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SCIENCE & MORMONISM SERIES 1

COSMOS, EARTH, AND MAN

DAVID H. BAILEY, JEFFREY M. BRADSHAW, JOHN S. LEWIS,
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FROM ALL ETERNITY TO ALL ETERNITY: DEEP TIME AND THE GOSPEL

Bart J. Kowallis

*Now for this cause I know that man is nothing, which thing I never had supposed.*¹

Like Moses, I often feel my own nothingness when compared to the greatness of God and His creations. In his face-to-face encounter with God, Moses was told that “worlds without number have I created”² and that “there are many worlds that have passed away ... and many that now stand, and innumerable are they unto man.”³ Not only were the worlds that God created innumerable but the heavens as well.⁴ With this revealed understanding of the enormity of God’s creations, I am never troubled by the idea of deep time.⁵

Deep time is also called “geologic time” and refers to the vast length of time scientists have determined it took for the earth and the heavens to arrive at their current form and station. Imagine with me for a moment a movie with perhaps a catchy title like “Earth: The Movie” and that this movie shows the entire history of the earth from its creation to the present day. The producers have reduced each year of earth history down to one second of movie time. So, being an interested student of natural history, you grab a jumbo popcorn and a caffeine-free diet Coke and join a throng of others for the opening night release of the movie. After watching for the first couple of hours, you begin to wonder how much longer this movie is going to last, and in spite of the severe social consequences, you pull out your phone and make a quick calculation. Hmm — 60 seconds in a minute, 60 minutes in an hour, 24 hours in a day, and 365.25 days in a year gives you 31,557, 600 seconds in a year. So that means if the producers reduced earth’s history to one second for each year, and the earth is 4.6 billion years old, then this movie is going to be playing for



Carina Nebula As Seen from the Hubble Space Telescope, 2010

about 146 years! At that point you decide you'd better get up and get a refill on your popcorn and soda.

So how do we reconcile such long periods with our religion? In both science and religion we rely on faith in our beliefs to guide us and help us interpret the world. In our LDS faith, the Prophet Joseph Smith laid down the thirteen articles of faith⁶ that succinctly provide us with a snapshot look at our foundational beliefs. I like to summarize in a similar way the basic faith and beliefs of scientists in what I call the scientist's articles of confession and belief. These are:

1. We confess that nothing in science is ever absolutely proved. Absolute proof requires us to have no room for error, no approximations, no tests left undone, no possibility of future modification. Science never reaches this point, no matter what the principle happens to be. Neither gravity nor motion nor relativity nor deep geologic time has been proven in an absolute sense. But simply because they have not reached the level of absolute proof does not mean that they are not useful. As far as we have been able to determine, they are true.

2. We confess that all scientific laws and theories are based upon assumptions and approximations. Even though our scientific laws and theories are based upon assumptions and approximations, we use them because they work. Newton's laws of motion and gravity are approximations that work well enough for us to plan,

plot, and send rockets to the Moon, to Mars, and to the farthest corners of our Solar System. An exact answer in most scientific problems is unattainable, but our approximate answers can still get us close enough to the exact answer to be very useful.

3. We confess that science cannot answer the ultimate question of “why?” For example, why do two objects attract one another? We might answer that they attract because of gravity. But why is there gravity? We might respond that there is gravity because the objects have mass and that masses create a kind of depression in the fabric of space and time into which nearby objects will fall. But why? Why do objects with mass affect space and time in this manner? We don’t know. They just do. The beautiful thing in science is that no matter how many questions we answer, there are always more that are unanswered for us to investigate.

4. We claim that the first principles and assumptions of science are: first, faith in the existence of the physical universe; second, requisite causes for all events; third, between two contrary positions, only one can be true; and fourth, laws of nature apply equally to all people and objects.

These are some of the basic assumptions of science, none of which we can prove, but which appear to be true based upon numerous observations and tests. Here are a few more of our fundamental assumptions.

5. We believe that the same principles of science apply in all directions and all places, whether we are located high or low, far or near, east or west, in Provo or Salt Lake City.

6. We believe that all men will find the principles of science to be the same whether they be at rest or in motion; indeed we claim that motion itself can only be measured in a relative sense; that is to say, there is no absolute motion.

7. We believe that the principles of science are the same today, yesterday, and forever, that they are unaffected by the passage of time.

I will stop there. That is not quite as many articles as the Prophet Joseph laid out for our faith, and more could probably be added to this list. However, these will suffice for our discussion here, where I will focus my remarks primarily upon the last one: our belief that the principles of science are the same today, yesterday, and forever. In my field of geology, this idea has been called “uniformitarianism,”⁷ a somewhat unfortunate term that sounds a bit like a religious sect. Physicists call the idea “time symmetry.”

