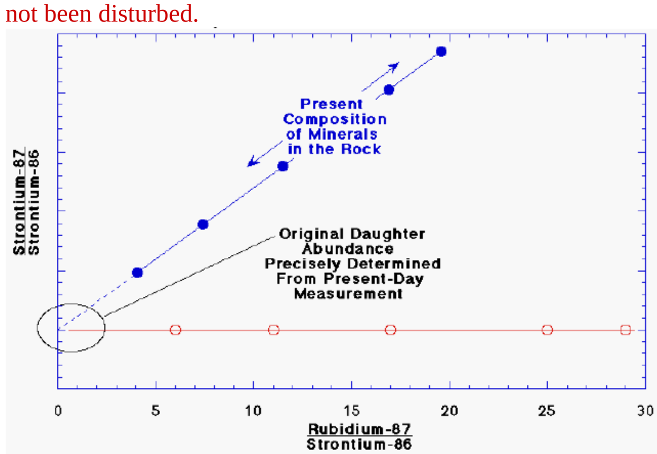

Figure 5. The original amount of the daughter strontium-87 can be precisely determined from the present-day composition by extending the line through the data points back to rubidium-87 = 0. This works because if there were no rubidium-87 in the sample, the strontium composition would not change. The slope of the line is used to determine the age of the sample.

This is the theory, but how does it work in practice?

For the method to work we need a number of samples which all had the same isotopic ratio initially. The samples can be a collection of different whole-rock samples from the same large igneous body, or they can be a collection of different minerals from the same rock sample (as Wiens describes here). But the key is that all the samples had to have had the same isotopic composition initially. In other words, the magma chamber had to have been thoroughly mixed before the rock solidified.

But how could anyone ever confirm that was true? It can't be done. In fact, it would be highly unlikely for a large body of magma to have exactly the same isotopic ratio throughout. It is commonly envisaged that magma was drawn from different sources and carried by several conduits to the magma chamber where it mixes together. In this case the resultant rock will have a range of ratios between those of the different magmas. For such samples the straight line produced on the graph will have a slope, but the slope will have nothing to do with age. Actually, magma mixing is one of the interpretations that geologists use whenever the calculated age is older than the age they anticipated. The line is called a 'mixing line' and the 'age' is disregarded.

A second problem is that all the samples had to have solidified (or rather, become closed systems) at the same time. For an igneous intrusion kilometers across this won't be valid because it cools from the inside out. It is also a problem for a single rock sample because different minerals become closed at different temperatures (called the 'closing temperature'). Thus, as a rock cools the different minerals will 'close' at different times. This is a serious problem because large rock bodies are routinely said to have cooled over millions of years. One example in Faure (a respected text on isotopic dating) has an igneous complex that supposedly took more than 200 million years too cool.[19]

Another difficulty is we need samples with a variety of chemical compositions. If they are all similar they will all plot at about the same point on the graph and we will have spot, and not a line. But by choosing samples that are different it is less likely that they came from the same magma, which was thoroughly mixed, and that the isotopic ratios of all the samples were the same when they solidified.

Several things can on rare occasions cause problems for the rubidium-strontium dating method. One possible source of problems is if a rock contains some minerals that are older than the main part of the rock. This can happen when magma inside the Earth picks up unmelted minerals from the surrounding rock as the magma moves through a magma chamber. Usually a good geologist can distinguish these "xenoliths" from the younger minerals around them. If he or she does happen to use them for dating the rock, the points represented by these minerals will lie off the line made by the rest of the points.

This is called an 'inherited age', and the explanation is routinely used when the age turns out to be too old (with what is expected). There are two different things mentioned here. Older minerals called 'xenocrysts' (foreign crystals) are crystals that solidified before the rock solidified. They were carried along by the magma. It is quite subjective to decide which minerals crystallized before the rock formed. The main criterion is the age of the crystals. If the calculated age of the crystal is older than the rock then it is likely to be interpreted that the crystal is foreign. But if the calculated age is the same as the rock it is likely to be interpreted that the crystal forms part of the rock.

The other term is 'xenolith' which means 'foreign rock', and refers to pieces of rock picked up by the magma. These are usually easy to identify and can be relatively easily excluded from any samples tested.

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[19] Faure, G., *Principles of Isotope Geology,* 2nd ed., John Wiley & Sons, New York, p. 110, 1986.

Another difficulty can arise if a rock has undergone metamorphism, that is, if the rock got very hot, but not hot enough to completely re-melt the rock. In these cases, the dates look confused, and do not lie along a line. Some of the minerals may have completely melted, while others did not melt at all, so some minerals try to give the igneous age while other minerals try to give the metamorphic age. In these cases there will not be a straight line, and *no date is determined*.

> This explanation is used when the age is too young. In practice this tends to become an after-the-event explanation for why samples, which were anticipated to produce a straight line, did not work. No one would ever go to the trouble of testing this hypothesis. It is an explanation that is simply asserted if the results do not work out.

In a few very rare instances the rubidium-strontium method has given straight lines that give wrong ages. This can happen when the rock being dated was formed from magma that was not well mixed, and which had two distinct batches of rubidium and strontium. One magma batch had rubidium and strontium compositions near the upper end of a line (such as in Fig. 4), and one batch had compositions near the lower end of the line. In this case, the minerals all got a mixture of these two batches, and their resulting composition ended up near a line between the two batches. This is called a two-component mixing line. It is a very rare occurrence in these dating mechanisms, but at least thirty cases have been documented among the tens of thousands of rubidium-strontium dates made. If a two-component mixture is suspected, a second dating method must be used to confirm or disprove the rubidium-strontium date. The agreement of several dating methods is the best fail-safe way of dating rocks.

> We have already mentioned mixing lines, and they are not such a rare result. And there is no way of telling the difference between a 'mixing line' and a valid 'isochron', excepting if the age turns out to be different from what was expected. How do we know that it's the wrong age? Because it disagrees with the geology of the area. Geology is king, and radioactive dating the lap dog.
>
> Faure gives several examples of mixing lines, determined to be mixing lines simply because the age is wrong.[20] In one, flows of lava along the border of Uganda, Zaire and Rwanda, East Africa, are know to be recent, some possibly within historical times. Yet rubidium-strontium analysis gave an age of 773 million years. So the result is interpreted as a mixing line.
>
> When several dates agree it confirms the validity of the methods. But if the dates do not agree it does not count against them. Always a story is invented to explain the situation.
>
> For example, Okudaira *et al*. measured mineral isochron ages of amphibolite from SE India to obtain 481±16 Ma with rubidium-strontium and 824±43 Ma with

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[20] Faure, G., *Principles of Isotope Geology,* 2nd ed., John Wiley & Sons, New York, pp. 145–147, 1986.

samarium-neodimium.[21] The disagreement between the two methods was simply explained away. The older age was interpreted as the timing of metamorphism while the younger age was interpreted as the time of a later heating. No matter what the results, a plausible story can always be invented.

The Samarium-Neodymium, Lutetium-Hafnium, and Rhenium-Osmium Methods. All of these methods work very similarly to the rubidium-strontium method. They all use three-isotope diagrams similar to Figure 4 to determine the age. The samarium-neodymium method is the most-often used of these three. It uses the decay of samarium-147 to neodymium-143, which has a half-life of 105 billion years. The ratio of the daughter isotope, neodymium-143, to another neodymium isotope, neodymium- 144, is plotted against the ratio of the parent, samarium-147, to neodymium-144. If different minerals from the same rock plot along a line, the slope is determined, and the age is given by the same equation as above. The samarium-neodymium method may be preferred for rocks that have very little potassium and rubidium, for which the potassium-argon, argon-argon, and rubidium-strontium methods might be difficult. The samarium-neodymium method has also been shown to be more resistant to being disturbed or re-set by metamorphic heating events, so for some metamorphosed rocks the samarium-neodymium method is preferred. For a rock of the same age, the slope on the neodymium-samarium plots will be less than on a rubidium-strontium plot because the half-life is longer. However, these isotope ratios are usually measured to extreme accuracy--several parts in ten thousand--so accurate dates can be obtained even for ages less than one fiftieth of a half-life, and with correspondingly small slopes.

The lutetium-hafnium method uses the 38 billion year half-life of lutetium-176 decaying to hafnium-176. This dating system is similar in many ways to samarium-neodymium, as the elements tend to be concentrated in the same types of minerals. Since samarium-neodymium dating is somewhat easier, the lutetium-hafnium method is used less often.

The rhenium-osmium method takes advantage of the fact that the osmium concentration in most rocks and minerals is very low, so a small amount of the parent rhenium-187 can produce a significant change in the osmium isotope ratio. The half-life for this radioactive decay is 42 billion years. The non-radiogenic stable isotopes, osmium-186 or -188, are used as the denominator in the ratios on the three-isotope plots. This method has been useful for dating iron meteorites, and is now enjoying greater use for dating Earth rocks due to development of easier rhenium and osmium isotope measurement techniques.

The story is the same with all these methods. They can be used to produce isochron plots as shown in figure 4, either with whole-rock samples, or minerals from a single sample. Or they can be used to produce model ages, where the initial isotopic composition is assumed, based on a model about the past. Whichever way, the story is the same.

[21] Okudaira, T., Hamamoto, T., Prasad, B.H. and Kumar, R., Sm-Nd and Rb-Sr dating of amphibolite from the Nellore-Khammam schist belt, S.E. India: constraints on the collision of the Eastern Ghats terrane and Dharwar-Bastar craton, *Geological Magazine*, **138**(4):495–498, 2001.

Uranium-Lead and related techniques. The uranium-lead method is the longest-used dating method. It was first used in 1907, about a century ago. The uranium-lead system is more complicated than other parent-daughter systems; it is actually several dating methods put together. Natural uranium consists primarily of two isotopes, U-235 and U-238, and these isotopes decay with different half-lives to produce lead-207 and lead-206, respectively. In addition, lead-208 is produced by thorium-232. Only one isotope of lead, lead-204, is not radiogenic. The uranium-lead system has an interesting complication: none of the lead isotopes is produced directly from the uranium and thorium. Each decays through a series of relatively short-lived radioactive elements that each decay to a lighter element, finally ending up at lead. Since these half-lives are so short compared to U-238, U-235, and thorium-232, they generally do not affect the overall dating scheme. The result is that one can obtain three independent estimates of the age of a rock by measuring the lead isotopes and their parent isotopes. Long-term dating based on the U-238, U- 235, and thorium-232 will be discussed briefly here; dating based on some of the shorter-lived intermediate isotopes is discussed later.

The uranium-lead system in its simpler forms, using U-238, U-235, and thorium-232, has proved to be less reliable than many of the other dating systems. This is because both uranium and lead are less easily retained in many of the minerals in which they are found. Yet the fact that there are three dating systems all in one allows scientists to easily determine whether the system has been disturbed or not. Using slightly more complicated mathematics, different combinations of the lead isotopes and parent isotopes can be plotted in such a way as to minimize the effects of lead loss. One of these techniques is called the lead-lead technique because it determines the ages from the lead isotopes alone. Some of these techniques allow scientists to chart at what points in time metamorphic heating events have occurred, which is also of significant interest to geologists.

> Uranium-lead dating is one of the most widely-used dating methods, and because there are two radioactive isotopes we can calculate two independent dates for the one sample. You would expect them to agree, right? Actually, like the multiple ages of the argon-argon method, the results usually don't agree, which is why Wiens says that 'both uranium and lead are less easily retained in many of the minerals in which they are found.'
>
> Not only can we obtain two uranium-lead dates from the one sample, but we can test individual minerals within the one rock. Again, different minerals usually do not give the same age. Zircon crystals are especially used for the uranium-lead method because zircon is assumed to remain a sealed system under much more adverse conditions than other minerals. So, do multiple tests on zircon crystals agree? Again, usually not. This is where the 'slightly more complicated mathematics' comes in. It is assumed that the zircon crystals have been partially reset, and by means of a graphical model a single date can be calculated from the discordant results of multiple crystals. Again, the date has to be interpreted according to the geology.

The technology has improved so much that multiple dates can be analyzed on a *single* zircon. Interestingly, the dates calculated from tiny spots on a single zircon are different. But again this is no problem because the researcher simply develops a geological story about the zircon to explain the results, as Wiens alludes to with his reference to the 'points in time metamorphic heating events occurred'.

The Age of the Earth

We now turn our attention to what the dating systems tell us about the age of the Earth. The most obvious constraint is the age of the oldest rocks. These have been dated at up to about four billion years. But actually only a very small portion of the Earth's rocks are that old. From satellite data and other measurements we know that the Earth's surface is constantly rearranging itself little by little as Earthquakes occur. Such rearranging cannot occur without some of the Earth's surface disappearing under other parts of the Earth's surface, re-melting some of the rock. So it appears that none of the rocks have survived from the creation of the Earth without undergoing remelting, metamorphism, or erosion, and all we can say--from this line of evidence--is that the Earth appears to be at least as old as the four billion year old rocks.

