

# **RADIOCARBON DATING**



# THE AGE OF THE EARTH

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#### Radiocarbon Dating and the Age of the Earth

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A common young-earth creationist claim, particularly from those with some background in engineering or science, is that radiocarbon dating backs a young- earth position. Many young- earth creationists claim that tiny amounts of carbon- 14 found in some fossils, coal deposits, and diamonds *prove* that these samples and, therefore, Earth itself cannot be older than about 50,000 years.<sup>1</sup> Today, this "evidence" stands as the most widely broadcast and believed challenge to independent scientific measurements of Earth's age. Such measurements consistently establish that Earth is  $4.5662\pm0.0001$  billion years old.<sup>2</sup>

A wider understanding of radiocarbon dating is essential to assess claims regarding Earth's age. Although technical, radiocarbon dating can be understood by anyone who wants to evaluate the evidence on either side of this issue. The purpose of this paper is to clarify how this dating method works and show how it's intended to be used. Another purpose is to show how radiocarbon dating has been misapplied by those who challenge the idea, based on a misreading of the Bible, that Earth could be more than some thousands of years old.

Radiocarbon dating is a method that uses the decay of carbon-14 to measure the ages of carboncontaining materials. When cosmic rays pass through Earth's atmosphere, neutrons are produced. The resulting neutrons generate the following reaction: nitrogen-14 + neutron  $\rightarrow$  carbon-14 + proton. This reaction produces approximately 22,000 carbon-14 atoms per second on every square meter of Earth's surface.

The abundance of carbon-14 in an organism when it dies is equal to the abundance of carbon-14 in the atmosphere at that same time. However, when the organism ceases to breathe, the quantity of carbon-14 decreases from that time onward due to the radioactive decay process. Based on the constancy of the carbon-14 decay rate, scientists can determine the date when the organism (or organic material) ceased to live.

The basis for young-earth creationists' assertions is the fact that carbon-14 has a half-life of 5,715 years.<sup>3</sup> This figure means that half of the carbon-14 in the remains of an organism (or organic sample) will decay into nitrogen-14 by 5,715 years after its death. By 11,430 years after its death, just a quarter of the original carbon-14 will exist in the sample. By 22,860 years after its death, just one sixteenth of the original carbon-14 will remain in the sample. At this decay rate, only 0.001 of the original quantity of carbon-14 remains at 57,150 years after the organism's death. At this decay rate, any fossil, coal sample, or diamond that is more than a million years old "should" contain no carbon-14 atoms at all—that's *if* these atoms come from no other source. The fact that some fossils, coal samples, and diamonds dated by other methods to be at least a million years old and yet still contain small amounts of carbon-14 suggests to young-earth creationists that something is wrong with these other dating methods and that Earth really must be less than 57,150 years old.



Because mainstream scientists rarely comment on or explain the *inevitable* presence of carbon-14 in ancient fossils, coal, and diamonds, young-earth creationists claim, erroneously, that these scientists have no valid explanation for carbon-14 in these samples *if* the Earth is, in fact, ancient. Thus, they assert that mainstream scientists are wrong about Earth's age. Reasons to Believe scientists and other scientists have provided a valid explanation. It can be found in multiple books and articles.<sup>4</sup> What follows, however, is a comprehensive explanation for the presence of carbon-14 in nearly all ancient organic matter, zircons, and diamonds. This explanation is based on a broad and up-to-date survey of reputable scientific literature.

#### **Anticipated Dating Inaccuracies**

No age measurement, radiometric or otherwise, can be absolutely accurate given that all measuring techniques are subject to some level of imprecision. The imprecision, or uncertainty, may be labeled as statistical, systematic, or both. *Statistical errors*, also known as random errors, refer to imperfections in the measuring process. *Systematic uncertainties* refer to various environmental and instrumental factors that can shift all the measurements either up or down by an equal amount.

Published carbon-14 dating measurements often include a reference to the statistical errors, but only rarely do authors make note of likely systematic uncertainties. Even more rarely do they assign a value to the possible magnitude of the uncertainties. These omissions leave room for young-earth creationists to assert (or assume) that a sample's published date measurement, along with its statistical error, accurately represents the range of possible ages for the sample.

For example, they claim a published carbon-14 age for a sample of 52,000±5,500 years implies that the sample cannot be much older than 57,500 years. Their survey of such published carbon-14 dates for fossils, coal, zircons, and diamonds leads them to argue that there are no carbonaceous materials on or in Earth that can be more than about 57,000 years old and, therefore, Earth itself must be younger than 57,000 years.

#### **Carbon-14 Dating Limitations**

Accelerator mass spectrometers have the technical capacity to detect the presence of individual carbon-14 atoms within a given sample (see figure 1). This amazing detection capability initially led to confidence that scientists would be able to use these instruments to date samples up to 100,000 years old.





**Figure 1: FT-ICR (Fourier Transform Ion Cyclotron Resonance) Mass Spectrometer** Credit: Michael Pereckas, Creative Commons Attribution



However, researchers' hopes to extend carbon-14 dating back to 100,000 years ago have been foiled by machine "background" (minor imperfections and/or variability) inherent within all Accelerator Mass Spectroscopy (AMS) instruments. For example, the AMS electronic circuitry and software used to process the instrument's data produce false positives for the presence of carbon-14 atoms. As it turns out, there are non-carbon-14 ions that closely mimic carbon-14 ions. Consequently, many ions that are not carbon-14 get counted as carbon-14 ions. Thus, all AMS-measured samples will yield carbon-14 ages much younger than 100,000 years, regardless of how old the samples are.

More problematic than machine issues are background signals from the presence of contaminant carbon-14 atoms. If a sample has been buried, carbon-14 may have been introduced during the burial process and/or when the sample was recovered from its burial site. Virtually any kind of sample recovery is likely to introduce some level of carbon- 14 contamination.