Time Symmetry and the Age of the Earth

In geology, the idea that time was long and deep originated with James Hutton, a Scottish gentleman-farmer, who was one of the first to see the earth and its processes through the lens of time. In 1788, his *Theory of the Earth* was published by the Royal Society of Edinburgh.⁸ This paper included two key ideas that continue to shape the way scientists think about time and about the earth. First, Hutton stated, “In examining things present, we have data from which to reason with regard to what has been; and, from what has actually been, we have data for concluding with regard to that which is to happen hereafter. Therefore, upon the supposition that the operations of nature are equable and steady, we find, in natural appearances, means for concluding a certain portion of time to have necessarily elapsed, in the production of those events of which we see the effects.”⁹

In summary Hutton was proposing that the processes and systems which operate on the earth today also operated in the past and that as we try to interpret the history locked up in earth’s rocks, we should use modern processes and systems to guide our interpretations and to understand the time required to accomplish the tasks. The idea was popularized by the phrase: “The present is the key to the past.”¹⁰

Hutton’s second landmark contribution was the idea that the history of the earth was endless. He proposed that, “Time, which measures every thing in our idea, and is often deficient to our schemes, is to nature *endless* and as nothing; it cannot limit that by which alone it had existence; and as the natural course of time, which to us seems *infinite*, cannot be bounded by any operation that may have an end, the progress of things upon this globe, that is, the course of nature, cannot be limited by time, which must proceed in a continual succession.”¹¹ Hutton’s paper ended by reaffirming this belief in the unlimited nature of time, stating that, “The result, therefore, of our present enquiry is, that we find no vestige of a beginning — no prospect of an end.”¹²

In the late 1700s Hutton’s ideas were not well received by the religious community. In their book *The Discovery of Time*, Tolmin and Goodfield proposed that the “bitterness and virulence aroused” by Hutton’s ideas were related to the aftermath of the French Revolution when the “impiety and free thought common among French intellectuals” before the revolution had been met with terror and brutality by the revolutionaries.¹³ In Great Britain, Hutton was criticized by chemist and naturalist Richard Kirwan, president of the Royal Irish Academy. Kirwan defended a strict interpretation of the Bible and applied this interpretation to earth events.¹⁴ Interestingly, Kirwan’s classical view of God as “from all eternity . . . to all eternity” with no beginning and no end¹⁵ resonates with Hutton’s “no vestige of a beginning, no prospect of an end.” But that was as far as their agreement would go. Kirwan, obviously referring to Hutton’s ideas, said, “The existence of the world, say [the scholastics], is eternally possible; . . . their inference, that the [creation], resulting from an eternally omnipotent cause, could also be eternal is inadmissible, as causation essentially requires priority of existence.” The physical creation, Kirwan



James Hutton, 1726 - 1797. Geologist, 1776, Henry Raeburn (1756–1823)

goes on to say, “implies, at least, an instant, in which the created ... did not exist: otherwise existence could not have been bestowed upon it.”¹⁶

Today, we would agree with Kirwan and not Hutton on the idea that the earth has no “vestige of a beginning nor prospect of an end,” for it appears that the earth definitely had a beginning, but we would side with Hutton in his idea of using the physical laws and processes that are observed operating on the earth today as the means to understand the past and that, by using those physical laws and processes, the age of the earth appears to be incredibly old.

Determination of the Earth’s Age

Over the years since Hutton’s time, scientists have tried a number of methods to determine the age of the earth. One of the earliest attempts to arrive at a non-biblical age for the earth actually came a decade before Hutton. It was made by French naturalist Georges-Louis Leclerc, also known as le Comte de Buffon in 1779.¹⁷ Buffon reasoned that the earth had cooled from an initial hot sphere, and using experiments on a small sphere of hot iron, he determined that it would have taken about 75,000 years for the earth to reach its present state and temperature.

Using similar reasoning but starting with a molten earth, Lord Kelvin (at the time still called William Thomson) in 1862 determined an age of 20 to 400 million years for the earth to cool to its present state.¹⁸ He later refined his estimate to somewhere between 20 and 40 million years. Although this estimate was quite a

bit older than what Buffon had determined, it was much too young for Hutton's followers.