Some of the oldest rocks on Earth are found in Western Greenland. Because of their great age, they have been especially well studied. The table below gives the ages, in billions of years, from twelve different studies using five different methods on one particular rock formation in Western Greenland, the Amitsoq gneisses.

Technique	Age Range
uranium-lead	3.60±0.05
lead-lead	3.56±0.10
lead-lead	3.74±0.12
lead-lead	3.62±0.13
rubidium-strontium	3.64±0.06
rubidium-strontium	3.62±0.14
rubidium-strontium	3.67±0.09
rubidium-strontium	3.66±0.10
rubidium-strontium	3.61±0.22
rubidium-strontium	3.56±0.14
lutetium-hafnium	3.55±0.22
samarium-neodymium	3.56±0.20

(compiled from Dalrymple, 1991)

Note that scientists give their results with a stated uncertainty. They take into account all the possible errors and give a range within which they are 95% sure that the actual value lies. The top number, 3.60±0.05, refers to the range 3.60+0.05 to 3.60-0.05. The size of this range is every bit as important as the actual number. A number with a small uncertainty range is more accurate than a number with a larger range.

> The error range is not the error on the age, but the error of the laboratory technique. In other words, the quantities of the isotopes in the rock were measured very accurately, but this is not the same as the age.

For the numbers given above, one can see that *all of the ranges overlap and agree between 3.62 and 3.65 billion years* as the age of the rock. Several studies also showed that, because of the great ages of these rocks, they have been through several mild metamorphic heating events that disturbed the ages given by potassium-bearing minerals (not listed here). As pointed out earlier, different radiometric dating methods agree with each other most of the time, over many thousands of measurements. Other examples of agreement between a number of different measurements of the same rocks are given in the references below.

See box on next page for comment.

This gives a misleading impression of the way dating systems work in practice. As Wiens has frequently said, radioactive dates *always* need to be checked against something else. Always the scientist's thinking is constrained by the big picture framework for the origin and evolution of the earth over billions of years—the consensus worldview. He compares his results with what he would expect within that worldview. Usually there is some sort of a conflict. Rather than a problem, he's excited by this, and applies himself to develop ways of resolving the conflict. He may resolve it in the way he interprets the date, or by inventing a new hypothesis about processes that occurred, or by challenging conclusions of previously published work. The whole idea is to get a unified explanation that fits the evidence. But he never challenges the basic worldview (at least not in mainstream journals), which means he never imagines that radioactive dating might not work.

Comment on the box about the Amitsoq gneisses.

The list of numbers quoted in the box gives the impression that the rocks are simply dropped into a machine and out pops the dates. The list hides the incredible amount of subjective selection and interpretation involved, although Wiens hints at this when he speaks of potassium-bearing minerals being disturbed.

The geology of the area of the Amitsoq gneisses is very complicated and involves numerous episodes of folding, intrusion, faulting and metamorphism. The relative ages of the different rocks are worked out, not from radioactive dating, but from their field relationships which are carefully studied. All interpretations of dating results have to agree with the field relationships.

Interestingly, the first Rb-Sr date on the list was calculated from an isochron of 13 samples collected from veins of gneiss over a distance of several kilometers. (Dalrymple, *The Age of the Earth*, pp. 148–149, 1991.) With such a wide separation it is unlikely that the isotopes were thoroughly mixed and *identical* in all samples at the beginning. With such disturbed geology it is even difficult to be sure that the all the veins sampled represent the same physical magma.

Dalrymple quotes K-Ar and Ar-Ar ages for the minerals biotite, hornblende and muscovite obtained from the gneiss ranging from 1.67 billion years to 4.85 billion (Dalrymple, p. 150). Note that the first figure is less than *half* the claimed age of the gneiss, and the last figure is *older* than the age of the earth! So, Wiens is not correct when he claims that the dates from all the different methods agree. They obviously do not.

As always, every inconsistency is resolved by the way the dates are *interpreted*. In this case the K-Ar and Ar-Ar dates are claimed to be affected by open system behaviour during a later metamorphic event. But why do the whole-rock samples give consistent results if the rocks were open systems? Answer: the rocks were only a little bit open, enough to affect the K-Ar but not enough to affect the other isotopes. Inconsistent dates never count against the dating methods.

Wiens's above discussion about old rocks and plate tectonics is simply a retelling of the evolutionary worldview. It's a story about events in the past, events which no-one observed, and which mostly occurred in places that are inaccessible.

For many years now, it has been held that earth formed from meteorites (called planetesimals) 4.6 billion years ago. Then, due to gravity the earth contracted, and as a result heated and melted. This allowed the heavy elements like iron and nickel to sink to the middle and the lighter material to move to the outside. This produced more heating, so the earth was completely molten for about 500 million years by which time it had cooled enough for the first rocks to solidify and the oceans to form. This period has been named the Hadean (or hell-like) Era even though no rocks this old have been found.

But recently these ideas changed when zircons (or parts of zircons) from Western Australia were dated at 4.4 billion years, and interpreted (through their oxygen content) to have crystallized in a wet environment.[22] This contradiction with the previous story meant something had to give. The mood at present is to change the story about the early earth, that it cooled much faster than previously thought (to my mind, 200 million years is not long enough for the earth to differentiate and cool, but the prevailing thinking is that it's okay). However, there are many adjustments that can be made to the models, such as reinterpreting the zircon evidence, invoking a rapid cooling process, or even having the earth form earlier. Only time will tell where the consensus view will move.

The point is that the interpretive framework drives the interpretation of the evidence. If researchers had the inclination (and creationist scientists are people who do) the same evidence can be interpreted within a biblical framework. In the biblical view the isotopic content of the rocks is not the result of radioactive decay over long periods of time. One possibility is that it represents a progressive sampling of different parts of the interior of the earth as it was melted during the global Flood. The zircon evidence for water is easily explained within the creationist view. It's the same evidence but a different framework.

When scientists began systematically dating meteorites they learned a very interesting thing: nearly all of the meteorites had practically identical ages, at 4.56 billion years. These meteorites are chips off the asteroids. When the asteroids were formed in space, they cooled relatively quickly (some of them may never have gotten very warm), so all of their rocks were formed within a few million years. The asteroids' rocks have not been re-melted ever since, so the ages have generally not been disturbed. Meteorites that show evidence of being from the largest asteroids have slightly younger ages. The moon is larger than the largest asteroid. Most of the rocks we have from the moon do not exceed 4.1 billion years. The samples thought to be the oldest are highly pulverized and difficult to date, though there are a few dates extending all the way to 4.4 to 4.5 billion years. Most scientists think that all the bodies in the solar system were created at about the same time. Evidence from the uranium, thorium, and lead isotopes links the Earth's age with that of the meteorites. This would make the Earth 4.5-4.6 billion years old.

Before the age of the earth (or anything) can be calculated we have to assume its history. The generally accepted secular story at present (as Wiens describes) is

[22] Wilde, S.A., Valley, J.W., Peck, W.H. and Graham, C.M., Evidence from detrital zircons for the existence of continental crust and oceans on the earth 4.4 Gyr ago, *Nature* **409**(6817):175–178, 11 January 2001.

that our earth and solar system formed from a contracting and concreting solar nebula, and the idea is that most meteorites represent debris left over from that nebula.

The French philosopher Laplace (1749–1827) published his nebula hypothesis in 1796. When Napoleon commented that Laplace never mentioned the Creator, Laplace said, 'I do not need that hypothesis'. The materialists continually make this assertion, that they can explain everything without the Creator God, but that is not true. Observations in our solar system are more and more contradicting the nebula hypothesis, which is repeatedly salvaged by inventing more and more secondary hypotheses, which are more and more miraculous in their effect.[23]

Clare Patterson in 1956 produced an isochron using the lead isotope ratios measured in five meteorites, giving an age of 4.55 billion years. He claimed these meteorites were all left over fragments from the accretion of the earth, and thus claimed 4.55 billion was the age of the earth. At the time, famous geochronologist Arthur Holmes said that using meteorites to calculate the age of the earth was 'unsound in principle'. That's because the meteorites raise a host of unknowns about their origin and history, unknowns which are impossible to resolve by observation. If there is no genetic relationship between meteorites and the earth then the result is meaningless. Holmes said that the correct method was to use terrestrial materials, but as Weins points out, there do not appear to be any primordial rocks left on the earth.

Nevertheless, Patterson's number quickly became the consensus and it still stands to this day. But today the assumptions that Patterson made about the earth are no longer accepted as valid (e.g. that ocean sediments represent the earth's average lead composition, and the earth only underwent a single stage differentiation), which means that his calculation is not valid. So why is his number still accepted? One geologist said that his result was fortuitous. It is interesting to consider just how fortuitous it was to get *precisely* the right age for the earth, to the second decimal point, and to do it by luck, using wrong assumptions.

To me that illustrates how the age of the earth a philosophical issue. From a secular perspective, the age needs to be old enough to allow time for the geological evolution of the earth, and young enough to allow time for the astronomical evolution of the universe. Anywhere between 3 and 7 billion years would be reasonable. It's also important that the number be precise, believable, convincing and not change from year to year. 4.55 billion fits the bill.

Because the isotopic measurements are always interpreted within this framework they always appear to be consistent, even when the numbers do not agree. For example, potassium argon dates measured in the 1960s for iron meteorites ranged from 5 to 13 billion years whereas a rubidium-strontium isochron gave 4.7

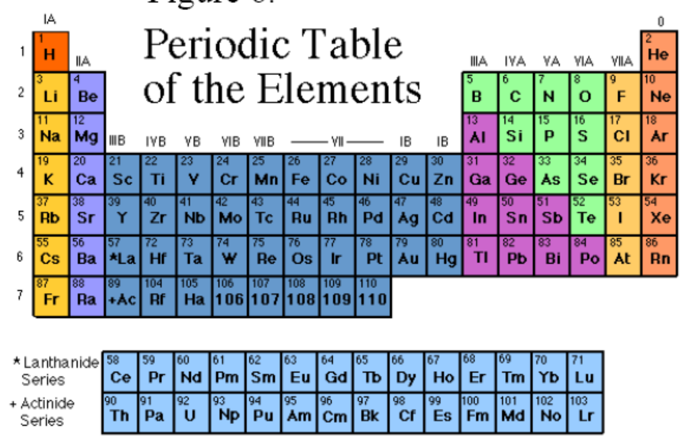
[23] Spencer, W., Revelations in the solar system, *Creation* **19**(3):26–29, 1997.

billion.[24] Argon-argon dates for L-chondrites gave ages around 500 million years.[25] It is a simple matter to make these different dates look like they are consistent by the way they are interpreted. The very old potassium argon dates are said to be caused by excess argon. The rubidium-strontium result is said to represent the age of the earth. The younger meteorites are said to be fragments from a planet that disintegrated long after the solar system formed. And who can argue with those assertions?

It was recently reported that meteorites have significantly more neodymium-142 than rocks on the earth,[26] but we would expect them to be the same if the earth was originally made from meteorites. Could it be that meteorites are not genetically related to the earth after all? That would not be a welcome suggestion. However, the problem is easily resolved by the story that was invented. The story so far was that, early after its formation, the interior of the earth was completely reorganized (it differentiated), with the heavy elements moving to the middle and lighter elements to the outside. The latest results are incorporated into this story by saying that when the earth differentiated the missing neodymium-142 collected into a reservoir at the base of the mantle, a reservoir that has 'never been sampled'. In other words, the interpretive framework is continually salvaged through secondary hypotheses that use more unknowns to explain the unknowns.

Extinct Radionuclides: The Hourglasses That Ran Out

Figure 6:



There is another way to determine the age of the Earth. If we see an hourglass whose sand has run out, we know that it was turned over longer ago than the time interval it measures. Similarly, if we find that a radioactive parent was once abundant but has since run out, we know that it too was set longer ago than the time interval it measures. There are in fact many, many more parent isotopes than those listed in Table 1. However, most of them are no longer found naturally on Earth—they have run out. Their half-lives range down to times shorter than we can measure. *Every single element has radioisotopes that no longer exist on Earth!*

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[24] Wasserburg, G.J., Burnett, D.S. and Frondel, C., Strontium-Rubidium Age of an Iron Meteorite, *Science* **150**(3705):1814–1818, 31 December 1965.
[25] Haack, H., Farinella, P., Scott E.R.D. and Keil K., Meteoritic, asteroidal, and theoretical constraints on the 500 Ma disruption of the L chondrite parent body, *Icarus* 119(1):182–191, 1996.
[26] Boyet, M. and Carlson, R.W., ^{142}Nd evidence for early (>4.53 Ga) global differentiation of the silicate earth, *Science* **309**(5734):576–581, 22 July 2005.