Further, even while a sample is stored in preparation for AMS testing, atmospheric carbon-14 contamination cannot be avoided. Neither can it be prevented during laboratory processing. It's simply beyond the realm of possibility to completely shield a sample from exposure to background radiation such as cosmic rays, radioisotopes, and neutrinos.

Laboratories engaged in carbon-14 measurements do their best to prepare samples, especially those anticipated to be older than 40,000 years, by subjecting them to rigorous cleaning, chemical pretreatment, and to heating for more than an hour at 240°C under vacuum conditions. When this preparation is done well, the practical dating limit for a 1 milligram carbon-containing sample is 55,000 years. That is, only if the sample's true age is less than 55,000 years can an accurate carbon-14 date determination be made. For a 0.5 milligram sample, the dating limit is 50,000 years.<sup>5</sup> For a 0.1 milligram sample the dating limit is only 15,000 years.<sup>6</sup>

Due to the ongoing decay of the radioisotope potassium-40 (with a 1.25-billion- year half-life), carbon-14 background radiation will always be present on Earth's surface. This background radiation inevitably occurs because the radioisotope decay of potassium-40 will convert some of the ambient nitrogen-14 into carbon-14. (Nitrogen-14 comprises 78 percent of Earth's atmosphere.) Therefore, no carbon-14 testing laboratory can be perfectly shielded from potassium-40 radiation. Even a carbon- free sample of aluminum or titanium, if tested for carbon-14, would likely get a radiocarbon date of 50,000–55,000 years old.

All samples of once-living organisms and deposits comprised largely of the decay products of organisms (for example, coal, petroleum, asphalt, limestone, marble) contain considerable amounts of potassium-40 and nitrogen-14. Therefore, some background level of carbon-14 will exist in these samples, no matter how old they may be.

Potassium-40 is not the only radioisotope that transforms nitrogen-14 into carbon-14. The decay of uranium-235 (half-life = 704 million years), uranium-238 (half-life = 4.47 billion years), thorium-232 (half-life = 14.1 billion years), and radium-226 (an intermediate product in the decay chain of uranium-238, with a half-life = 1,600 years), and other radioisotopes also produce carbon-14. Potassium-40, thorium-232, and uranium-238 are present throughout Earth's surface, crust, and mantle. Thus, contamination at some level from these radioisotopes simply cannot be avoided.



Another unavoidable source of background contamination arises from the sample holder itself. In AMS laboratories, any sample to be tested for its carbon- 14 level must be held in place by some kind of container, tweezers, or calipers. The sample holder inevitably is exposed to atmospheric carbon, microbes, and ambient radiation. It is impossible to rid the sample holder of all possible sources of carbon-14 contamination.

#### **Missing Carbon-14**

From an old-earth perspective, carbon-14 should be absent from all deep- underground deposits of natural gas and oil, but only until they are exposed to carbon-14 sources on Earth's surface. When such ancient deposits are tested via atomic mass spectrometry, the carbon-14 dates range from 62,000 to 50,000 years ago. This date range is exactly what one would expect from very ancient deposits due to varying levels of laboratory contamination.

More definitive evidence comes from air samples taken above electricity- generating power plants and cement production factories in the United States (US). These power plants and cement factories burn enormous quantities of natural gas and oil taken from deep-underground deposits. If, in fact, the fossil fuels burned in these plants and factories contain no carbon-14, then air samples taken above the plants and factories should exhibit diluted quantities of carbon-14. That is, the amount of carbon-14 in the atmospheric carbon dioxide (CO2) above power plants and cement factories should be less by predictable amounts than the amount of carbon-14 in the atmospheric CO2 above regions where no such power plants and cement factories exist.

At ten specific locations in the US, a team of atmospheric physicists confirmed this prediction. After calculating the quantities of natural gas and oil burned by the power plants and cement factories at these locations, they used precise measurements of <sup>14</sup>CO2 in extensive air samples from the National Oceanic and Atmospheric Administration's (NOAA's) air sampling network (see figure 2). By this means, the team determined that the <sup>14</sup>CO2 measurements in the air samples above the ten locations revealed the expected dilution effects of burning fossil fuels that contained no carbon- 14.<sup>7</sup>





# Figure 2: Global Air Sampling Network

Credit: National Oceanic and Atmospheric Administration

The team compared the CO2 emissions they had analyzed with results from three global inventories used to account for CO2 emissions in the US as well as with calculations made by the US Environmental Protection Agency. In each case, the quantity of CO2 emissions the team computed exists above power plants and cement factories proved slightly higher by roughly 3 or 2 standard deviations, respectively. However, their figures closely matched the latest findings of the high- resolution, US-specific Vulcan emission data product, considered the most accurate and reliable measure of total CO2 emissions from fossil fuel combustion by electricity-power generating plants and cement production factories. Thus, the team concluded that data from the NOAA air sampling network yielded an accurate and reliable measure of emissions from US fossil fuel combustion by power plants and cement production.

The team's study, therefore, established that the quantity of <sup>14</sup>CO2 in air samples taken above power plants and cement factories matched the carbon-14 dilution factor expected from the burning of fossil fuels that contained no carbon-14. The team's conclusion was affirmed by an independent research team's use of tree rings to measure the quantity of carbon-14 in CO2 emissions from fossil fuel burning in Beijing.<sup>8</sup> A second confirmation came from another research team's determination of the fossil fuel components in atmospheric CO2 based on atmospheric <sup>14</sup>CO2 measurements at the Beromünster tall- tower station in Switzerland.<sup>9</sup> Based on all these findings, and counter to the claims made by young-earth creationists, natural gas and oil from deep underground sources burned in the US, in the Beijing area, and in Switzerland must be considerably older than 100,000 years.