Another early attempt at determining the earth's age was made by John Joly and published in 1899, using the idea that salt accumulated at a constant rate over time into the oceans.¹⁹ Joly was an Irish geologist, mineralogist, and inventor who is best known for his pioneering efforts at treating cancer with radiation.²⁰ Actually it was Edmund Halley, most famous for his astronomy studies, who proposed, even before Hutton's time, that the age of the ocean might be determined by its saltiness.²¹ But Halley never made the actual calculation of the earth's age using this method. Joly did. Joly arrived at an age of 100 million years, substantially older than the 20-40 million proposed by Lord Kelvin, but still too young for many geologists, biologists, and other naturalists.²² The problem with Joly's calculations was that they did not take into account the removal of salt from the ocean to form thick layers of salt that have been documented in many places in the geologic record.²³

Radioactivity, discovered and studied in the late 1800s and early 1900s by Henri Becquerel, Marie and Pierre Curie, Ernest Rutherford, and Frederick Soddy, was recognized early by some scientists as an internal source of heat that would keep the earth from cooling at the rate determined by Lord Kelvin.²⁴ By 1907, American chemist Bertram Boltwood, in a series of papers published in prestigious journals, outlined the use of radioactivity in determining the ages of rocks and minerals as uranium decayed through several steps to form lead.²⁵ He found ages as old as 2.2 billion years for some samples. At the time the work was oddly "met with indifference," and most geologists discounted the effect of radioactivity on the earth's age and temperature.²⁶ Englishman Arthur Holmes, however, championed the idea and was for the next two decades almost the only scientist who persevered in studying the use of radioactivity as a dating technique.²⁷ The evidence accumulated by Holmes and a few others eventually became too much for the scientific community to ignore, and the use of radioactive decay to determine the ages of earth events became the common practice.

Myths about Earth's Age and Creation

So how have these ideas about time and creation been received by LDS Church leaders? To examine this history, I would like to discuss ideas about time by looking at what I call the "Myths about science."

Myth #1: Scientific Theories are Just Speculation; Since They Are Not Facts, I Don't Need to Believe or Worry About Them

Every myth usually has some truth mixed with varying amounts of fantasy. This myth, which I find very prevalent among my students and the general public, has this grain of truth: no one has to believe anything he or she does not want to believe. But those who choose not to believe the theories of science should at least understand what is meant by theory. In science a theory is quite different from a

hypothesis. A hypothesis is an idea, a question, a speculation, or a possibility, with very little data to back it up. Hypotheses give direction to our research and help us continue to expand the frontiers of knowledge by providing us with challenges and questions to answer. My impression is that most nonscientists do not distinguish between a hypothesis and a theory.

A theory is quite different. A theory is not just speculation, even though the word is often used in conversation in this manner. Someone might say, “I have a theory that the football team would play better if they just drank more pickle juice.” Among scientists this would be a hypothesis, not a theory. To make it into a theory, data would need to be collected in very carefully constructed tests. This data would then be examined and analyzed to look for patterns and trends. The tests would then need to be duplicated by other scientists working with other football teams, and eventually a soundly reasoned explanation, based on all the available evidence and data, would be constructed. This would then become a model or theory and might be given a name like “The Pickle Juice Theory” or something equally catchy.



Rewriting the Law of Gravity, 2012, John Cole

Scientific laws are no different; they are really just impressive theories. The Law of Gravity, for example, is an explanation for why objects are attracted to each other. It could just as easily be called the Theory of Gravity. You do not have to believe in the Theory of Gravity, and indeed there are still scientists who are questioning this theory and suggesting that perhaps it needs to be modified.²⁸ However, I would recommend it to you as a very good explanation for many physical phenomena — an explanation that you probably do not want to ignore if you plan to have an active life.

So, when scientists say “theory,” they mean a well reasoned explanation that satisfies all or most of the available data and has been demonstrated to work. That is why we use them. They work. Does this mean our theories or laws will never be modified or changed? Certainly not. Anytime new, reliable, reproducible data or observations appear that do not fit the explanations, the theories must be looked at again and modified. In the end we keep the explanations that work and discard those that do not.

In our context here, the theories that explain radioactive decay and the use of radioactive elements as clocks are some of the most widely tested and tried explanations in science. They have been demonstrated to work in many places and under many different conditions.²⁹ Do you have to believe them? No. Just as I said

earlier with the theory of gravity, you are free to believe whatever you want, but you should understand that by rejecting the theory you are rejecting something that has been demonstrated to work based on years of scientific data and careful scientific review. In the context of the LDS Church, I personally do not believe there is any conflict between the theories of radioactive decay and gospel doctrine. There is, however, in some quarters, the perception that an old earth would violate church doctrine. This is the next myth I wish to discuss.

Myth #2: Official LDS Church Doctrine Is That the Earth Is Only a Few Thousand Years Old

I have not found any official statement by the First Presidency on the age of the earth. However, many individuals, including a number of LDS scientists and writers as well as several General Authorities, have made statements about its age. This is indeed a case of where, if you want to rely on someone else's answer, you can pick your favorite, because the statements of LDS authorities and scientists vary widely. I will briefly outline here a few of the writings and statements made on this issue.