Perhaps the hour glass had no sand at the top at the beginning. How do they know that the parent element was *abundant* at the beginning? Where do they say the elements come from anyway? Materialists speculate that all the elements were made within stars by nuclear reactions over billions of years. These stars, at the end of their lives, supposedly exploded in a supernova and scattered their elements throughout the universe. Some of these elements eventually came together to form our solar system. Materialists are talking about events they claim happened billions of years ago in now non-existent stars that were supposedly billions of miles away. Like a fortune teller looking at tea leaves, they can easily change the details of their story to accommodate any observation. Anyway, the RATE group's hypothesis of accelerated nuclear decay would account for extinct radionuclides.

Many people are familiar with a chart of the elements (Fig. 6). Nuclear chemists and geologists use a different kind of figure to show all of the isotopes. It is called a chart of the nuclides. Figure 7 shows a portion of this chart. It is basically a plot of the number of protons vs. the number of neutrons for various isotopes. Recall that an element is defined by how many protons it has. Each element can have a number of different isotopes, that is, atoms with different numbers of neutrons. So each element occupies a single row, while different isotopes of that element lie in different columns. For potassium found in nature, the total neutrons plus protons can add up to 39, 40, or 41. Potassium-39 and –41 are stable, but potassium-40 is unstable, giving us the dating methods discussed above. Besides the stable potassium isotopes and potassium-40, it is possible to produce a number of other potassium isotopes, but, as shown by the half-lives of these isotopes off to the side, they decay away rather quickly.

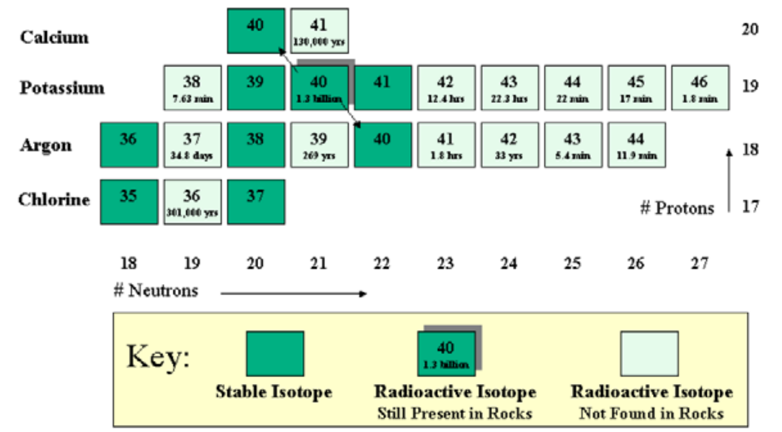


Figure 7. A portion of the chart of the nuclides showing isotopes of argon and potassium, and some of the isotopes of chlorine and calcium. Isotopes shown in dark green are found in rocks. Isotopes shown in light green have short half-lives, and thus are no longer found in rocks. Short-lived isotopes can be made for nearly every element in the periodic table, but unless replenished by cosmic rays or other radioactive isotopes, they no longer exist in nature.

All this is good experimental science, based on measuring (and re-measuring) processes that can be observed in the present.

Now, if we look at which radioactive isotopes still exist and which ones do not, we find a very interesting fact: Nearly all of the radioisotopes with half-lives shorter than half a billion years are no longer in existence.

> Omit the word 'still' and change 'no longer' to 'not' and this would be a statement of fact. But as it stands the sentence is laden with philosophical assumptions about the unobserved past.

For example, although most rocks contain significant quantities of calcium, the isotope calcium-41 (half-life 130,000 years) does not exist in nature, just as potassium- 38, -42, -43, etc. do not (Fig. 7). Just about the only radioisotopes found naturally are those with very long half-lives of close to a billion years or longer, as illustrated in the time line in Fig. 8. The only isotopes present with shorter half-lives are those that have a source constantly replenishing them. Chlorine-36 (shown in Fig. 7) is one such "cosmogenic" isotope, as we are about to discuss below.

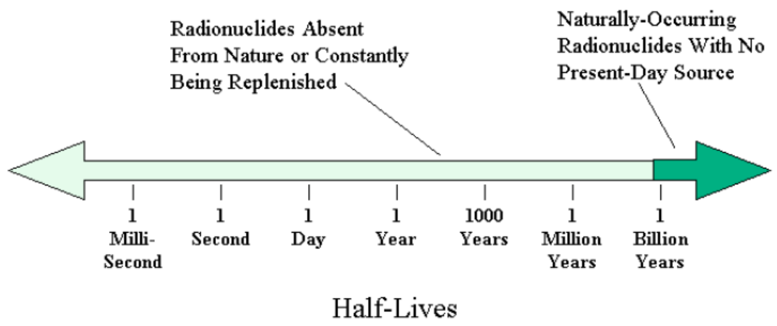


Figure 8. The only naturally-occurring radionuclides that exist with no presentday source have half-lives close to 1 billion years or longer, which still exist from the creation of the Earth. Isotopes with half-lives shorter than that no longer exist in rocks unless they are being replenished by some source.

> This is not correct. As mentioned earlier, carbon-14 has been found in Precambrian diamonds, and is an example of a short half-life isotope that did not have a source of replenishment.[6]

In a number of cases there is evidence, particularly in meteorites, that shorter-lived isotopes existed at some point in the past, but have since become extinct. Some of these isotopes and their half-lives are given in Table II. This is conclusive evidence that the solar system was created longer ago than the span of these half lives! On the other hand, the existence in nature of parent isotopes with half lives around a billion years and longer is strong evidence that the Earth was created not longer ago than several billion years. The Earth is old enough that radioactive isotopes with half-lives less than half a billion years decayed away, but not so old that radioactive isotopes with longer half-lives are gone. This is just like finding hourglasses measuring a long time interval still going, while hourglasses measuring shorter intervals have run out.

> The idea that these short-lived isotopes once existed is not an observable fact, but an inference from an assumed scenario for how the elements were formed. Why should a Christian presuppose that God created these elements in the first place?

Why would God create short-lived isotopes which emit massive radiation that would be hazardous to life and leach into the water supply?

On the other hand, the existence of long-lived isotopes is no problem for a 6,000-year-old earth because they do not produce significant amounts of dangerous radiation.

Cosmogenic Radionuclides: Carbon-14, Beryllium-10, Chlorine-36

Table II Extinct parent isotopes for which there is strong evidence that these once existed in substantial amounts in meteorites, but have since completely decayed away.

Extinct Isotope	Half-Life (Years)
Plutonium-244	82 million
Iodine-129	16 million
Palladium-107	6.5 million
Manganese-53	3.7 million
Iron-60	1.5 million
Aluminum-26	700,000
Calcium-41	130,000

The last 5 radiometric systems listed up in Table I have far shorter half-lives than all the rest. Unlike the radioactive isotopes discussed above, these isotopes are constantly being replenished in small amounts in one of two ways. The bottom two entries, uranium-234 and thorium-230, are replenished as the long-lived uranium-238 atoms decay. These will be discussed in the next section. The other three, Carbon-14, beryllium-10, and chlorine-36 are produced by cosmic rays--high energy particles and photons in space—as they hit the Earth's upper atmosphere. Very small amounts of each of these isotopes are present in the air we breathe and the water we drink. As a result, living things, both plants and animals, ingest very small amounts of carbon-14, and lake and sea sediments take up small amounts of beryllium-10 and chlorine-36.

The cosmogenic dating clocks work somewhat differently than the others. Carbon-14 in particular is used to date material such as bones, wood, cloth, paper, and other dead tissue from either plants or animals. To a rough approximation, the ratio of carbon-14 to the stable isotopes, carbon-12 and carbon-13, is relatively constant in the atmosphere and living organisms, and has been well calibrated. Once a living thing dies, it no longer takes in carbon from food or air, and the amount of carbon-14 starts to drop with time. How far the carbon-14/carbon-12 ratio has dropped indicates how old the sample is. Since the half-life of carbon- 14 is less than 6,000 years, it can only be used for dating material less than about 45,000 years old. Dinosaur bones do not have carbon-14 (unless contaminated), as the dinosaurs became extinct over 60 million years ago. But some other animals that are now extinct, such as North American mammoths, can be dated by carbon-14. Also, some materials from prehistoric times, as well as Biblical events, can be dated by carbon-14.

Carbon-14 dating is based on assumptions too, including that the amount is ‘relatively constant in the atmosphere’. But this ignores the effects of the global Flood about 4,500 years ago, which totally disrupted the carbon balance on the earth. Carbon from inside the mantle was discharged into the atmosphere, vegetation containing carbon was buried, carbonates were deposited, etc.

As already mentioned, carbon-14 is commonly found in samples that are supposedly millions of year old, including coal, wood and *diamonds*. But as Wiens indicates above, such evidence is dismissed as 'contaminated', purely because it disagrees with the long-age worldview. In the case of diamonds, though, there is no known way to contaminate them with the necessary C-14. Wiens's 'contamination' response proves that dating is constrained by philosophy and not by the evidence. Any result that is unacceptable is simply dismissed.

The carbon-14 dates have been carefully cross-checked with non-radiometric age indicators. For example growth rings in trees, if counted carefully, are a reliable way to determine the age of a tree. Each growth ring only collects carbon from the air and nutrients during the year it is made. To calibrate carbon-14, one can analyze carbon from the center several rings of a tree, and then count the rings inward from the living portion to determine the actual age. This has been done for the "Methuselah of trees", the bristlecone pine trees, which grow very slowly and live up to 6,000 years. Scientists have extended this calibration even further. These trees grow in a very dry region near the California-Nevada border. Dead trees in this dry climate take many thousands of years to decay. Growth ring patterns based on wet and dry years can be correlated between living and long dead trees, extending the continuous ring count back to 11,800 years ago. "Floating" records, which are not tied to the present time, exist farther back than this, but their ages are not known with absolute certainty. An effort is presently underway to bridge the gaps so as to have a reliable, continuous record significantly farther back in time. The study of tree rings and the ages they give is called "dendrochronology".

Can you see how this is calibrating carbon-14 against itself? First, they use carbon-14 to decide how old the dead tree is because you can't tell the age of an isolated dead log. Then they match the tree rings between logs to get a long record of tree rings. But ring matching is very subjective because the pattern of rings is not so distinctive and a variety of matches is possible.[27] Naturally, the matches are chosen that make the best calibration curve. They also assume that these trees only grew one ring per year, but that was never observed. The trees in the 'dry climate' are chosen because they have the most rings, but it turns out that is most likely because they grew multiple rings per year.[28] Because the environment is so dry they tend to grow a ring whenever there is rainfall. Similar trees growing in the valleys where the environment is wetter have many less rings. Very likely there were as many as a half-dozen growth rings per year on such trees during the post-Flood Ice Age when global climate fluctuations were extreme. Note too that the term 'floating' means that they have no idea what the age of the tree is, so they count the rings and 'float' its results until they nicely fit the curve

[27] Batten, D., Tree ring dating (dendrochronology), <www.creationontheweb.com/content/view/2441>.
[28] Matthews, M., Evidence for multiple ring growth per year in Bristlecone Pines, *Journal of Creation* **20**(3):95–103, 2006.

Tree rings do not provide continuous chronologies beyond 11,800 years ago because a rather abrupt change in climate took place at that time, which was the end of the last ice age. During the ice age, long-lived trees grew in different areas than they do now. There are many indicators, some to be mentioned below, that show exactly how the climate changed at the end of the last ice age. It is difficult to find continuous tree ring records through this period of rapid climate change. Dendrochronology will probably eventually find reliable tree records that bridge this time period, but in the meantime, the carbon-14 ages have been calibrated farther back in time by other means.

As shown above, tree ring calibration exercises are not independent confirmation of carbon-14, but dependent on it.

Calibration of carbon-14 back to almost 50,000 years ago has been done in several ways. One way is to find yearly layers that are produced over longer periods of time than tree rings. In some lakes or bays where underwater sedimentation occurs at a relatively rapid rate, the sediments have seasonal patterns, so each year produces a distinct layer. Such sediment layers are called "varves", and are described in more detail below. Varve layers can be counted just like tree rings. If layers contain dead plant material, they can be used to calibrate the carbon-14 ages.

Calibrating carbon-14 against varves has all the problem of tree rings. Sediment cores are generally retrieved from many different areas and the different cores are assembled into a long sequence by matching the patterns of layers from each core, assuming one core is older than the other. Matching the layers is very subjective. The concept of 'floating' cores is also employed, where the results are moved sideways until they form a nice curve with the other results. Even then, the results do not agree with the carbon-14 results. So the differences are interpreted as a 'calibration curve'. In other words, because the results do not agree they decide which one to adjust so that they will agree, and in this case they adjust the carbon-14 results.