#### Carbon-14 in Ancient Deposits, Fossils, and Minerals

Typically, atomic mass spectroscopy measurements of fossils and coal samples determined by other independent dating methods to be many millions of years old *do* contain tiny quantities of carbon-14, notably greater quantities than the trace amounts in natural gas and oil from deep underground deposits. This slightly greater quantity of carbon-14 is expected from an old-earth perspective, given that these fossils and coal samples contain considerably more nitrogen-14. The greater presence of nitrogen-14 leads to increased opportunity for radioisotopes such as potassium-40, thorium-232, and uranium-238 in these fossils and samples and in their environment to transform this nitrogen-14 into carbon-14. It also means greater opportunity for cosmic rays to transform the nitrogen-14 in the fossils and samples into carbon-14.

Diamonds proven by other dating methods (measuring the quantities in the diamonds' mineral inclusions of the long-lived radioisotopes uranium-238, uranium-235, lutetium- 176, Rubidium-87, and Rhenium-187 and their respective daughter isotopes [decay product isotopes] lead-206, lead-297, hafnium-176, strontium-87, and osmium-187) to be millions of years old contain tiny amounts of carbon-14. They do so because natural diamonds are not pure carbon. They typically contain about 0.1 percent nitrogen. This nitrogen does not come from the atmosphere. It comes from Earth's mantle formation. Radioisotopes near the places where diamonds form in Earth's mantle will convert some of this resident nitrogen into carbon-14. As soon as the diamonds are exposed to the atmosphere, incident cosmic rays will generate additional carbon-14.

Further, about 1.1 percent of the carbon in natural diamonds is carbon-13. Carbon-13, depending on the energy of the impacting neutrons, has a neutron absorption cross section that ranges from 100 times less to 20 times more than that for nitrogen-14.<sup>10</sup> Consequently, just as with nitrogen-14, some carbon-13 in diamonds will be transformed into carbon-14.

Typically, the amount of carbon-14 arising from this transformation of carbon-13 is low compared to the amount arising from the transformation of nitrogen-14. However, to achieve the highest quality date in AMS carbon-14 dating, the quantity of carbon-13 must also be measured. As many researchers have demonstrated, an accurate measure of the quantity of carbon-13 in a sample is necessary to correct AMS carbon-14 data for isotopic transformation of carbon-13.<sup>11</sup> In other words, contaminant sources of both carbon-14 and carbon-13 must be taken into account, because these background sources of carbon- 14 and carbon-13 *both* contribute to making samples appear younger than they really are.

Cosmic rays and radioisotopes are not the only environmental factors that contribute to a background carbon-14 signature in samples that are millions of years old. Bacteria and fungi, as carbon-, nitrogen-, and potassium-rich organisms, also make a substantial contribution. Vast amounts of bacteria and fungi live on Earth's surface as well as deep underground. Bacteria are known to exist more than 3,400 meters (11,200 feet) below Earth's surface.<sup>12</sup> Indigenous bacteria have been found to inhabit petroleum deposits at depths of 2,000 meters (6,600 feet).<sup>13</sup>

Most bacteria produce methane and/or carbon dioxide as a byproduct of their metabolic activity. If present in a coal, oil, or gas deposit, bacteria may have reintroduced some carbon-14 into the deposit. Therefore, even fossil fuel samples found to be devoid of bacteria and bacterial remains could carry a carbon-14 signature from ancient bacteria and bacterial remains.



Bacteria and fungi are especially abundant on Earth's surface and in Earth's lower atmosphere. They are present everywhere—even in atomic mass spectroscopy laboratories. Consequently, some level of carbon-14 contamination from ambient bacteria and fungi is inevitable.

In addition to the effects of radiation and microbes on background carbon-14 signals, other systematic effects are known to exist. Nuclear tests, both above and below ground,<sup>14</sup> and emissions and meltdowns from nuclear power plants, represent the most carefully studied.<sup>15</sup> For example, atmospheric carbon-14 levels in the Northern Hemisphere nearly doubled during the atmospheric nuclear weapons tests conducted in the 1960s (see figure 3).<sup>16</sup>



Figure 3: Carbon-14 Spike from Nuclear Weapons Tests Credit: Oak Ridge National Laboratory

Both light-water- and heavy-water-cooled uranium nuclear power plants are known to convert nitrogen-14 and oxygen-17 into carbon-14.<sup>17</sup> Additionally, high- temperature-gas- cooled nuclear reactors convert carbon-13 into carbon-14.<sup>18</sup> Consequently, carbon-14 has a high production rate in all uranium nuclear reactors and is present in virtually all parts of the reactor systems.<sup>19</sup> Nuclear reactors release carbon-14 to their terrestrial and marine environments through liquid and gas discharges and radioactive waste disposal.

Other known systematic effects must also be accounted for. Solar flares can cause carbon-14 spikes.20 Lightning strikes, especially cloud-ground strikes, produce carbon-14.21 Rocket launches release some carbon-14.22

The broad diversity of known causes of background carbon-14 signals suggests the existence of several other unknown contributors to the background signals. While these unknown systematic



effects are unlikely to make major contributions to the background carbon-14 level, no scientist working today can claim to have an accurate measure of the total background carbon-14 level in any sample subjected to carbon-14 dating.

While researchers do not know with precision the upper limit to the background carbon- 14, they do know the lower limit.

For sufficiently young samples—those younger than 40,000–35,000 years with a sample mass greater than 2 milligrams—the background level will add little to the statistical uncertainty in the determined carbon-14 date. However, any sample older than 55,000 years, even one that is billions of years old, inevitably will possess a tiny amount of carbon-14. The systematic uncertainty due to the presence of this small quantity of carbon-14 in the dating of such a sample is almost always greater than the statistical uncertainty in the carbon-14 date.