Statements That Are Supportive of or Neutral about an Old Earth

In January 1844, at the time Joseph Smith was prophet, a letter from W.W. Phelps to William Smith was published in the *Times and Seasons* that included the interesting statement:

Eternity ... has been going on in this system, (not this world) almost two thousand five hundred and fifty five millions of years: and to know at the same time, that deists, geologists and others are trying to prove that matter must have existed hundreds of thousands of years.³⁰

Phelps apparently arrived at this number by equating the 7 days of creation to 7,000 years on Kolob and calculating that one Kolob year of 365 days was equivalent to 365,000 earth years, giving a total of 2.555 billion years.³¹ Apart from the somewhat unusual idea of trying to put an age on eternity, this passage suggests that the idea of an old creation (of at least 2.555 billion years) for our "system," as Phelps called it, was not foreign to the early members of the Church.

The Prophet Brigham Young, in a discourse delivered in the Tabernacle in Salt Lake City on May 14, 1871, stated:

We differ very much with Christendom in regard to the sciences of religion. Our religion embraces all truth and every fact in existence no matter whether in heaven, earth, or hell. ... The Lord is one of the most scientific men that ever lived; you have no idea of the knowledge that he has with regard to the sciences.³²

In this same address President Young said:

Our religion will not clash with or contradict the facts of science in any particular. You may take geology, for instance, and it is a true science; not that I would say

for a moment that all the conclusions and deductions of its professors are true, but its leading principles are; they are facts — they are eternal. ... As for the Bible account of creation we may say that the Lord gave it to Moses, or rather Moses obtained the history and traditions of the fathers, and from these picked out what he considered necessary, and that account has been handed down from age to age, and we have got it, no matter whether it is correct or not, and whether the Lord found the earth empty and void, whether he made it out of nothing or out of the rude elements; or whether he made it in six days or in as many millions of years, is and will remain a matter of speculation in the minds of men unless he give revelation on the subject.³³

In a later discourse given on September 17, 1876, President Young stated:

It is said in this book [the Bible] that God made the earth in six days. This is a mere term, but it matters not whether it took six days, six months, six years, or six thousand years. The creation occupied certain periods of time. We are not authorized to say what the duration of these days was.³⁴

I do not propose that President Young was advocating here for an old earth of millions of years in age but that he was suggesting that it did not matter and that he was supportive of science in general.

B. H. Roberts, member and president of the First Council of Seventy, wrote on many topics including the age of the earth. He wrote in 1924 that:

While the Bible may teach that it was only about six thousand years since man was placed upon the earth, how long it required to prepare this planet with all its wealth of fruits and vegetables and animal life, for the abode of man, is not known.³⁵

Roberts added that the days of creation were not twenty-four-hour days, but “great periods of time.”³⁶

On 9 August 1931, Apostle and former professor of geology James E. Talmage delivered an address in the Tabernacle entitled, “The Earth and Man.” The talk was later printed in full in the *Deseret News*.³⁷ Talmage’s oft-quoted statement that, “The opening chapters of Genesis and scriptures related thereto were never intended as a textbook of geology, archaeology, earth-science, [or man-science] ... We do not show reverence for the scriptures when we misapply them through faulty interpretation,”³⁸ is similar to Galileo’s statement in 1613 in his *Letter to Castelli*: “Scripture deals with natural matters in such a cursory and allusive way that it looks as though it wanted to remind us that its business is not about them but about the soul ...”³⁹

President David O. McKay, in a speech given at BYU in October 1956 while he was President of the Church, said:

And now I have just time to comment of the opportunity of the BYU to teach these fundamental truths. ... Whatever the subject may be, the principles of the gospel of Jesus Christ may be elaborated upon without fear of anyone’s objecting,



Artist's Conception of Planets Over the Nebulae in Space

and the teacher can be free to express his honest conviction regarding it, whether that subject be in geology, the history of the world, the millions of years that it took to prepare the physical world, whether it be in engineering, literature, art — any principle of the gospel may be briefly or extensively touched upon for the anchoring of the student who is seeking to know the truth.⁴⁰

I do not think that this statement necessarily shows President McKay's personal views on the age of the earth, but it demonstrates that, at least in his mind, there was no issue with those who held that belief.