But even if the results did agree, that would not prove they were measuring age accurately. Both processes could have been influenced by a common factor. From a creationist perspective, the production of carbon-14 and varves was affected by the global flood. The carbon-14 imbalance after the Flood would mean that the carbon-14 ages are too old. And the drainage of water after the Flood and the Ice Age would mean that more than one sedimentary layer would be formed in one year.

Another way to calibrate carbon-14 farther back in time is to find recently-formed carbonate deposits and cross-calibrate the carbon-14 in them with another short-lived radioactive isotope. Where do we find recently-formed carbonate deposits? If you have ever taken a tour of a cave and seen water dripping from stalactites on the ceiling to stalagmites on the floor of the cave, you have seen carbonate deposits being formed. Since most cave formations have formed relatively recently, formations such as stalactites and stalagmites have been quite useful in cross-calibrating the carbon-14 record.

This is not a calibration in the engineering sense because they are not using things of known age. No one saw the stalactites form thousands of years ago and marked the date on them.

What does one find in the calibration of carbon-14 against actual ages? If one predicts a carbon-14 age assuming that the ratio of carbon-14 to carbon-12 in the air has stayed constant, there is a slight error because this ratio has changed slightly. Figure 9 shows that the carbon-14 fraction in the air has decreased over the last 40,000 years by about a factor of two. This is attributed to a strengthening of the Earth's magnetic field during this time. A stronger magnetic field shields the upper

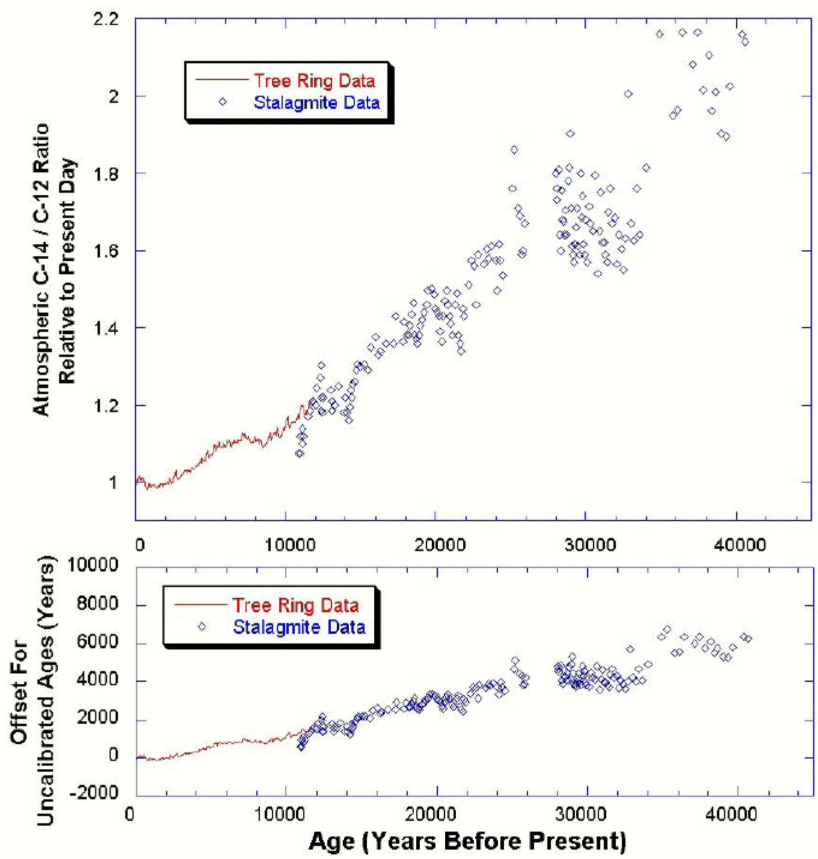


Figure 9. Ratio of atmospheric carbon-14 to carbon-12, relative to the present-day value (top panel). Unlike long-term radiometric dating methods, radiocarbon relies on knowing the fraction of radioactive carbon-14 in the atmosphere at the time the object being dated was alive. The production of carbon-14 by cosmic rays was up to a factor of about two higher than at present in the timescales over which radiocarbon can be used. Data for the last 11,800 years comes from tree-ring counting, while the data beyond that age comes from other sources, such as from a carbonate stalagmite for the data shown here. The bottom panel shows the offset in uncalibrated ages caused by this change in atmospheric composition. Tree-ring data are from Stuiver et al., *Radiocarbon 40*, 1041-1083, 1998; stalactite data are from Beck et al., *Science 292*, 2453-2458, 2001.

atmosphere better from charged cosmic rays, resulting in less carbon-14 production now than in the past. (Changes in the Earth's magnetic field are well documented. Complete reversals of the north and south magnetic poles have occurred many times over geologic history.) A small amount of data beyond 40,000 years (not shown in Fig. 9) suggests that this trend reversed between 40,000 and 50,000 years, with lower carbon-14 to carbon-12 ratios farther back in time, but these data need to be confirmed.

> In other words, the calibration did not work as expected. Note that there is a 6,000-year error in 40,000 years (in this exercise). In order to preserve the dating method, additional unseen factors are invoked to get the results to make sense. Notice too how scattered the results in figure 9 are.

What change does this have on uncalibrated carbon-14 ages? The bottom panel of Figure 9 shows the amount of offset in the uncalibrated ages. The offset is generally less than 1500 years over the last 10,000 years, but grows to about 6,000 years at 40,000 years before present. Uncalibrated radiocarbon ages *underestimate* the actual ages. Note that a factor of two difference in the atmospheric carbon-14 ratio, as shown in the top panel of Figure 9, does not translate to a factor of two offset in the age. Rather, the offset is equal to one half-life, or 5,700 years for carbon-14. This is only about 15% of the age of samples at 40,000 years. The initial portion of the calibration curve in Figure 9 has been widely available and well accepted for some time, so reported radiocarbon dates for ages up to 11,800 years generally give the calibrated ages unless otherwise stated. The calibration curve over the portions extending to 40,000 years is relatively recent, but should become widely adopted as well.

> In other words, the results do not agree. But that is not a problem in their mind because the errors are incorporated into a 'calibration curve'. Now, when that calibration is applied these results do agree. So the claim that these methods have been independently calibrated is not correct.

Radiometric Dating of Geologically Young Samples (<100,000 Years)

It is sometimes possible to date geologically young samples using some of the long-lived methods described above. These methods may work on young samples, for example, if there is a relatively high concentration of the parent isotope in the sample. In that case, sufficient daughter isotope amounts are produced in a relatively short time. As an example, an article in *Science* magazine (vol. 277, pp. 1279- 1280, 1997) reports the agreement between the argon-argon method and the actual known age of lava from the famous eruption of Vesuvius in Italy in 79 A.D.

> This article proves the opposite of the point that Wiens is making. The article proves the dating methods are not independent. In this case, they collected a sample of sanidine from pumice of *known* age based on historical eyewitness reports of the 24 August 79 AD eruption, the only way of knowing the true age of anything. Their total argon gas results gave an age of 3,300 years, which they knew was wrong because the correct answer was 1,918 years. So, using the

known age they calculated the amount of ‘excess’ argon. The paper is a warning to researchers to watch out for excess argon.

There are other ways to date some geologically young samples. Besides the cosmogenic radionuclides discussed above, there is one other class of short-lived radionuclides on Earth. These are ones produced by decay of the long-lived radionuclides given in the upper part of Table 1. As mentioned in the Uranium-Lead section, uranium does not decay immediately to a stable isotope, but decays through a number of shorter-lived radioisotopes until it ends up as lead. While the uranium-lead system can measure intervals in the millions of years generally without problems from the intermediate isotopes, those intermediate isotopes with the longest half-lives span long enough time intervals for dating events less than several hundred thousand years ago. (Note that these intervals are well under a tenth of a percent of the half-lives of the long-lived parent uranium and thorium isotopes discussed earlier.) Two of the most frequently-used of these “uranium-series” systems are uranium-234 and thorium-230. These are listed as the last two entries in Table 1, and are illustrated in Figure 10.

Yes, uranium series dating is a popular technique.

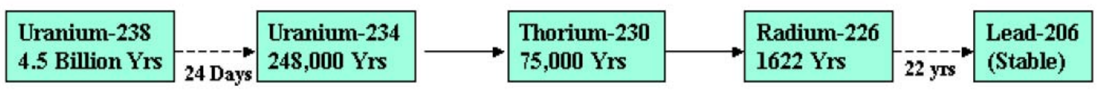


Figure 10. A schematic representation of the uranium-238 decay chain, showing the longest-lived nuclides. Half-lives are given in each box. Solid arrows represent direct decay, while dashed arrows indicate that there are one or more intermediate decays, with the longest intervening half-life given below the arrow.

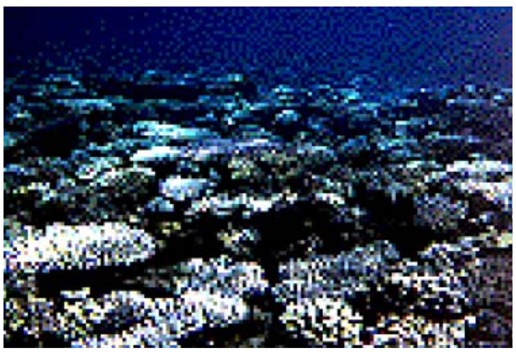
Like carbon-14, the shorter-lived uranium-series isotopes are constantly being replenished, in this case, by decaying uranium-238 supplied to the Earth during its original creation. Following the example of carbon-14, you may guess that one way to use these isotopes for dating is to remove them from their source of replenishment. This starts the dating clock. In carbon-14 this happens when a living thing (like a tree) dies and no longer takes in carbon-14-laden CO_2. For the shorter-lived uranium-series radionuclides, there needs to be a physical removal from uranium. The chemistry of uranium and thorium are such that they are in fact easily removed from each other. Uranium tends to stay dissolved in water, but thorium is insoluble in water. So a number of applications of the thorium-230 method are based on this chemical partition between uranium and thorium.

Once again, the method depends on knowing the initial conditions for the clock (and what happened since), and since we were not present to measure what was happening, we can only make assumptions. And if the date is unacceptable they can always change their assumptions, especially since some of the elements are so soluble in water.

Sediments at the bottom of the ocean have very little uranium relative to the thorium. Because of this, the uranium, and its contribution to the thorium abundance, can in many cases be ignored in sediments. Thorium-230 then behaves similarly to the long-lived parent isotopes we discussed earlier. It acts like a simple parent-daughter system, and it can be used to date sediments.

> That's the theory but, like all dating methods, the results are interpreted depending on the expected age of the sediments.

On the other hand, calcium carbonates produced biologically (such as in corals, shells, teeth, and bones) take in small amounts of uranium, but essentially no thorium (because of its much lower concentrations in the water). This allows the dating of these materials by their *lack* of thorium. A brand-new coral reef will have essentially no thorium-230. As it ages, some of its uranium decays to thorium-230. While the thorium-230 itself is radioactive, this can be corrected for. The equations are more complex than for the simple systems described earlier, but the uranium-234 / thorium-230 method has been used to date corals now for several decades. Comparison of uranium-234 ages with ages obtained by counting annual growth bands of corals proves that the technique is highly accurate when properly used (Edwards *et al.*, *Earth Planet. Sci. Lett. 90*, 371, 1988). The method has also been used to date stalactites and stalagmites from caves, already mentioned in connection with long-term calibration of the radiocarbon method. In fact, tens of thousands of uranium-series dates have been performed on cave formations around the world.



The uranium-234 / thorium-230 method is now being used to date animal and human bones and teeth. Previously, dating of anthropology sites had to rely on dating of geologic layers above and below the artifacts. But with improvements in this method, it is becoming possible to date the human and animal remains themselves. Work to date shows that dating of tooth enamel can be quite reliable. However, dating of bones can be more problematic, as bones are more susceptible to contamination by the surrounding soils. As with all dating, the agreement of two or more methods is highly recommended for confirmation of a measurement. If the samples are beyond the range of radiocarbon (e.g., > 40,000 years), a second method for confirmation of thorium-230 ages may need to be a non-radiometric method such as ESR or TL, mentioned below.

> This explains the theory, but even when multiple methods agree it does not mean that the date is accepted. It is only accepted if the age agrees with what it is believed it should be. See the example of dating Mungo Man where four methods agreed but geologists still disputed the date.[29]

[29] See Bowler, J.M. and Magee, J.W., Redating Australia's oldest human remains: a sceptic's view, *Journal of Human Evolution* **38**:719–726, 2000 for how undesirable dates are so easily dismissed. See also Walker, T., The dating game, *Creation* **26**(1):36–39, 2003 for a summary of this situation.