#### **Other Dating Methods**

Young-earth creationists point to tiny amounts of carbon-14 found in samples of fossils, coal, and diamonds as if their presence discounts *all* radiometric measurements indicating ages greater than 50,000 years. The fallacy here is that many other radiometric dating methods applied to thousands of samples— terrestrial, meteoritic, and lunar—yield dates in the millions and billions of years. In these cases, the systematic errors are not just smaller than the statistical errors, but several orders of magnitude smaller (factors of thousands to millions of times smaller) than the statistical errors. That is to say, the systematic effects have no measurable consequences on these determined dates.

One reason for geophysicists' and astronomers' certainty that Earth and the rest of the solar system are many millions of years old is that Earth's crust, meteorites, lunar rocks, and the Sun no longer contain short half-life radioisotopes, other than the extremely tiny amounts received from recent, nearby supernova eruptions. They find no neptunium-237 (half-life = 2.14 million years), no aluminum-26 (half-life = 720,000 years), no calcium-41 (half-life = 103,000 years), no iodine-129 (half-life = 17 million years), and no technetium-98 (half-life = 4.2 million years).<sup>23</sup> Yet, they do find the isotopes of the decay products (daughter isotopes) of these short-lived radioisotopes. The presence of these daughter isotopes confirms that the parent radioisotopes were present and abundant on Earth long ago. Therefore, the present- day lack of these short-lived radionuclides in Earth, in lunar rocks, in meteorites, or on the Sun convinces geophysicists and astronomers that Earth and the solar system must be older than a quarter billion years (15 half-lives x 17 million = 255 million years).

The absence of neptunium-237, aluminum-26, calcium-41, iodine-129, and technetium- 98 on Earth, in meteorites and lunar rocks, and on the Sun does not mean they never existed or do not exist. Astronomers have detected these radioisotopes in cosmic rays and the spectra of stars and in the interstellar medium (gas and dust existing between stars) that are demonstrably very much younger (by independent dating methods) than either the Sun, the Moon, or Earth.<sup>24</sup> In recently formed stars, astronomers have even detected radioisotopes with half- lives of only a few years.<sup>25</sup>

Thanks to newly available ultrasensitive accelerator mass spectrometry techniques, physicists have found extremely tiny amounts of iron-60 (half-life = 1.5 million years) and plutonium-244 (half-life = 82 million years) in deep-sea crust samples, Antarctic snow, and some lunar rocks.<sup>26</sup> The measured abundances and isotope ratios are entirely explained by Earth receiving pulses of



supernova dust from two nearby core-collapse supernovae that erupted 3 and 7 million years ago. (Very massive stars at the end of their nuclear burning undergo core collapse when nuclear fusion becomes unable to sustain the core against its own gravity. This collapse produces radioisotopes heavier than iron-56.)

## **RATE Study**

Recognizing that multiple independent radioisotope dating methods establish that Earth, the solar system, and the universe are all several billions of years old, the following young- earth creationist organizations—Institute for Creation Research, Answers in Genesis, and the Creation Research Society—jointly formed the RATE (Radioisotopes and the Age of the Earth) research group in 1997 to search for ways to interpret radiometric decay in a young-earth context.<sup>27</sup> After eight years of research, the RATE group acknowledged that if radiometric decay rates are constant throughout Earth's and the universe's history, then the universe and Earth must be billions of years old.<sup>28</sup> In their 2-volume report of their research achievements, the group conceded, "All these products of nuclear decay were indeed produced by nuclear decay! But the amounts of those products we observe are much greater than thousands of years could produce—at today's rates."<sup>29</sup> They continued, "A change in the decay constant of the order of 10<sup>9</sup> may be required, if the accelerated decay is restricted to the one-year period of the Genesis Flood A one-year episode of accelerated decay at the time of the Flood may not be enough. Other episodes during Creation week or during the Fall may also be necessary."<sup>30</sup>

To sustain their young-earth beliefs, the RATE group speculated that radiometric decay rates must have accelerated by at least a factor of several hundred million times during Noah's flood and in the few months after Noah's flood and/or either during the first few Genesis creation days or at the time of Adam's fall into sin in the Garden of Eden.<sup>31</sup> As purported evidence for their speculation, the RATE group cited laboratory physics experiments where physicists had induced small, brief amounts of accelerated radiometric decay through subjecting tiny samples to extremely high pressures and temperatures.<sup>32</sup>

Physicists have observed accelerated radiometric decay under normal pressure and temperature conditions in those *rare* instances where decay occurs as electrons stray into the nucleus. In the most successful such experiment, physicists forced an accelerated decay rate by encasing some radiometric atoms inside buckyballs (soccer- ball-like lattices of sixty carbon atoms), which surrounded the atoms with a dense field of electrons.<sup>33</sup> However, even for this highly contrived circumstance, the radiometric decay rate was sped up by only 0.8 percent. This extraordinary experiment in no way alters any radiometric dates for Earth's age or provides any support for the RATE team's speculation about exponentially accelerated radiometric decay rates.

#### **Changing Decay Rates?**

The appeal to vastly accelerated radiometric decay rates runs into several intractable scientific challenges. It also runs counter to several explicit biblical statements.

**Biblical challenge:** The Bible describes the universe's laws of physics as unchanging from the beginning until God replaces the universe with the new creation (Revelation 21-22). In Jeremiah 33, God rebuked the Jews for doubting his declared promises. In Jeremiah 33:25, the prophet compared the certainty of God's promises to "the fixed laws of heaven and earth." The clear implication here is that just as the laws of physics, from thermodynamics to gravity to



electromagnetism and more, can be counted on to have remained unchanged, so, too, can God's promises be counted on to be unaltered.

Genesis 1–9, along with other Bible passages, affirms that starlight, sunlight, metabolism of food, and productive human work occurred both before and after the advent of human sin and before, during, and after Noah's flood.