Apostle John A. Widstoe wrote in his book *Evidences and Reconciliations* in 1960 that the:

word translated day in Genesis really means, in the original, "an age or undefined period of time," and concluded his chapter on the age of the earth by stating that, "Every person must decide for himself, on the basis of the evidence produced, which of these three opinions as to the age of the earth, before Adam, seems most reasonable to him, whether (1) six days, or (2) six thousand years, or (3) many millions of years. Clearly it does not matter to one's daily welfare or ultimate salvation which view he adopts, except that every Latter-day Saint must seek and cherish truth above all else."⁴¹

Dr. William Lee Stokes, professor of geology at the University of Utah and a faithful member of the LDS Church, wrote in his 1979 book *The Creation Scriptures*:

Common sense and a minimum of research should convince anyone ... that God's Days and Nights cannot be the days and nights of human experience. The scriptural account is clear on this point. There could be no ordinary astronomical day-night relationships without a light-giving sun and no sun is mentioned until

the fourth day of creation. It seems to have been the intent of God to commence the designation of creative days even while the earth was without form, certainly before the “firmament” of heaven was created.⁴²

As an Apostle, Elder Bruce R. McConkie, in somewhat of a reversal of his earlier views, wrote in June 1982:

“In six days the Lord made heaven and earth, the sea, and all that in them is, and rested the seventh day” (Exodus 20:11). . . . But first, what is a day? It is a specified time period; it is an age, an eon, a division of eternity; it is the time between two identifiable events. And each day, of whatever length, has the duration needed for its purposes.⁴³

Dr. Henry Eyring, father of President Henry B. Eyring, wrote in his 1983 book *Reflections of a Scientist*:

In my judgment, anyone who denies the orderly deposition of sediments with their built-in radioactive clocks places himself in a scientifically untenable position. . . . I am completely content that there is room in the Church for people who think that the periods of creation were twenty-four hours, one thousand years, or millions of years. I think it is fine to discuss these questions and for each individual to try to convert others to what he thinks is right. It is only fair to warn parents and teachers that a young person is going to face a very substantial body of scientific evidence supporting the earth’s age as millions of years and that a young person might ‘throw the baby out with the bath’ unless allowed to seek the truth, from whatever source, without prejudice.⁴⁴

Dr. Sterling B. Talmage, son of Apostle James E. Talmage and a professor of geology, wrote in his 2001 book, *Can Science Be Faith Promoting?* that, “As one who believes in God ‘from all eternity to all eternity,’ I object to any attempt to wrest the scriptures so as to crowd all of his terrestrial activities into a week.”⁴⁵

Statements That Are Opposed to an Old Age for the Earth

In 1878 Apostle Orson Pratt said:

Geologists may study, year after year, all the best works they can obtain, concerning the geological phenomena of our globe; they may speculate and say, the earth is several millions of years old, founding their speculations upon geological appearances; they may say, that it must have passed through successive changes for millions of years. But after all, what do they really know?⁴⁶

In 1954, then Apostle Joseph Fielding Smith wrote in his book *Man: His Origin and Destiny* that the scriptures were clear that the days of creation were celestial days of one thousand years and that the earth is now passing through another celestial week of its mortal existence.⁴⁷ He cites scripture and statements by the Prophet Joseph Smith in support of this interpretation.

Elder Bruce R. McConkie, in the 1966 version of his book, *Mormon Doctrine*, stated on the subject of the age of the earth:

Evolutionary theories assume that hundreds of millions of years were involved, first in the creation of the earth as a habitable globe, and again in the evolution of spontaneously generated, single celled forms of life into the complex and multitudinous forms of life now found on its face. We have rather specific scriptural indications that the creative period was of relatively short duration. The record says: "It was after the Lord's time, which was after the time of Kolob" (one day on which planet is equal to a thousand years of our time); "for as yet the Gods had not appointed unto Adam his reckoning" (Abraham 5:13). However, for our present purposes, it is sufficient to know that the time element since mortal life began on earth is specifically and pointedly made known. We are now nearing the end of the sixth thousand years of this earth's "continuance, or its temporal existence" (D&C 77:6), and the millennial era will commence "in the beginning of the seventh thousand years" (D&C 77:12). That is, we are approaching the end of the sixth of the periods of one thousand years each, all of which periods have occurred since the fall, since the earth became temporal, since it gained its telestial status, since it became the natural earth that we know, since death and mortality entered the scene. Thus the period during which birth, and life, and death have been occurring on this earth is less than 6,000 years.⁴⁸