Non-Radiometric Dating Methods for the Past 100,000 Years

We will digress briefly from radiometric dating to talk about other dating techniques. It is important to understand that a very large number of accurate dates covering the past 100,000 years has been obtained from many other methods besides radiometric dating. We have already mentioned dendro-chronology (tree ring dating) above. Dendrochronology is only the tip of the iceberg in terms of non-radiometric dating methods.

> And every method depends on assumptions about the past.

Here we will look briefly at some other non-radiometric dating techniques.

Ice Cores. One of the best ways to measure farther back in time than tree rings is by using the seasonal variations in polar ice from Greenland and Antarctica. There are a number of differences between snow layers made in winter and those made in spring, summer, and fall. These seasonal layers can be counted just like tree rings. The seasonal differences consist of a) visual differences caused by increased bubbles and larger crystal size from summer ice compared to winter ice, b) dust layers deposited each summer, c) nitric acid concentrations, measured by electrical conductivity of the ice, d) chemistry of contaminants in the ice, and e) seasonal variations in the relative amounts of heavy hydrogen (deuterium) and heavy oxygen (oxygen-18) in the ice. These isotope ratios are sensitive to the temperature at the time they fell as snow from the clouds. The heavy isotope is lower in abundance during the colder winter snows than it is in snow falling in spring and summer. So the yearly layers of ice can be tracked by each of these five different indicators, similar to growth rings on trees. The different types of layers are summarized in Table III.

> These are all stories about what happened in the unobserved past. There is a big difference in reliability between observing phenomena in the present, and checking the observations over and over, and speculating about what may have happened thousands of years ago.

Ice cores are obtained by drilling very deep holes in the ice caps on Greenland and Antarctica with specialized drilling rigs. As the rigs drill down, the drill bits cut around a portion of the ice, capturing a long undisturbed "core" in the process. These cores are carefully brought back to the surface in sections, where they are catalogued, and taken to research laboratories under refrigeration. A very large amount of work has been done on several deep ice cores up to 9,000 feet in depth. Several hundred thousand measurements are sometimes made for a single technique on a single ice core.

> Good observational science.

A continuous count of layers exists back as far as 160,000 years.

This was not observed. This is an interpretation based on philosophical assumptions. Change 160,000 years to 9,000 feet and we have a scientific fact. Note that most of the alleged 160,000 years occurs rather suspiciously in the bottom few meters of the core.[30]

In addition to yearly layering, individual strong events (such as large-scale volcanic eruptions) can be observed and correlated between ice cores. A number of historical eruptions as far back as Vesuvius nearly 2,000 years ago serve as benchmarks with which to determine the accuracy of the yearly layers as far down as around 500 meters.

Again this is based on assumptions, but creationists lean to the view that the cores can be reasonably interpreted in the period since the Ice Age.[31]

As one goes further down in the ice core, the ice becomes more compacted than near the surface, and individual yearly layers are slightly more difficult to observe. For this reason, there is some uncertainty as one goes back towards 100,000 years.

'Slightly more difficult to observe' is an understatement. Identification of layers is highly subjective in the lower part of the core, and the results are model driven.[32]

Ages of 40,000 years or less are estimated to be off by 2% at most. Ages of 60,000 years may be off by up to 10%, and the uncertainty rises to 20% for ages of 110,000 years based on direct counting of layers (D. Meese et al., *J. Geophys. Res. 102*, 26,411, 1997).

What were these ages calibrated against to be able to quote such error values?

Recently, absolute ages have been determined to 75,000 years for at least one location using cosmogenic radionuclides chlorine-36 and beryllium-10 (G. Wagner et al., *Earth Planet. Sci. Lett. 193*, 515, 2001). These agree with the ice flow models and the yearly layer counts.

Of course they agree, just like the carbon-14 and varves and coral agree. The various parameters are tweaked until they do.

Note that there is no indication anywhere that these ice caps were ever covered by a large body of water, as some people with young-Earth views would expect.

No, because the ice caps formed *after* the Flood. It seems that Wiens does not believe the Flood happened.

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[30] Oard, M.J., *The Frozen Record*, Institute for Creation Research, El Cajon, CA, 2005

[31] Oard, M.J., Do Greenland ice cores show over one hundred thousand years of annual layers? *Journal of Creation* **15**(3):39–42, 2001.

[32] Woodmorappe, J., Greenland ice cores: implicit evidence for catastrophic deposition, *Journal of Creation* **16**(3):14–16, 2002.

Table III Polar ice core layers, counting back yearly layers, consist of the following:

Visual Layers	Summer ice has more bubbles and larger crystal sizes	Observed to 60,000 years ago
Dust Layers	Measured by laser light scattering; most dust is deposited during spring and summer	Observed to 160,000 years ago
Layering of Electrical Conductivity	Nitric acid from the stratosphere is deposited in the springtime, and causes a yearly layer in electrical conductivity measurement	Observed through 60,000 years ago
Contaminant Chemistry Layers	Soot from summer forest fires, chemistry of dust, occasional volcanic ash	Observed through 2,000 years; some older eruptions noted
Hydrogen and Oxygen Isotope Layering	Indicates temperature of precipitation. Heavy isotopes (oxygen-18 and deuterium) are depleted more in winter.	Yearly layers observed through 1,100 years; Trends observed much farther back in time

The layers may be easy to identify in the upper parts of the core, but as Wiens acknowledges above they become progressively more and more subjective.[32] And the results are always constrained by the long-age time framework. Ice accumulated at a much faster rate immediately after the Flood[31] and that is not taken into account in all these correlations because the researchers do not believe the global Flood happened.

Varves. Another layering technique uses seasonal variations in sedimentary layers deposited underwater. The two requirements for varves to be useful in dating are 1) that sediments vary in character through the seasons to produce a visible yearly pattern, and 2) that the lake bottom not be disturbed after the layers are deposited. These conditions are most often met in small, relatively deep lakes at mid to high latitudes. Shallower lakes typically experience an overturn in which the warmer water sinks to the bottom as winter approaches, but deeper lakes can have persistently thermally stratified (temperature-layered) water masses, leading to less turbulence, and better conditions for varve layers. Varves can be harvested by coring drills, somewhat similar to the harvesting of ice cores discussed above. Overall, many hundreds of lakes have been studied for their varve patterns. Each yearly varve layer consists of a) mineral matter brought in by swollen streams in the spring. b) This gradually gives way to organic particulate matter such as plant fibers, algae, and pollen with fine-grained mineral matter, consistent with summer and fall deposition. c) With winter ice covering the lake, fine-grained organic matter provides the final part of the yearly layer. Regular sequences of varves have been measured going back to about 35,000 years. The thicknesses of the layers and the types of material in them tells a lot about the climate of the time when the layers were deposited. For example, pollens entrained in the layers can tell what types of plants were growing nearby at a particular time.

> All varve chronologies depend on the assumption that the layers are annual but varve-like layers form naturally in minutes from flowing water when the sediment is composed of different kinds of particles.[33] Laboratory experiments show that the layers form quickly; similar observations have been made of sand and volcanic ash.

Other annual layering methods. Besides tree rings, ice cores, and sediment varves, there are other processes that result in yearly layers that can be counted to determine an age. Annual layering in coral reefs can be used to date sections of coral. Coral generally grows at rates of around 1 cm per year, and these layers are easily visible. As was mentioned in the uranium-series section, the counting of annual coral layers was used to verify the accuracy of the thorium-230 method.

> Coral reefs grow at different rates depending on the conditions.[34] The size of living coral reefs is consistent with an origin since the Flood, 4,500 years ago.[35]

Thermoluminescence. There is a way of dating minerals and pottery that does not rely directly on half-lives. Thermoluminescence dating, or TL dating, uses the fact that radioactive decays cause some electrons in a material to end up stuck in higher-energy orbits. The number of electrons in higher-energy orbits accumulates as a material experiences more natural radioactivity over time. If the material is heated, these electrons can fall back to their original orbits, emitting a very tiny amount of light. If the heating occurs in a laboratory furnace equipped with a very sensitive light detector, this light can be recorded. (The term comes from putting together *thermo*, meaning heat, and *luminescence*, meaning to emit light). By comparison of the amount of light emitted with the natural radioactivity rate the sample experienced, the age of the sample can be determined. TL dating can generally be used on samples less than half a million years old. Related techniques include optically stimulated luminescence (OSL), and infrared stimulated luminescence (IRSL). TL dating and its related techniques have been cross calibrated with samples of known historical age and with radiocarbon and thorium dating. While TL dating does not usually pinpoint the age with as great an accuracy as these other conventional radiometric dating, it is most useful for applications such as pottery or fine-grained volcanic dust, where other dating methods do not work as well.

> There are many unknowns, and many assumptions are needed, including the amount of radiation 'stored' in the mineral at a certain time in the past, that the change in radiation has only been affected by the radiation in the environment, that the radiation in the environment has remained constant, and that the sensitivity of the crystal to radiation has not changed with time. All these factors can be affected by water, heat, sunlight, the accumulation or leaching of minerals in the environment, and many other causes. Once again, the dates are accepted

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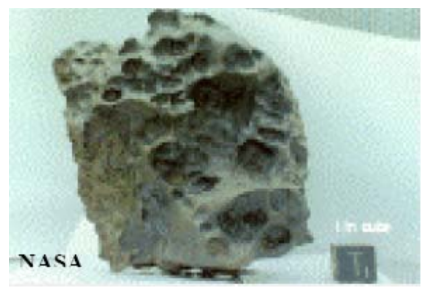
33 Snelling, A.A., Sedimentation experiments: *Nature* finally catches up! *Journal of Creation* **11**(2):125–126, 1997.
34 Read P. and Snelling, A., How old is Australia's Great Barrier Reef? *Creation* **8**(1):6–9, 1985.
35 How long does a coral reef take to grow? *Creation* **14**(1):14–15, 1991.

when they are consistent with other information but disregarded when they disagree.

Electron spin resonance (ESR). Also called electron paramagnetic resonance, ESR dating also relies on the changes in electron orbits and spins caused by radioactivity over time. However, ESR dating can be used over longer time periods, up to two million years, and works best on carbonates, such as in coral reefs and cave deposits. It has also seen extensive use in dating tooth enamel.

Electron-spin resonance (ESR) dates are based on the same principles as TL and OSL. However, the 'stored' radiation in the sample is measured by exposing it to gamma radiation and measuring the radiation emitted. The measuring technique does not destroy the 'stored' radiation (as does TL and OSL), so the measurement can be repeated on the same sample. The calculated date is based on the same assumptions, and affected by the same uncertainties, as for TL and OSL.

Cosmic-ray exposure dating. This dating method relies on measuring certain isotopes produced by cosmic ray impacts on exposed rock surfaces. Because cosmic rays constantly bombard meteorites flying through space, this method has long been used to date the 'flight time' of meteorites—that is the time from when they were chipped off a larger body (like an asteroid) to the time they land on Earth. The cosmic rays produce small amounts of naturally-rare isotopes such as neon-21 and helium-3, which can be measured in the laboratory. The cosmic-ray exposure ages of meteorites are usually around 10 million years, but can be up to a billion years for some iron meteorites. In the last fifteen years, people have also used cosmic ray exposure ages to date rock surfaces on the Earth. This is much more complicated because the Earth's magnetic field and atmosphere shield us from most of the cosmic rays. Cosmic ray exposure calibrations must take into account the elevation above sea level because the atmospheric shielding varies with elevation, and must also take into account latitude, as the magnetic shielding varies from the equator to the poles. Nevertheless, terrestrial cosmic-ray exposure dating has been shown to be useful in many cases.



Not only does this method have the problem of knowing how much of each isotope was present in the meteorite originally, but it assumes that certain isotopes were produced by exposure to cosmic rays. No matter what combination of numbers is produced from the measurements, some unknown and unseen cause can always be invoked to explain them. Very likely cosmic-ray influxes to the earth's surface were much higher during the Ice Age than they are today, because the earth's magnetic shield was much more leaky.

Can We Really Believe the Dating Systems?

We have covered a lot of convincing evidence that the Earth was created a very long time ago. The agreement of many different dating methods, both radiometric and non-radiometric, over hundreds of thousands of samples, is very convincing.

> The ‘agreement’ is not surprising, given 1) that the researchers really believe the methods work, 2) they are highly creative, 3) any number of unknown and unobserved processes can be used in any order to devise a story that explains the results, 4) conflicting results are presented as a new discovery that reveals new insights, and, 5) funding for further research depends on finding inconsistencies to study. And as we have discussed, there are other explanations for a general trend in isotopic ‘ages’.