Romans 8:20 states that the creation has been subjected to "frustration" or "futility." Verses 21–22 declare that all creation—the entire universe—was, and is, in a state of "slavery to decay" or "bondage to corruption." Romans 8:23 tells us that the laws of physics will remain pervasively in effect until God's redemptive work is complete. The completion of this work will occur when the full number of humans God intends to redeem have embraced his offer of rescue in Christ.

What clearer depiction could be offered for the second law of thermodynamics, the law of ongoing, continual decay? Revelation 21 and Ecclesiastes 1 and 3 support the claim that the whole of nature has been subjected to and continually experiences ongoing decay.

**Biological challenge:** The slightest variation in any of the physical laws at any time in cosmic history would have rendered many life-critical functions impossible. Even a tiny change in any of the laws of physics would have immediately exterminated all life-forms on Earth. Accelerated radioisotope decay at the level required to sustain young-earth interpretations of Earth's and humanity's history would have instantly vaporized all life and all water on Earth. Both the Bible and the scientific record rule out such vaporization events.

*Astronomical challenges:* If radioisotope decay were occurring at an accelerated rate at any time in cosmic history, the spectra of stars and galaxies would reveal it. Measuring past radioisotope decay rates can be indirect and difficult for geophysicists but direct and easy for astronomers. Because they routinely observe stars and galaxies thousands, millions, and even billions of light-years away, astronomers directly observe radiometric isotopes as they were some thousands, millions, and billions of years ago. At no time during the history of the universe do astronomers observe any change in radioisotope decay rates.

Astronomers routinely measure at high precision the wavelength positions of certain spectral lines emitted by stars, galaxies, and quasars. They observe the degree to which spectral lines are shifted by interactions with the fundamental forces of physics. For example, such measurements yield the value of the fine-structure constant at the moment light was emitted from the star, galaxy, or quasar.

Thousands of measurements made by astronomers show that the fine-structure constant in stars, galaxies, and quasars at distances ranging from 4 light-years to 12.9 billion light-years away differ by no more than 1 part in a million from its measured value on Earth today.<sup>34</sup> These measurements imply that any variations in the value of the fine-structure constant (a fundamental physics constant that quantifies the strength of the electromagnetic interaction between elementary charged particles) can be no greater than 7.8 x 10<sup>-17</sup>/year over the past 12.9 billion years.

Similarly, astronomical observations of spectral lines in stars, galaxies, and quasars show that



variations in the electron-to-proton mass ratio must be no greater than  $1.36 \times 10^{-17}$ /year over the past 7.34 billion years<sup>35</sup> and no greater than  $1.6 \times 10^{-17}$ /year throughout the past 12.9 billion years.<sup>36</sup> The same kinds of observations establish that the gravitational force constant has varied by no more than 7.9 x  $10^{-12}$ /year over the past 11.0 billion years.<sup>37</sup>

Astronomical measurements definitively and comprehensively affirm the repeated biblical declaration that there has been no change in any of the laws of physics. Astronomical measurements also affirm that the velocities of light, neutrinos, and gravity waves are identical to one another and have not varied throughout the history of the universe.<sup>38</sup>

*Ice- and sediment-core challenges:* Three ice cores from Antarctica, Dome C, Dome F, and Vostok, provide a continuous record of the past 800,000, 720,000, and 420,000 years respectively.<sup>39</sup> Two ice cores in Northern Greenland (NEEM and NGRIP) and two ice cores in central Greenland (GRIP and GISP2) yield a continuous record of the past 135,000, 123,000, 105,000, and 105,000 years respectively.<sup>40</sup>

The annual layers of the ice cores contain radioisotopes. Analysis of those isotopes establish that radiometric decay constants indeed did not vary at any time throughout the past 800,000 years.<sup>41</sup> Evidence that the ice core layers really are annual events arises from four sources.

First, embedded within the layers are dust signatures of known volcanic eruptions. For example, multiple independent historical records confirm that the Krakatoa eruption took place in 1883, and the Vesuvius eruptions occurred in 79, 472, 512, 968, 1037, 1139, 1631, and 1944 AD. By counting the number of layers between layers that contain the dust signatures of these eruption events, researchers have confirmed that each layer indeed corresponds to one year.<sup>42</sup>

Second, known intense solar storms, such as the ones that occurred in 660 BC, 775 AD, and 994 AD, show beryllium-10 enhancements.<sup>43</sup> These enhancements affirm that the ice core layers indeed are annual events. The layers perfectly align with tree-ring records.

Third, cyclical variations in the eccentricity (a measure of the non-circularity) of Earth's orbit about the Sun and Earth's obliquity (a measure of the tilt of Earth's rotation axis) are clearly seen in the Antarctica ice cores (see figure 4). Differing seasonal changes resulting from variations in Earth's orbital eccentricity and axial tilt affect ice core layer thicknesses. As Earth's orbital eccentricity and axial tilt increases, the seasonal changes increase in direct proportion. Earth's eccentricity changes are driven primarily by Earth's interactions with the gravitational fields of Jupiter and Saturn. The Moon is predominantly responsible for Earth's axial tilt variations. Earth's gravitational interactions with the Moon, Jupiter, and Saturn generate a 100,000-year periodic cycle in Earth's climate, a cycle is clearly visible in the thickness variations of deep ice core layers.





**Figure 4: Earth's Orbital Eccentricity and Axial Tilt Cycles Seen in an Ice Core** The 800,000 layers in the Dome C Antarctic ice core reveal layer thickness variations (schematically drawn) driven by the periodic variations in the eccentricity of Earth's orbit and the tilt of Earth's rotation axis. Also evident in the annual layers are dust signatures of volcanic eruptions that occurred throughout recorded history.