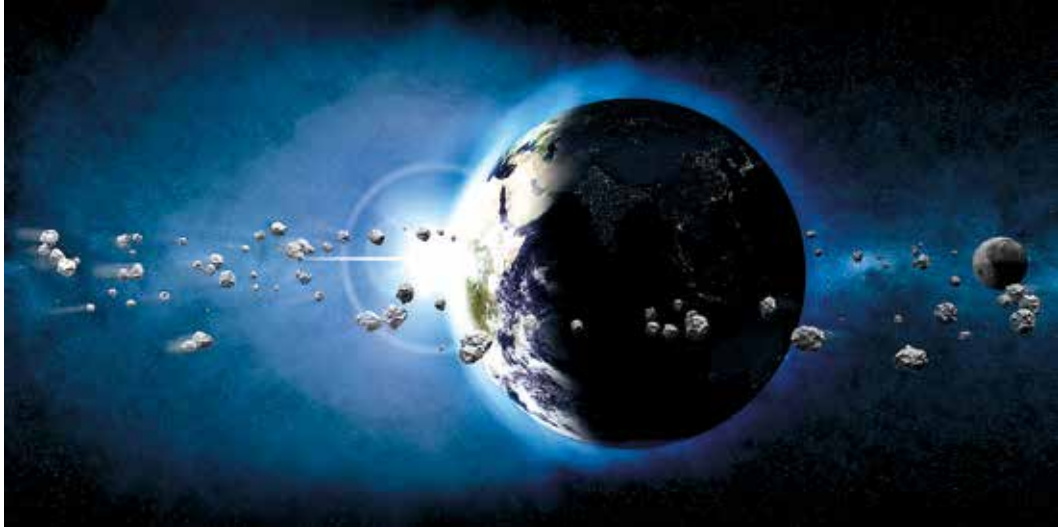
Dr. Melvin A. Cook and M. Garfield Cook, a father and son team of two LDS scientists who founded the IRECO Chemical Company, wrote a lengthy defense in support of a young earth in their book, *Science and Mormonism*, in 1967.⁴⁹ Although neither of the Cooks were trained as geologists or geochronologists, they both had degrees in science fields.⁵⁰

Certainly we can see that among faithful LDS scientists and Church leaders there is ample room for differences of opinion on the subject of earth's age. My personal views are that the earth is very old, and I see no reason why that view is in any way at odds with my firm belief in God, His creation, and the doctrines of the gospel.⁵¹

Myth #3: The Earth Is Old Because It Was Made From Pieces of Older Planets

In 1841 William Clayton, the Prophet Joseph Smith's private secretary, reported that the prophet said: "This earth was organized or formed out of other planets which were broke up and remodeled and made into the one on which we live."⁵² Later, the Prophet Joseph in the King Follett discourse stated that, "the word create ... does not mean to create out of nothing; it means to organize; the same as a man would organize materials to build a ship."⁵³

This was a surprising doctrine for the 1840s and counter to the prevailing view of creation among religions of the time. Even today, creation *ex nihilo* is accepted by most Christian sects.⁵⁴ Today, science firmly believes that the earth and indeed our whole solar system was created from the remnants left behind when an earlier star, which most likely had planets of its own, was destroyed in a supernova explosion, an explosion that allowed the formation of elements heavier than iron.⁵⁵ So the Prophet Joseph was not only ahead of his time theologically but scientifically as well.



Artist's Conception of Earth with Rising Sun and Asteroid Belt

Apostle Orson Pratt extended Joseph's idea to explain the old ages being proposed for the earth. In a discourse given in 1876 he said:

Geologists pretend to say that this earth must have existed many millions of years. ... We will go further than geologists dare to go, and say that the materials of which the earth is composed are eternal, they will never have an end. ... We are willing, for the sake of argument, to admit that the materials themselves are as old as geologists dare to say they are; but then, that does not destroy the idea of a God, that does not destroy the idea of a great Creator, who, according to certain fixed and unalterable laws, brought these materials, from time to time, into a certain organization.⁵⁶

I would agree with Elder Pratt that the old ages proposed by geologists do nothing to destroy the idea of a great Creator; however, I would disagree with his explanation for these old ages. I have heard this idea used in LDS settings to explain the fossils found in earth's rocks. These ideas do not hold up under the scrutiny of a careful analysis of the available evidence. All of the evidence gathered from studying the earth indicates that its surface was molten and very hot early in its history. These conditions would have destroyed any fossils (if by some miracle they had survived the supernova that wiped out the earlier star system), and the heat and molten nature of the surface would also have reset any radioactive clocks to zero. The radioactive clocks used by scientists are more like stopwatches than clocks. They start when a rock or mineral cools to a certain temperature and can be reset to zero if they are reheated. We call the temperature at which minerals begin to accumulate "time" as their "closure temperature."

Different minerals and different radiometric methods have different closure temperatures ranging from more than 900° C. for the uranium-lead method — using the mineral zircon — to less than 100° C. for the fission-track method using the mineral apatite.⁵⁷ The value in minerals and systems that are sensitive to different temperatures is that we can use a variety of these methods to help us construct a