Yet, some Christians question whether we can believe something so far back in the past. My answer is that it is similar to believing in other things of the past. It only differs in degree. Why do you believe Abraham Lincoln ever lived? Because it would take an extremely elaborate scheme to make up his existence, including forgeries, fake photos, and many other things, and besides, there is no good reason to simply have made him up. Well, the situation is very similar for the dating of rocks, only we have rock records rather than historical records.

> The difference between observation and speculation is the crux of the issue and Wiens confuses the two. We know about Abraham Lincoln through eyewitness reports and a written record. If something connected with Abraham Lincoln (the paper he wrote on, or his toenail) carbon-dated at 1,500 years we would not believe the carbon date over the historical evidence. We would know that something was wrong, even if we did not know exactly what. It is the same for Christians who believe the Bible. We accept that as a written record of eyewitness reports. We know that there must be a problem with any date that contradicts the biblical record, even if we don’t know exactly what.

Consider the following:

• There are well over forty different radiometric dating methods, and scores of other methods such as tree rings and ice cores.

> All compared with each other and carefully interpreted to give results consistent with the long-age belief system.

• *All of the different dating methods agree*--they agree a great majority of the time over millions of years of time. Some Christians make it sound like there is a lot of disagreement, but this is not the case. The disagreement in values needed to support the position of young-Earth proponents would require differences in age measured by orders of magnitude (e.g., factors of 10,000, 100,000, a million, or more). The differences actually found in the scientific literature are usually close to the margin of error, usually a few percent, not orders of magnitude!

> They do not always agree, but that does not cause a problem because they are interpreted to give a consistent story. No number is accepted on its own. They are all compared with the rest of the framework and once they are interpreted they look like they give convincing support to the long-age belief system.

• Vast amounts of data overwhelmingly favor an old Earth. Several hundred laboratories around the world are active in radiometric dating. Their results consistently agree with an old Earth. Over a thousand papers on radiometric dating were published in scientifically recognized journals in the last year, and hundreds of thousands of dates have been published in the last 50 years. Essentially all of these strongly favor an old Earth.

> Of course they favour an old earth because that is the way they are written. This simply proves that the scientific establishment overwhelmingly operates within a uniform long-age paradigm about the past. But most of the scientific research that has benefited our society, such as medical advances, computers and air travel, does not deal with things that happened in the past but with things happening in the present. For this scientific research the long-age paradigm is irrelevant. It has no influence on the way the research is undertaken or its conclusions.[36]

• Radioactive decay rates have been measured for over sixty years now for many of the decay clocks without any observed changes. And it has been close to a hundred years since the uranium-238 decay rate was first determined.

> This is good operational science. Laboratory measurements have also shown that under certain conditions decay rates can be greatly accelerated.[10] But the basic problem for radioactive dating won't go away. We don't know what conditions existed in the past and how these would have affected the decay rates in practice.

• Both long-range and short-range dating methods have been successfully verified by dating lavas of historically known ages over a range of several thousand years.

> The dating of historic lava flows has also shown problems with the methods.[37]

• The mathematics for determining the ages from the observations is relatively simple.

> This is irrelevant.

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[36] Wieland, C., Evolution and practical science *Creation* **20**(4):4, 1998; <www.creationontheweb.com/content/view/736>

[37] Snelling, A.A., Radioactive 'dating' failure: recent New Zealand lava flows yield 'ages' of millions of years, *Creation* **22**(1):18–21, 1999. Also: Austin, S.A., Excess argon within mineral concentrates from the new dacite lava dome at Mount St Helens volcano, *Journal of Creation* **10**(3):335–343, 1996.

The last three points deserve more attention. Some Christians have argued that something may be slowly changing with time so all the ages look older than they really are. The only two quantities in the exponent of a decay rate equation are the half-life and the time. So for ages to appear longer than actual, all the half-lives would have to be changing in sync with each other.

> Yes, and there are a few good reasons why such a synchronized change occurred. In fact, research by RATE showed a rough, factor-of-two consistency between various long half-life methods.

One could consider that time itself was changing if that happened (remember that our clocks are now standardized to atomic clocks!). And such a thing would have to have occurred without our detection in the last hundred years, which is already 5% of the way back to the time of Christ.

> One critical period is 2,500 years before the time of Christ, when God intervened strongly into the physical world to produce the worldwide, catastrophic Genesis Flood. Once Wiens has accepted uniformitarianism he cannot consider anything other than a slow gradual change of decay throughout Earth's history. Changing half lives is only one possibility. What was the isotopic distribution inside the earth after Creation Week when it formed? How was the interior of the earth sampled during the Flood, as material within the earth melted and progressively erupted onto the surface? What effect would the rate of eruption of magma have on the retention of argon? These are just a few issues that need to be explored.

Beyond this, scientists have now used a "time machine" to prove that the half-lives of radioactive species were the same millions of years ago. This time machine does not allow people to actually go back in time, but it does allow scientists to observe ancient events from a long way away. The time machine is called the telescope. Because God's universe is so large, images from distant events take a long time to get to us. Telescopes allow us to see supernovae (exploding stars) at distances so vast that the pictures take hundreds of thousands to millions of years to arrive at the Earth. So the events we see today actually occurred hundreds of thousands to millions of years ago. And what do we see when we look back in time? Much of the light following a supernova blast is powered by newly created radioactive parents. So we observe radiometric decay in the supernova light. The half-lives of decays occurring hundreds of thousands of years ago are thus carefully recorded! These half-lives completely agree with the half-lives measured from decays occurring today. We must conclude that all evidence points towards unchanging radioactive half-lives.

> There is no such thing as a time machine. Once again, these conclusions are based on a multitude of paradigm-driven assumptions, and the processes inside distant stars and supernova are not necessarily relevant to the processes that have been occurring on Earth.

Some individuals have suggested that the speed of light must have been different in the past, and that the starlight has not really taken so long to reach us. However, the astronomical evidence mentioned above also suggests that the speed of light has *not* changed, or else we would see a significant apparent change in the half-lives of these ancient radioactive decays.

> Yes, scientists have suggested that the speed of light was different in the past, including secularist scientists who proposed a higher speed of light to salvage some aspects of big bang cosmology. Most creationists today don't propose a change in the speed of light to solve some of the questions of age.

Doubters Still Try

Some doubters have tried to dismiss geologic dating with a sleight of hand by saying that no rocks are completely closed systems (that is, that no rocks are so isolated from their surroundings that they have not lost or gained some of the isotopes used for dating).

> Mainstream geologists do not doubt the millions of years—they accept that on faith. But they never accept a radioactive date without checking it with other information. In other words, they are skeptical of radioactive dating, *and* they routinely invoke open system behaviour in their interpretations of radioisotopic dates.

Speaking from an extreme technical viewpoint this might be true--perhaps 1 atom out of 1,000,000,000,000 of a certain isotope has leaked out of nearly all rocks, but such a change would make an immeasurably small change in the result. The real question to ask is, "is the rock sufficiently close to a closed system that the results will be same as a really closed system?" Since the early 1960s many books have been written on this subject. These books detail experiments showing, for a given dating system, which minerals work all of the time, which minerals work under some certain conditions, and which minerals are likely to lose atoms and give incorrect results. Understanding these conditions is part of the science of geology. Geologists are careful to use the most reliable methods whenever possible, and as discussed above, to test for agreement between different methods.

> Many books have been written about open system behaviour because it is such a problem. But in spite of all this research geologists will not accept dates without question. Every date still has to be interpreted.

Some people have tried to defend a young Earth position by saying that the half-lives of radionuclides can in fact be changed, and that this can be done by certain little-understood particles such as neutrinos, muons, or cosmic rays. This is stretching it. While certain particles can cause nuclear changes, they do not change the half-lives. The nuclear changes are well understood and are nearly always very minor in rocks. In fact the main nuclear changes in rocks are the very radioactive decays we are talking about.

> The age of the earth is a philosophical issue and cannot be resolved scientifically. Both young- and old-earthers encounter situations that seem contradictory, and it is standard scientific practice to propose hypotheses to resolve contradictions. The idea that half-lives have changed in the past is an idea that could potentially resolve the question and is worth pursuing. There are other lines of evidence that suggest half-lives may have changed in the past.[12]

There are only three quite technical instances where a half-life changes, and these do not affect the dating methods we have discussed.

1. Only one technical exception occurs under terrestrial conditions, and this is not for an isotope used for dating. According to theory, electron-capture is the most likely type of decay to show changes with pressure or chemical combination, and this should be most pronounced for very light elements. The artificially-produced isotope, beryllium-7 has been shown to change by up to 1.5%, depending on its chemical environment (*Earth Planet. Sci. Lett. 171*, 325-328, 1999; see also *Earth Planet. Sci. Lett. 195, 131-139, 2002*). In another experiment, a half-life change of a small fraction of a percent was detected when beryllium-7 was subjected to 270,000 atmospheres of pressure, equivalent to depths greater than 450 miles inside the Earth (*Science 181*, 1163-1164, 1973). All known rocks, with the possible exception of diamonds, are from much shallower depths. In fact, beryllium-7 is not used for dating rocks, as it has a half-life of only 54 days, and heavier atoms are even less subject to these minute changes, so the dates of rocks made by electron-capture decays would only be off by at most a few hundredths of a percent.

> Agreed, this observed and measured process in the present only produces small effects on half life. But Wiens seems unable to accept that God has intervened into Earth's history, especially at the time of the Flood, which is a view much more uniformitarian than Christian.

2. Physical conditions at the center of stars or for cosmic rays differ very greatly from anything experienced in rocks on or in the Earth. Yet, self-proclaimed "experts" often confuse these conditions. Cosmic rays are very, very high-energy atomic nuclei flying through space. The electron-capture decay mentioned above does not take place in cosmic rays until they slow down. This is because the fast-moving cosmic ray nuclei do not have electrons surrounding them, which are necessary for this form of decay. Another case is material inside of stars, which is in a plasma state where electrons are not bound to atoms. In the extremely hot stellar environment, a completely different kind of decay can occur. 'Bound-state beta decay' occurs when the nucleus emits an electron into a bound electronic state close to the nucleus. This has been observed for dysprosium-163 and rhenium-187 under very specialized conditions simulating the interior of stars (*Phys. Rev. Lett., 69,* 2164-2167; *Phys. Rev. Lett., 77,* 5190-5193, 1996). All normal matter, such as everything on Earth, the Moon, meteorites, etc. has electrons in normal positions, so these instances never apply to rocks, or anything colder than several hundred thousand degrees.

Who knows what sort of conditions could have applied during Creation Week, or even during the Flood, for that matter.

As an example of incorrect application of these conditions to dating, one young-Earth proponent suggested that God used plasma conditions when He created the Earth a few thousand years ago. This writer suggested that the rapid decay rate of rhenium under extreme plasma conditions might explain why rocks give very old ages instead of a young-Earth age. This writer neglected a number of things, including: a) plasmas only affect a few of the dating methods. More importantly, b) rocks and hot gaseous plasmas are completely incompatible forms of matter! The material would have to revert back from the plasma state before it could form rocks. In such a scenario, as the rocks cooled and hardened, their ages would be completely reset to zero as described in previous sections. If this person's scenario were correct, instead of showing old ages, all the rocks should show a uniform ~4,000 year age of creation. That is obviously not what is observed.

Not necessarily. This is a 'straw man'. Wiens fails to mention the much more realistic scenarios suggested by the RATE scientists. Factors to consider include the distribution of isotopes in the mantle and crust at the end of Creation Week.

3. The last case also involves very fast-moving matter. It has been demonstrated by atomic clocks in very fast spacecraft. These atomic clocks slow down very slightly (only a second or so per year) as predicted by Einstein's theory of relativity. No rocks in our solar system are going fast enough to make a noticeable change in their dates.

I know of no-one proposing this idea.

These cases are very specialized, and all are well understood. None of these cases alter the dates of rocks either on Earth or other planets in the solar system. The conclusion once again is that half-lives are completely reliable in every context for the dating of rocks on Earth and even on other planets. The Earth and all creation appears to be very ancient.

As I have said a number of times, there are more possible explanations for the distribution of isotopes within rocks than accelerated radioactive decay in the past.

Apparent Age?

It would not be inconsistent with the scientific evidence to conclude that God made everything relatively recently, but with the appearance of great age, just as Genesis 1 and 2 tell of God making Adam as a fully grown human (which implies the appearance of age).

Let's think about this. The age of something comes from its history. At the end of Creation Week Adam and Eve were one day old, but compared with us they looked like they were, say, 20 years. That is because our history is different from theirs. We encounter the same situation today when we say that someone 'looks young'. The problem arises because we are making a wrong comparison *in our minds* of their assumed history.