Background image credit: Tony Travouil, University of New South Wales; diagram credit: Phil Chien

The 800,000 Dome C ice core layers show eight complete cycles of variation in Earth's climate that are driven by the cyclical variations in Earth's orbital eccentricity and axial tilt. Even the deepest layers in the Dome C ice core show no evidence of folding, which supports the integrity of the annual layers in the ice- core stratigraphy.<sup>44</sup> The Dome F and Vostok ice cores show seven and four complete cycles, respectively. Thus, the law of gravity dictates that the Antarctica ice core layers are annually deposited layers, that Earth is at least 800,000 years old, and that radioisotope dating yields reliable dates throughout the past 800,000 years.

Fourth, a marine sediment core off the coast of South Island, New Zealand, reveals southern hemisphere climate changes throughout the past 3.9 million years.<sup>45</sup> The sediment layers in this core show the same cycles in the periodic variations of Earth's orbital eccentricity and axial tilt as do the three deep Antarctic ice cores, thereby confirming that the three ice cores really do provide a faithful record of the past 800,000 years of Earth's history. Conversely, the Antarctic ice cores indicate that the New Zealand sediment core can be trusted in showing that Earth is at least 3.9 million years old, and that radioisotope dating provides trustworthy dates throughout the past



#### 3.9 million years.

*Tree rings, varves, corals challenges:* Cosmic rays predominantly come from the remnants of supernova eruptions and from supermassive black holes. Because of the uneven distribution of supernova remnants and supermassive black holes on the celestial sphere, cosmic rays reaching Earth's atmosphere are slightly variable on a yearly basis. Furthermore, during the past 50,000 years, at least five supernova events have occurred within 250–1,000 light-years from Earth.<sup>2</sup> Those events were close enough to have altered carbon-14 dates. The alterations result in the carbon- 14 ages being undervalued by 0 to 14 percent.

Fortunately, the alterations due to variable cosmic ray exposure can be accurately determined. The quantities of carbon-14 measured in the annual layers in tree rings, varves, and ice cores allow scientists to accurately establish the varying rates at which cosmic rays strike Earth's atmosphere. Such measurements enable scientists to distinguish between the apparent carbon-14 date and the calibrated, or real, carbon-14 date. As with the layers in deep ice cores, the dust signatures of known volcanic eruptions and climate changes driven by cyclical variations in Earth's rotation axis tilt and in Earth's orbit about the Sun prove that the tree rings and varve layers indeed are annual. The latest calibration curve is IntCal20 (see figure 5).





#### Figure 5: Radiocarbon Date Calibration

Credit: adapted from Timothy J. Heaton et al., "The IntCal20 Approach to Radiocarbon Calibration Curve Construction: A New Methodology Using Bayesian Splines and Errors- in-Variables," *Radiocarbon* 62, no. 4 (August 2020): 821–863, doi:10.1017/RDC.2020.46

The calibration of carbon-14 dating by tree ring, varve, coral, and ice core data leaves no reason to doubt that carbon-14 measurements correctly date once-living things back to at least 40,000 years ago. It also leaves no doubt that Noah's flood must have occurred prior to 40,000 years ago. Therefore, key components of all young-earth creationist models are undeniably incorrect.

#### No Reasons to Doubt

Young-earth creationists are correct in saying that no single background issue or contaminant source fully accounts for all the carbon-14 found in samples of coal, diamonds, and fossils. However, no one or two contributors alone account for the carbon- 14 background or contamination in carbonaceous samples. Fourteen contributors do, and, in addition to these known factors, several other yet-to-be- discovered factors may also contribute. The combination of fourteen or more factors readily adds up to a carbon-14 abundance that is sufficient to explain why million- or multi-million-year-old samples would appear—by this particular measuring technique—only about 55,000 years old.

# Accuracy of Earth's Age

As noted earlier, no age measurement, radiometric or otherwise, is absolutely accurate. Uncertainties, both statistical and systematic, are unavoidable. For carbonaceous samples older than 40,000 years, the uncertainties in the carbon- 14 dates can be quite large. As explained, these uncertainties make precise dating of any carbonaceous samples older than 55,000 years impossible. All that can be done is to establish *lower* age limits to such samples. Young-earth creationists are mistaken when they claim that carbon-14 dating establishes *upper* limits to such samples' ages.



Determining the age of the earth is an entirely different matter. Rather than just one radioisotope clock at researchers' disposal, four are readily available. For all four, the statistical and systematic errors are minuscule. The background and contamination factors are orders of magnitude smaller than the statistical errors. The statistical errors are small because the half-lives of the four clocks are all close to Earth's age. The end products (daughter isotopes) of the radiometric decay in these four clocks are isotopes that arise from no source other than radiometric decay—with the rare exception of insignificant contributions from neutron bombardment. While some of this radiometric decay occurred before the formation of Earth, the ratios of the radioisotopes and their daughter isotopes relative to one another reveal the amounts of such decay.

The four radioisotope "clocks" are uranium-235, uraniuim-238, thorium-232, and potassium-40. The decay products of these four "clocks" are lead-206, lead-207, lead- 208, and argon-40, respectively. Thus, any sample that contains measurable amounts of uranium-235, uranium-238, thorium-232, potassium-40, lead-206, lead- 207, lead-208, and argon-40 yields eight independent measurements of the sample's age. While not all eight are measurably present in all rock samples known as building blocks for Earth's formation, at least six usually are.

Lead is very dense. Thus, very little, if any, diffuses into or out of a sample. In rare instances where a trace of lead does escape from a sample, the ratios of the different lead isotopes relative to one another reveals the three different rates of escape and, therefore, provides accurate correction factors. From the abundances of various lead isotopes relative to other non-radioactive isotopes in rock samples (those devoid of thorium and uranium), scientists can determine the original quantities of lead isotopes in Earth's primordial crust and mantle.