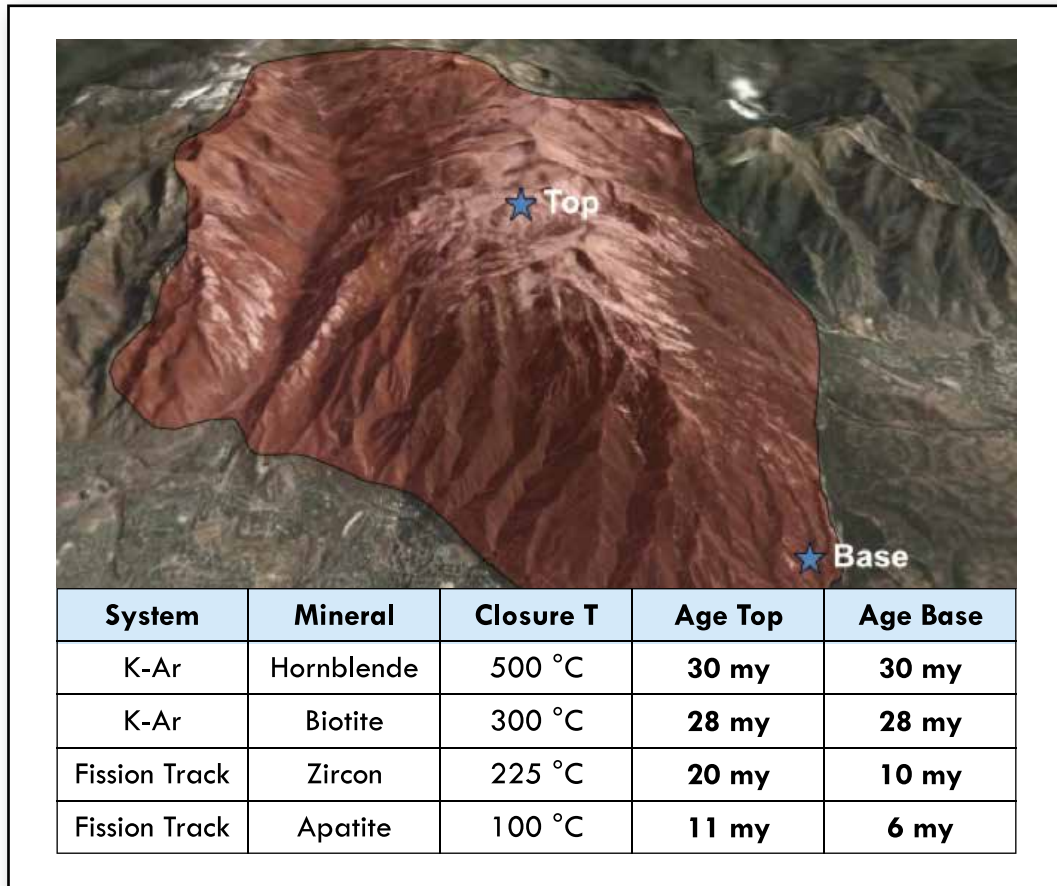
CLOSURE TEMPERATURES FOR SOME ISOTOPIC DATING SYSTEMS

System	Mineral	Closure T - °C
U-Pb	Zircon	>900
K-Ar	Hornblende	500
K-Ar	Biotite	300
Fission Track	Zircon	225
Fission Track	Apatite	100

thermal history of a rock, and by knowing its thermal history, we can infer the timing of different events in its past.⁵⁸

Let me use as an example the Salt Lake Temple granite, called by geologists the Little Cottonwood Stock. This granite is found in the Wasatch Mountains at the south end of the Salt Lake Valley. The granite crops out along the Wasatch fault at the base of Lone Peak and continues all the way up to the top of that mountain. A few years ago, I had a couple of my students collect samples of the granite from the top to the bottom of the mountain. This granite had already been dated using the potassium-argon method and was found to be approximately 30 million years old using the mineral hornblende and 28 million years old using the mineral biotite.⁵⁹ These minerals have closure temperatures that are fairly high. Since granite melts at about 700° C., these ages seemed to represent times close to but somewhat after the time the granite was emplaced. We extracted two other minerals from the granite samples my students collected: apatite and zircon. These we dated using the fission-track method. The closure temperature for fission tracks is lower than for many other radiometric systems, and we hoped to be able to see how and when the granite had cooled through these lower temperatures. Our results confirmed what others had proposed about the uplift of the Wasatch Mountains along the Wasatch fault — the ages at the top of the mountain were older than those at the bottom. Using the differences in the ages determined from the top and bottom of the mountain, we were able to calculate an uplift rate and cooling history for the mountain.⁶⁰ The Wasatch Mountains near Salt Lake City are rising at an average rate of about 0.68 mm/year. It is this uplift that triggers occasional earthquakes along the Wasatch fault.

So when geologists “date” a rock or mineral, they are not dating the age of the elements, but they are dating thermal events. Therefore, when we find minerals that give very old ages of billions of years, we believe that these ages represent old events. The event could be anything that causes the sample to cool below its closure temperature, such as the eruption of a volcano, the uplift of a mountain, or perhaps



in the case of the oldest ages, the cooling of the earth after its formation. These ages are not the ages of the elements that make up the rocks or the mountains or the earth but rather the ages of events in the earth's history.