This idea was captured by Phillip Henry Gosse in the book, *"Omphalos: An Attempt to Untie the Geological Knot"*, written just two years before Darwin's *"Origin of Species"*. The idea of a false appearance of great age is a philosophical and theological matter that we won't go into here. The main drawback—and it is a strong one—is that this makes God appear to be a deceiver.

Did God deceive Adam and Eve by making them complete and mature on Day 6? No. He told them plainly what their history was. So even though they looked 'old' to their children who were born in the now-normal way, they knew their true age because of God's Word.

However, some people have no problem with this. Certainly whole civilizations have been incorrect (deceived?) in their scientific and theological ideas in the past.

For 1,800 years most Christians believed the world was not yet 6,000 years old, based on a careful study of the Bible. But if the world is actually millions of years old, as Wiens says, then the Bible has deceived all those people with incorrect information.

Whatever the philosophical conclusions, it is important to note that an *apparent* old Earth is consistent with the great amount of scientific evidence.

An apparent old Earth comes from old-earth thinking, not from the evidence. The problem is that these long-age scientists have ignored what God told us in his Word and assumed the wrong history for the earth. Based on their erroneous assumptions they have calculated an old age which disagrees with what God told us. Does that make God a deceiver? No. They have deceived themselves because they have not taken notice of God's Word.

Rightly Handling the Word of Truth

As Christians it is of great importance that we understand God's word correctly. Yet from the middle ages up until the 1700s people insisted that the Bible taught that the Earth, not the Sun, was the center of the solar system. It wasn't that people just thought it had to be that way; they actually quoted scriptures: "The Earth is firmly fixed; it shall not be moved" (Psalm 104:5), or "the sun stood still" (Joshua 10:13; why should it say the sun stood still if it is the Earth's rotation that causes day and night?), and many other passages.

The Galileo affair is the standard line of the skeptic. But it's irrelevant and has been answered before many times.[38] All motion relates to a point of reference,

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[38] Schirrmacher, T., The Galileo affair: history or heroic hagiography? *Journal of Creationl* **14**(1):91–100, 2000.

and we can assume any point of reference we like depending on the particular problem we are dealing with. The Bible uses the earth as reference, as 99.9% of people routinely do in daily life today, because that is the most convenient choice. Meteorologists speak of the sun rising but we do not accuse them of promoting an outdated cosmology.

I am afraid the debate over the age of the Earth has many similarities.

No, they are different because the age of the earth involves, not an arbitrary reference point, but the true history of the earth. It involves the creation event, yes, but it also involves significant events such as the Fall, the pre-Flood civilization, the Flood, the Tower of Babel, Abraham, etc.

But I am optimistic. Today there are many Christians who accept the reliability of geologic dating, but do not compromise the spiritual and historical inerrancy of God's word. While a full discussion of Genesis 1 is not given here, references are given below to a few books that deal with that issue.

How can a person accept that the world is millions of years old *and* hold that the Bible is historically inerrant, at the same time? How can the Bible be historically inerrant if, for example, the Noah's Flood did not cover the globe? Unfortunately many Christians have been intimidated by radioactive dating to abandon the true history of the world as set out in the Bible, and as a result have lost the historical basis for every major Christian doctrine, and sacrificed the credibility of the Word of God.[39]

As scientists, we deal daily with what God has revealed about Himself through the created universe. The psalmist marveled at how God, Creator of the universe, could care about humans: "*When I consider Your heavens, the work of Your fingers, the moon and the stars, which You have set in place, what is man that You are mindful of him, the son of man that You care for him?*" (Psalm 8:3-4). Near the beginning of the twenty-first century we can marvel all the more, knowing how vast the universe is, how ancient are the rocks and hills, and how carefully our environment has been designed. Truly God is more awesome than we can imagine!

When we try to incorporate long ages into the Bible we actually destroy the goodness of God. David Attenborough asked how we can say that God is merciful and loving when there are parasitic worms that bore into the eyes of children in Africa, making them blind.[40] When we reject creation in six-days, as Genesis says, and claim the world is billions of years old, we put the fossil record before Adam and Eve. Thus we make God the source of death and suffering, and undermine the basis of the Gospel. Yes, as we learn more about the universe we

[39] Grigg, R., Genesis—the seedbed of all Christian doctrine, <www.creationontheweb.com/content/view/5073>.
[40] Why doesn't Sir David Attenborough give credit to God? <www.creationontheweb.com/content/view/4272>.

find that there is much to marvel at, which should make us humble ourselves before the Creator and accept him at his word.

But when we accept what the Bible sets out as the true history of the earth, it sets us on the path to discover our true identity, to appreciate the love and goodness of God, and to realize our need of a Saviour. That can lead us to the good news of Jesus Christ, God the Son, who miraculously became a human, lived a perfect life, died on the cross for our sins, and was raised from the dead and ascended into heaven. One day he is coming back to gather all those who love him, to establish a new heaven and new earth, free from death, disease, suffering and sin. What a wonderful Saviour.

APPENDIX: Common Misconceptions Regarding Radiometric Dating Methods
There are a number of misconceptions that seem especially prevalent among Christians. Most of these topics are covered in the above discussion, but they are reviewed briefly here for clarity.

1. *Radiometric dating is based on index fossils whose dates were assigned long before radioactivity was discovered.*
This is not at all true, though it is implied by some young-Earth literature. Radiometric dating is based on the half-lives of the radioactive isotopes. These half-lives have been measured over the last 40-90 years. They are not calibrated by fossils.

> Correct, the half-lives are not calibrated by the fossils. But ‘calibration’ of the radiometric dates is different. As Wiens has repeatedly said, all dates have to be checked against other dates to see if they are correct. In fact, every date needs to be interpreted. The ages of sedimentary rocks are usually determined by their fossils and they are assigned to a geological system, such as the Jurassic period. Radioactive dates of igneous and metamorphic rocks are interpreted from their geological relationships such that they are consistent with the ages assigned to the sedimentary rocks from the fossils. Sometimes a radioactive date may lead to the sedimentary rocks being reassigned, say from Jurassic to Cretaceous. Sometimes it may lead to the ages of the system to be changed, say the K-T boundary being changed from 64 million years to 65 million. But more likely, the sedimentary rocks will affect the way the radioactive date is interpreted. The whole thing is an interlocking system of observations, assumptions and interpretations.

2. *No one has measured the decay rates directly; we only know them from inference.*
Decay rates have been directly measured over the last 40-100 years. In some cases a batch of the pure parent material is weighed and then set aside for a long time and then the resulting daughter material is weighed. In many cases it is easier to detect radioactive decays by the energy burst that each decay gives off. For this a batch of the pure parent material is carefully weighed and then put in front of a Geiger counter or gamma-ray detector. These instruments count the number of decays over a long time.

> Measurement of decay rates in the present is good operational science. Saying what happened in the past involves assumption, conjecture and philosophy.

3. *If the half-lives are billions of years, it is impossible to determine them from measuring over just a few years or decades.*
The example given in the section titled, “The Radiometric Clocks” shows that an accurate determination of the half-life is easily achieved by direct counting of decays over a decade or shorter. This is because a) all decay curves have exactly the same shape (Fig. 1), differing only in the half-life, and b) trillions of decays can be counted in one year even using only a fraction of a gram of material with a half-life of a billion years. Additionally, lavas of historically known ages have been correctly dated even using methods with long half-lives.

Again, it's operational science.

4. *The decay rates are poorly known, so the dates are inaccurate.*
Most of the decay rates used for dating rocks are known to within two percent. Uncertainties are only slightly higher for rhenium (5%), lutetium (3%), and beryllium (3%), discussed in connection with Table 1. Such small uncertainties are no reason to dismiss radiometric dating. Whether a rock is 100 million years or 102 million years old does not make a great deal of difference.

Measuring decay rates is operational science. The calculation is routine. But whether the rates measured in the present applied in the past is an unprovable assumption.

5. *A small error in the half-lives leads to a very large error in the date.*
Since exponents are used in the dating equations, it is possible for people to think this might be true, but it is not. If a half-life is off by 2%, it will only lead to a 2% error in the date.

Correct.

6. *Decay rates can be affected by the physical surroundings.*
This is not true in the context of dating rocks. Radioactive atoms used for dating have been subjected to extremes of heat, cold, pressure, vacuum, acceleration, and strong chemical reactions far beyond anything experienced by rocks, without any significant change. The only exceptions, which are not relevant to dating rocks, are discussed under the section, "Doubters Still Try", above.

Again, this is operational science, but no-one would claim that we understand every possible factor that could affect decay rates, even in the present. It's an area that needs more work, and creationists are doing good research.[16]

7. *A small change in the nuclear forces probably accelerated nuclear clocks during the first day of creation a few thousand years ago, causing the spuriously old radiometric dates of rocks.*
Rocks are dated from the time of their formation. For it to have any bearing on the radiometric dates of rocks, such a change of nuclear forces must have occurred after the Earth (and the rocks) were formed. To make the kind of difference suggested by young-Earth proponents, the half-lives must be shortened from several billion years down to several thousand years—a factor of at least a million. But to shorten half-lives by factors of a million would cause large physical changes. As one small example, recall that the Earth is heated substantially by radioactive decay. If that decay is speeded up by a factor of a million or so, the tremendous heat pulse would easily melt the whole Earth, including the rocks in question! No radiometric ages would appear old if this happened.

We can't know what happened during Creation Week because the Bible clearly says that God created supernaturally. But the distribution of isotopes in the mantle and crust at the end of Creation Week would impact the initial isotopic composition of rocks formed during the Flood.

8. *The decay rates might be slowing down over time, leading to incorrect old dates.* There are two ways we know this didn't happen: a) we have checked them out with "time machines", and b) it doesn't make sense mathematically. Both of these points are explained in the section titled, "Can We Really Believe the Dating Systems?"

'Time machines' are science fiction; they don't exist. Statements about the past unless they are based on direct observation and eyewitness reports are simply speculation.

9. *We should measure the "full-life" (the time at which all of the parent is gone) rather than the half-life (the time when half of it is gone).*
Unlike sand in an hourglass, which drops at a constant rate independent of how much remains in the top half of the glass, the number of radioactive decays is proportional to the amount of parent remaining. Figure 1 shows how after 2 half-lives, ½ x ½ = ¼ is left, and so on. After 10 half-lives there is 2^{-10} = 0.098% remaining. A half-life is more easy to define than some point at which almost all of the parent is gone. Scientists sometimes instead use the term "mean life", that is, the average life of a parent atom. The mean life is always 1/ln(2) = 1.44 times the half-life. For most of us half-life is easier to understand.

Yes, but not relevant.

10. *To date a rock one must know the original amount of the parent element. But there is no way to measure how much parent element was originally there.*
It is very easy to calculate the original parent abundance, but that information is not needed to date the rock. All of the dating schemes work from knowing the *present* abundances of the parent and daughter isotopes. The original abundance N_0, of the parent is simply $N_0 = N\ e^{kt}$, where N is the present abundance, t is time, and k is a constant related to the half life.

As well as the present abundances of parent and daughter, every dating scheme must know the *initial* abundance of the daughter, and whether there has been subsequent gain or loss of isotopes from the system. The fatal flaw of all schemes is that we cannot know any of these past factors.

11. *There is little or no way to tell how much of the decay product, that is, the daughter isotope, was originally in the rock, leading to anomalously old ages.*
A good part of this article is devoted to explaining how one can tell how much of a given element or isotope was originally present. Usually it involves using more than one sample from a given rock. It is done by comparing the ratios of parent and daughter isotopes relative to a stable isotope for samples with different relative amounts of the parent isotope. For example, in the rubidium-strontium method one compares rubidium-87/strontium-86 to strontium-87/strontium-86 for different minerals. From this one can determine how much of the daughter isotope would be present if there had been no parent

isotope. This is the same as the initial amount (it would not change if there were no parent isotope to decay). Figures 4 and 5, and the accompanying explanation, tell how this is done most of the time. While this is not absolutely 100% foolproof, comparison of several dating methods will always show whether the given date is reliable.

> Agreed. No method is foolproof because we don't have access to the past. Practically every dating method is protected from this problem by interpreting each date so that it is consistent with everything else. Dating methods are not the primary method of determining the age of anything. They give an air of precision, but their results are always harmonized with other information.

12. *There are only a few different dating methods.*
This article has listed and discussed a number of different radiometric dating methods and has also briefly described a number of non-radiometric dating methods. There are actually many more methods out there. Well over forty different radiometric dating methods are in use, and a number of non-radiogenic methods not even mentioned here.

> Every dating method depends on assumptions about the past.