Ratios of uranium-235, uranium-238, and thorium-232 relative to one another and relative to the lead end-products—along with the ratios of the various lead end products to one another—provide six consistent dates for the oldest crystals in Earth's crust. These dates, thus, give us a measure of Earth's age.

Geophysicists have found zircon crystals in Earth's crust with measured abundances of uranium, thorium, and lead isotopes all bearing witness that these crystals formed between 4.4 and 4.1 billion years ago.<sup>46</sup> Researchers have also found primitive meteorites—Earth's primordial building blocks— that contain measurable amounts of uranium-235, uranium-238, thorium-232, lead-208, lead- 207, lead-206, amounts that consistently indicate Earth's age to be 4.5662±0.0001 billion years.<sup>47</sup> The error bar here includes both the statistical and systematic uncertainties.

With an atomic weight of 40, very little argon escapes Earth's atmosphere. The amount of argon-40 in Earth's atmosphere matches what would be expected from 4.5 billion years of potassium-40 decay. The quantity of argon-40 in the Moon's atmosphere and Mercury's atmosphere is likewise consistent with these bodies being 4.5 billion years old.

#### **Response to Rebuttals**

Young-earth creationists aware of the potency of these measurements in establishing that Earth's age respond to them by pointing to the amount of helium in primordial zircons and primitive meteorites. They say this quantity is inconsistent with the conclusion that these samples are billions of years old.



While it's true that helium is one of the end products of uranium-235, uranium-238, and thorium-232 decay, physicists have rejected helium as a useful chronometer for many reasons. For one, helium is the second most abundant element in the universe. It comprises 25 percent of the cosmos's ordinary matter, and more than 90 percent comes from sources other than radiometric decay.

Additionally, helium is, by far, the most slippery of all elements in the periodic table. It easily slips into and out of natural containers such as crystals, rocks, atmospheres, comets, and meteorites. It escapes or enters both thermally and nonthermally. It ranks as the worst chronometer among all the elements in the periodic table. For these reasons and more, physicists view helium as a completely useless and unreliable chronometer.

As the two-volume report from the RATE project repeatedly states, escaping the conclusion that Earth is 4.57 billion years old is impossible—unless radioisotope decay happened to accelerate by a factor of at least a million times when Adam sinned against God or when Noah's flood occurred, or both. As demonstrated earlier, the Bible, the astronomical and geological records, and the survival of Earth's life from the creation of Adam onward effectively rule out such a vastly accelerated radioisotope decay.

Biblically and scientifically no reasonable doubt about the unchangeable nature of the laws of physics remains. Neither, therefore, does any reasonable doubt that the universe and Earth must be very much older than young-earth creationists claim.

#### **Reliability of Cosmic Age**

Multiple radioisotope-dating methods deliver a consistent date for the age of the universe. These methods focus on dating the universe's oldest stars. Because it takes time for the universe to expand sufficiently to allow for the formation of stars, radioisotope dating can provide a *lower* limit for the universe's age. This limit shows us that the universe must be at least 13.5 billion years old.

Two methods yield actual age measures for the universe. One makes use of the angular size of the various hot and cold spots in maps of the cosmic microwave background radiation (the radiation remaining from the cosmic origin). The other is based on observable cosmic expansion rates. The first method is overly technical for most readers and is most clearly described in *The Creator and the Cosmos*, 4th edition.<sup>48</sup> The second method is a simple, assumption-free method.

When astronomers observe galaxies at different distances, they note that the more distant the galaxies, the closer they are to one another and the faster they are moving away from us. These observations tell us that the universe has been continually expanding from the cosmic creation event. By accurately measuring the distances to galaxies and the rate at which galaxies are moving away from Earth, astronomers obtain an assumption-free measurement of the universe's age. The equation is straightforward: Age = Distance/Cosmic Expansion Rate. Astronomers have measured the distance of several million galaxies ranging from a few million light-years distant to 13.4 billion light- years distant. These measurements leave no doubt that the universe is roughly 13.8 billion years old. The best cosmic expansion rate measurements combined with maps of the cosmic microwave background radiation hot spots and cooler spots allow us to determine that the universe =  $13.791\pm0.021$  billion years.<sup>49</sup>



#### **Appearance of Age?**

In the face of the compelling evidence for an ancient universe, some young- earth creationists argue that God could have created the universe with the mere appearance of age. They suggest that God artificially altered the age markers of bodies in the universe, making them all appear old when, in fact, they are all young. The problem here is that not all astronomical bodies look old. Some clearly appear to have been newly formed. Others measure to be just a few hundred or a few thousand years old. Many others have features that indicate they are several millions of years old. Then there are bodies with features that show them to be as old as 13.6 billion years old. Astronomers observe a continuous range of ages among objects in the universe, a range that runs from slightly more than 0 years old up to 13.6 billion years.

These observations raise a question. Why would God selectively add age markers that run continuously from less than 1 year to 13.6 billion years if indeed the universe were less than 10,000 years old? The only answer is that he intended to deceive us about the true age of the universe. However, Hebrews 6:18 declares, "It is impossible for God to lie." Numbers 23:19 states, "God is not human, that he should lie." 1 Samuel 15:29 proclaims, "He who is the Glory of Israel does not lie." These and other passages of Scripture would clearly negate such a possibility.

## No Scientific Debate

Even a cursory survey of the peer-reviewed scientific literature shows that research scientists will and do vigorously debate scientific issues where the possibility for debate exists. For example, even though Einstein's theories of special and general relativity have been exhaustively and rigorously tested and have passed every test with flying colors,<sup>50</sup> sometimes to twenty places of the decimal, astronomers and physicists continue to develop and propose alternate theories that could conceivably be applicable in those rare instances where still higher- precision tests may yet be performed.