Myth #4: Geologists have used carbon-14 to date the age of the earth.

This is a fairly prevalent myth as far as I have been able to determine from my limited sampling of students over the years. I once took a survey of my introductory geology students and asked if carbon-14 had been used to determine the age of the earth, and well over 50% of the class responded in the affirmative. The truth is that carbon-14 is not useful for dating the age of most rocks and certainly not for dating the age of the earth. Carbon-14 has a half-life of about 5730 years.⁶¹ Radioactive isotopes like carbon-14 can be used as clocks over a span of about 10 half-lives; for carbon-14 that would be about 57,300 years. Beyond 10 half-lives there is generally not enough of the isotope left in a material to get a reasonably accurate age. So have geologists used carbon-14 to determine an age for the earth? The answer is no! This method has not been used for this purpose. However, carbon-14 has been used to determine the age of many archaeological sites and some young geological events.⁶²

Today, methods based on the decay of uranium into lead are the foundation of most attempts to determine an age for the earth. The oldest zircons, dated using

this method on rocks found on the earth, come from Australia and have ages of 4.4 billion years.⁶³ Dating of minerals in meteorites, however, gives ages 150 million years older, or about 4.55 billion years.⁶⁴ We do not find rocks on earth that are as old as meteorites because it is very difficult to find anywhere on earth not thermally disturbed since its formation. So most of the events dated using earth rocks are younger than the time the planet first formed.

The use of these radiometric clocks has shown us that the earth does indeed have a beginning — a beginning that happened about 4.55 billion years ago, reaching back into time so deep that perhaps we can understand why Hutton saw “no vestige of a beginning, no prospect of an end.”

But should we worry or lose faith over an old age for the earth? I personally see no reason to do so. My sentiments on the significance of the age of the earth echo those of Dr. Henry Eyring, one of the most respected of LDS scientists. After reviewing the evidence from modern science for an old earth, he wrote in his book, *The Faith of a Scientist*:

Most scientists ... agree on an age for the earth of about four and one-half billion years. On the other hand, the exact age of the earth is apparently of so little import religiously that the scriptures sketch earth history only in the briefest terms. ... Gospel truths which influence our salvation are unaffected by considerations such as this.⁶⁵

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Endnotes

1. Moses 1:10.
2. Moses 1:33
3. Moses 1:35
4. Moses 1:38
5. The issue of deep time or geologic time in relation to the teachings of the LDS Church have been discussed many times and by many different authors. I do not claim to be the first, nor will I, certainly, be the last to discuss this issue. See for a few examples: John A. Widstoe, *Evidences and Reconciliations* (Salt Lake City: Bookcraft, 1960), 146–49; Henry Eyring, *The Faith of a Scientist* (Salt Lake City: Bookcraft, 1967), 89-93; John A. Tvedtnes, “Science and Genesis,” in W. M. Hess, R. T. Matheny, and D. D. Thayer, eds., *Science and Religion: Toward a More Useful Dialogue* (Geneva, IL: Paladin House, 1979), 39-60; Bart J. Kowallis, “Things of the Earth,” in D. L. Clark, ed., *Of Heaven and Earth* (Salt Lake City: Deseret Book, 1998), 29-46.
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26. Badash, "The Age-of-the-Earth-Debate," 96.
27. Ibid.
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His research since coming to BYU has focused on geologic mapping, geochronology, stratigraphy, and structural geology, particularly of the Mesozoic rocks in Utah and Tertiary rocks in Mexico. Since 2001, Bart and his students have concentrated their efforts in mapping and studying the rocks exposed along the south and north flanks of the Uinta Mountains in cooperation with the Utah Geological Survey and United States Geological Survey. He is a member of the American Geophysical Union, the American Association of Petroleum Geologists, the Utah Geological Association, and a Fellow of the Geological Society of America. At BYU he has been honored with several teaching awards: an Alcuin General Education Teaching Award (1986), a Karl G. Maeser General Education Professorship (2003), and a Religion Transfer Professor Award (2015).

In addition to publishing over seventy articles and books on geologic topics, Bart has also published on family history and genealogy, as well as an occasional article on issues of science and religion. He has served in a wide variety of LDS Church callings, including: Elders Quorum President, Counselor in an MTC Branch Presidency, Blazer Leader, Scoutmaster, Young Men President, Ward Mission Leader, Counselor in Bishopric, Bishop, High Councilor, Stake Family History Center Director, Provo Temple Ordinance Worker, and most importantly as a Nursery Worker in the Primary. He is married to the former Julee Clark, and they have four wonderful children and one precious granddaughter.