13. *"Radiation halos" in rocks prove that the Earth was young.*
This refers to tiny halos of crystal damage surrounding spots where radioactive elements are concentrated in certain rocks. Halos thought to be from polonium, a short-lived element produced from the decay of uranium, have been found in some rocks. A plausible explanation for a halo from such a short-lived element is that these were not produced by an initial concentration of the radioactive element. Rather, as water seeped through cracks in the minerals, a chemical change caused newly-formed polonium to drop out of solution at a certain place and almost immediately decay there. A halo would build up over a long period of time even though the center of the halo never contained more than a few atoms of polonium at one time. "Hydrothermal" effects can act in ways that at first seem strange, such as the well-known fact that gold--a chemically unreactive metal with very low solubilities--is concentrated along quartz veins by the action of water over long periods of time. Other researchers have found halos produced by an indirect radioactive decay effect called hole diffusion, which is an electrical effect in a crystal. These results suggest that the halos in question are not from short-lived isotopes after all.

At any rate, halos from uranium inclusions are far more common. Because of uranium's long half-lives, these halos take at least several hundred million years to form. Because of this, most people agree that halos provide compelling evidence for a very old *Earth*.

> What has been published about polonium halos to date, on the face of it, provides strong evidence for extremely rapid geologic processes within short timeframe. Naturally this creates a problem for those who believe in long ages. But they are so convinced that the earth is old that the evidence from the polonium halos does not cause them to reconsider for an instant. Instead, they apply their scientific mind to looking for ways to interpret the evidence within a long-age paradigm. That is what Wiens is doing here. And it is clear that he is not aware of any

convincing solution to date. If he thinks his scenario is possible, he should publish it in the journals *Science* or *Nature*, who have been looking for a plausible explanation for a long time and would be keen to grasp any reasonable straw. Brent Dalrymple at the 1981 Arkansas creation trial admitted that he had no answer to polonium halos but condescendingly dismissed the problem as 'a tiny mystery'.[41] This simply confirms the point that age is a philosophical issue, not a scientific one. No problem (such as polonium halos) will cause the researcher to abandon long ages. Rather, it generates research effort to find a solution within the long age paradigm. But when young-agers do the same thing the old-agers accuse them of being biased.

14. *A young-Earth research group reported that they sent a rock erupted in 1980 from Mount Saint Helens volcano to a dating lab and got back a potassium-argon age of several million years. This shows we should not trust radiometric dating.*
There are indeed ways to "trick" radiometric dating if a single dating method is improperly used on a sample. Anyone can move the hands on a clock and get the wrong time. Likewise, people actively looking for incorrect radiometric dates can in fact get them. Geologists have known for over forty years that the potassium-argon method cannot be used on rocks only twenty to thirty years old. Publicizing this incorrect age as a completely new finding was inappropriate. The reasons are discussed in the Potassium-Argon Dating section above. Be assured that multiple dating methods used together on igneous rocks are almost always correct unless the sample is too difficult to date due to factors such as metamorphism or a large fraction of xenoliths.

It is disingenuous to call it a 'trick' or to say that they used an improper method. It was a well constructed experiment to test the assumption that all argon escapes from molten lava before it crystallizes. The laboratory method was entirely appropriate, and the results showed that the amount of argon present was well within the range of the instruments. And the results demonstrate that the fundamental assumption of the potassium-argon method is not correct in this situation, one where it was possible to test it observationally.

15. *Low* [it should be 'high'] *abundances of helium in zircon grains show that these minerals are much younger than radiometric dating suggests.*
Zircon grains are important for uranium-thorium-lead dating because they contain abundant uranium and thorium parent isotopes. Helium is also produced from the decay of uranium and thorium. However, as a gas of very small atomic size, helium tends to escape rather easily.

Yes ... that's the point, which Wiens has apparently missed. If helium leaks out of zircon fast, then there would be very little of it left after 1.5 billion years, but there is.

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[41] Gentry, R.V., Creation's Tiny Mystery, Earth Science Associates, Knoxville, Tennessee, p.122, 1986.

Researchers have studied the rates of diffusion of helium from zircons, with the prediction from one study by a young-*Earth* creationist suggesting that it should be quantitatively retained despite its atomic size. The assumptions of the temperature conditions of the rock over time are most likely unrealistic in this case.

> Notice the claim, 'The assumptions … are most likely unrealistic in this case'. This proves the point. Every dating method is based on assumptions, and if the researcher does not like the result he simply change his assumptions. Notice too the words 'most likely' suggesting that Wiens has not really checked this one out.
>
> As a matter of fact, the RATE temperature assumptions were extremely generous to uniformitarians. It would take unrealistically low temperatures (minus 77 degrees C deep underground for nearly 1.5 billion years) to retain the large amount of helium found in the zircons.

16. *The fact that radiogenic helium and argon are still degassing from the Earth's interior prove that the Earth must be young.*
The radioactive parent isotopes, uranium and potassium, have very long half-lives, as shown in Table 1. These parents still exist in abundance in the Earth's interior, and are still producing helium and argon. There is also a time lag between the production of the daughter products and their degassing. If the Earth were geologically very young, very little helium and argon would have been produced. One can compare the amount of argon in the atmosphere to what would be expected from decay of potassium over 4.6 billion years, and in fact it is consistent.

> I would never say 'proves' the earth must be young' because every age calculation depends on assumptions. That the earth is still degassing is a problem for an old earth, but the age can be salvaged by making assumptions about the radioactive decay of material in the mantle—all of which is unobserved. The amount of argon in the mantle could be a problem for a young earth if it is assumed it all accumulated by radioactive decay, but that can be resolved by the kind of assumptions made about its primordial origin.

17. *The waters of Noah's flood could have leached radioactive isotopes out of rocks, disturbing their ages*.
This is actually suggested on one website! While water can affect the ability to date rock surfaces or other weathered areas, there is generally no trouble dating interior portions of most rocks from the bottom of lakes, rivers, and oceans. Additionally, if ages were disturbed by leaching, the leaching would affect different isotopes at vastly different rates. Ages determined by different methods would be in violent disagreement. If the flood were global in scope, why then would we have *any* rocks for which a number of different methods all agree with each other? In fact, close agreement between methods for most samples is a hallmark of radiometric dating.

Close agreement is overdone. For example, four different methods were applied to rocks from Grand Canyon and gave different results.[42] Also, it is well known that the evidence for the interaction of fluids with rocks is strong, and leaching is a standard explanation used to interpret dates that are much younger than expected from the geological setting.

18. *We know the Earth is much younger because of non-radiogenic indicators such as the sedimentation rate of the oceans.*
There are a number of parameters which, if extrapolated from the present without taking into account the changes in the *Earth* over time, would seem to suggest a somewhat younger *Earth*. These arguments can sound good on a very simple level, but do not hold water when all the factors are considered. Some examples of these categories are the decaying magnetic field (not mentioning the widespread evidence for magnetic reversals), the saltiness of the oceans (not counting sedimentation!), the sedimentation rate of the oceans (not counting Earthquakes and crustal movement, that is, plate tectonics), the relative paucity of meteorites on the Earth's surface (not counting weathering or plate tectonics), the thickness of dust on the moon (without taking into account brecciation over time), the Earth-Moon separation rate (not counting changes in tides and internal forces), etc. While these arguments do not stand up when the complete picture is considered, the case for a very old creation of the Earth fits well in all areas considered.

Every dating method depends upon assumptions and you can get any result you like depending on the assumptions you make. These are some of the many situations where creationists have applied uniformitarian assumptions (the same ones that materialists use) and obtained ages that are far too young for an old earth. Contrary to what Wiens suggests, magnetic reversals point to a young earth, not long ages.[43] Also creationist researchers *have* accounted for sedimentation and crustal movement in their calculations. One could argue that the majority of the data, when extended using their own uniformitarian assumptions, is in favor of a young earth. But this does not settle the argument because, as Wiens illustrates here, the old agers simply change the assumptions to get an age that they like philosophically. In fact, although long-agers have challenged these assumptions they have not satisfactorily resolved the problems for long-ages. See for example the discussion about helium retention in zircons.[44]

19. *Only atheists and liberals are involved in radiometric dating.*
The fact is that there are a number of Bible-believing Christians [but not believing those parts that mention a recent creation or worldwide Flood] who are involved in radiometric dating, and who can see its validity firsthand. A great number of other Christians [not

[42] Snelling, A.A., Radioisotope dating of rocks in the Grand Canyon, *Creation* **27**(3):44–49, 2005; <www.creationontheweb.com/content/view/4415>; See also ref. 4.
[43] Humphreys, D.R., New evidence for rapid reversals of the earth's magnetic field, *Creation Research Society Quarterly* **26**(4):132–133, 1990.
[44] Sarfati, J., Russ Humphreys refutes Joe Meert's false claims about helium diffusion, <www.creationontheweb.com/content/view/2578>.

Bible-believing?] are firmly convinced that radiometric dating shows evidence that God created the Earth billions, not thousands, of years ago.

> As we have discussed, there are many Christians who accept the billions of years, but none has satisfactorily resolved the problems this causes for the integrity of the word of God, the nature of God and the Gospel. Like the Bereans, we need to check the Scriptures for ourselves to see what is true, not rely on what other people say. On the other side of the coin, there are Christians involved in radioactive dating who believe the earth is only thousands of years old, and these scientists often help with young-earth creationist research.

20. *Different dating techniques usually give conflicting results.*
This is not true at all. The fact that dating techniques most often agree with each other is why scientists tend to trust them in the first place. Nearly every college and university library in the country has periodicals such as *Science*, *Nature*, and specific geology journals that give the results of dating studies. The public is usually welcome to (and should!) browse in these libraries. So the results are not hidden; people can go look at the results for themselves. Over a thousand research papers are published a year on radiometric dating, essentially all in agreement. Besides the scientific periodicals that carry up-to-date research reports, specific suggestions are given below for further reading, both for textbooks, non-classroom books, and web resources.

> As we have said before, when dates do not agree geologists do not think of them as conflicting dates. Rather, they simply interpret the different numbers to give a consistent story with the long-age paradigm. The rough agreement that does exist has alternative explanations, including accelerated nuclear decay on a young earth. If we have *two* theories that explain the rough consistency, then Wiens can't claim it as proof for his position.
>
> And yes, it can be helpful to check some of the science periodicals first hand, but it may not be easy for the uninitiated because they use much jargon. Abstracts for *Science* and *Nature* are available on-line. Here are a few pointers to watch:
>
> 1. The articles will sound very convincing, especially when the authors are explaining their own findings. They will be hard to understand (mostly) because they will use shorthand and unfamiliar terms.
> 2. Realize that any event or process that they invoke or describe or conclude that they say occurred millions of years ago was unobserved. If it was not observed then it is purely an invention. Ask yourself, 'How do they know that?' Try to imagine where the writer was physically standing to observe the process that he is describing.
> 3. If you have access to a full geological paper that reports dates note that every date is interpreted. The paper first reports what the researcher did and what he calculated. Then it says what the date means. This is the section that sounds so convincing. But again, ask yourself 'How does he know that?'

4. Realize that conflicting results are not reported as conflicting results. They are always reported as revealing some new unobserved insight about what is going on.
5. Be alert to how they compare their results with previous researchers (if they do). This can reveal the real problems. Frequently they will dismiss the results of other workers that conflict with their findings in a most cursory way, without testing their claims. Ask yourself whether the reasons they give for dismissing the previous results have been observed or justified.

Resources
In his paper Wiens cites a lot of resources that promote a billion-year age for the earth. He provides no references to young-earth resources. I won't repeat here the list he gives but I will provide a short list of young-earth creationist material.

On the Web
Creation on the Web
This is the web site of *Creation Ministries International*, an international Christian ministry committed to defending the truth of the Bible and thus its gospel message. The website has many thousands of articles that answer all manner of questions in the area of creation/evolution, radioactive dating and the young earth.
www.creationontheweb.com

Further Reading

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Vardiman, L. *et al*. (Eds.), *Radioisotopes and the Age of the Earth Vol. I*, ICR, El Cajon, CA, CRS, Chino Valley, AZ, 2000.

Vardiman, L. *et al*. (Eds.), *Radioisotopes and the Age of the Earth Vol. II*, ICR, El Cajon, CA, CRS, Chino Valley, AZ, 2005.

Woodmorappe, J., *The Mythology of Modern Dating Methods*, Institute of Creation Research, El Cajon, CA, 1999.

Creation magazine
A colour family magazine, published four times a year, that deals with creation, evolution and the age of the earth.

Journal of Creation
A peer-reviewed, in-depth science journal, published three times a year, that publishes creationist research including papers on radioisotope dating.

Creation Research Society Quarterly
A peer-reviewed science journal, issued four times a year that publishes creationist research including papers on radioisotope dating.