Some scientific issues, though, are no longer debated. No one in the peer- reviewed scientific literature seriously claims, based on scientific evidence, that Earth is flat. Neither is there any serious mention of scientific evidence for the universe and Earth being younger than some millions of years old.

Over the past four decades, not one of the doctoral-level scientists and engineers I've met who holds to a young-earth creationist perspective came to that view based on science. Nor could any name even one research scientist or engineer who, without any precommitment to a particular Bible interpretation, came to believe that either the universe or Earth was younger than a million or more years old.

This concession was made publicly on a radio program called *Bible on the Line*, airing on KKLA in North Hollywood, California, on December 6, 1987. The host and lawyer, John Stewart, interviewed John Morris, who held a doctorate in engineering geology and later became the president of the Institute for Creation Research (ICR). Their topic that day: the age of the Earth. The question Stewart posed to Morris near the interview's end was whether he (Morris) or any of his associates had ever known or know of a scientist who became persuaded that the universe or Earth is only thousands of years old based on scientific evidence alone—and apart from reference to a particular interpretation of the Bible. To his credit, Morris answered honestly with an unequivocal no. The same was the case when Steward interviewed the one-time vice president



of the ICR, Duane Gish. He, too, answered Stewart's question with an unequivocal no.

#### Not a Core Tenet

The three largest young-earth creationist organizations (Answers in Genesis, Institute for Creation Research, and Creation Ministries International) all claim belief millions of years for the universe, Earth, and Earth's life is *the* key underminer of the Christian faith today. In 2010, Ken Ham, president of Answers in Genesis and his colleague Terry Mortenson wrote, "Belief in millions of years (1) contradicts the clear teaching of Scripture, (2) assaults the character of God, (3) severely damages and distorts the Bible's teaching on death and (4) undermines the gospel by undermining the clear teaching of Genesis, which gives the whole basis for Christ's atonement and our need for a Redeemer."<sup>51</sup>

A Matter of Days, 2nd edition, offers a refutation of all four of these claims.<sup>52</sup> Of utmost importance is the observation that none of the Christian creeds includes any reference to or statement about the age of the universe or Earth. In the early church fathers' 2,000+ pages of commentary on the Genesis creation texts, the focus remained squarely on who the Creator is and on what and how he created. No more than 2 pages address the timing of God's creation. Nothing in these pages suggests the need for dogmatism regarding a date for the beginning of God's creative work.

#### An Issue for Biblical Inerrancy

In their book *Coming to Grips with Genesis*, young-earth creationists Terry Mortenson and Thane Ury assert that the 88 affirmations and denials in the Chicago Statements published by the International Council on Biblical Inerrancy<sup>53</sup> are "inadequate." They propose an additional set of affirmations and denials based on their specific interpretation the Genesis text.

For example, these authors want to add that the creation days must be 24-hours and to deny that "day" (in Hebrew) could have any other meaning.<sup>54</sup> They want to add that Adam's sin resulted not only in the death of humans but in the death of all animals and that the millions of years of geological and life history never happened.<sup>55</sup> What's more, they insist that the flood of Noah's time was a global and extremely catastrophic event responsible for virtually all Earth's fossils and all Earth's geological features.<sup>56</sup> According to their view, these additional affirmations and denials "are explicitly taught or implied by Holy Scripture."<sup>57</sup>

The great irony here is that a literal, historical, consistent interpretation encompassing all the biblical texts addressing creation, science, and Noah's flood—not just those in Genesis— contradicts the new affirmations and denials Mortenson and Ury have proposed and that several other young-earth creationist leaders have signed. As explained in the book *Rescuing Inerrancy*, biblical inerrancy cannot be defended from a young-earth perspective.<sup>58</sup> Psalm 95 and Hebrews 4, for example, indicate that God's seventh day (Genesis 2:1–4) continues throughout the entirety of human history. There is no "evening was, morning was" phrase for God's seventh day in Genesis 2 because the seventh day is not yet finished. God's sabbath rest continues, and we're invited to enter his rest. Another passage, Psalm 104 (a creation song), indicates that God established a cycle of animal extinction and replacement, prior to creating humanity.

#### **An Apologetics Issue**

While the age of Earth or the universe is not a salvation issue, it's a significant issue for proclaiming and defending the reliability of the Bible among thoughtful non- Christians. As the



demonstrably truthful Word of God, it deserves our attention and warrants our trust. We have sound reasons to believe and receive God's offer of redemption in Jesus Christ, as revealed in the Bible's pages. As Augustine of Hippo wrote fifteen centuries ago,

Usually, even a non-Christian knows something about the earth, the heavens, and the other elements of this world, about the motion and orbit of the stars and even their size and relative positions, about the predictable eclipses of the sun and moon, the cycles of the years and the seasons, about the kinds of animals, shrubs, stones, and so forth, and this knowledge he holds to as being certain from reason and experience . . .

If they [non-Christians] find a Christian mistaken in a field which they themselves know well and hear him maintaining his foolish opinions about our books, how are they going to believe those books in matters concerning the resurrection of the dead, the hope of eternal life, and the kingdom of heaven, when they think their pages are full of falsehoods and on facts which they themselves have learnt from experience and the light of reason?<sup>59</sup>

The book of Acts records James's appeal to the Jerusalem Council of apostles and elders: "We should not make it difficult for the Gentiles who are turning to God" (Acts 15:19). In response to this exhortation, the Jerusalem Council sent a letter to all the first century churches, encouraging them to avoid putting unnecessary stumbling blocks in the path of Gentiles who want to know God and form a relationship with him.

Likewise, we Christians in the twenty-first century would do well to avoid putting unnecessary stumbling blocks (in our case, young- earth creationism) in the path of scientists, engineers, and other educated people who need to know that they can trust what the Bible says about who God is and the gift he offers them, through Jesus Christ.



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