Chapter 10

Summary of Evidence for a Young Earth from the RATE Project

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Abstract. This chapter summarizes the technical results of the RATE Project and evaluates the significance of the overall project. The main purpose of the RATE Project was to investigate radioisotopic processes and rock-dating methods to determine why the conventional model for the age of the earth is not consistent with a young-earth time frame. The RATE team offers a scientific alternative favoring the thousands-of-years scenario for the age of the earth rather than simply critiquing the conventional billions-of-years scenario. The major result of the project is that nuclear decay processes appear to have been accelerated during brief periods in earth history. Some of the discussion addresses unresolved problems and objections that will likely be raised by critics.

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1. Background

When the RATE group began its investigation of radioisotopes and the age of the earth in 1997 it sought to resolve the conflict between the billions-of-years time frame of the conventional scientific community and the thousands-of-years time frame of the literal Biblical community. Each member of the team recognized that this conflict was a major problem that needed resolution. However, there was no initial agreement on how to approach this issue.

A few in the RATE group believed that the most likely solution lay in studying the rates at which radioactive decay had occurred in the past. If this approach were to be successful it meant that for the earth to be young the decay of parent isotopes and the production of daughter isotopes would have occurred at rates many orders of magnitude greater than they are currently estimated to be. Until the start of RATE few investigators had seriously entertained periods of extremely high rates of decay during earth history.

The concept of so-called *accelerated decay* would be highly controversial and not easily accepted by the scientific community or the public at large without strong supporting evidence. It also meant that global, catastrophic events, possibly even cosmic events, operating at scales and speeds far beyond anything observed today, had occurred during the history of the earth, if the earth is young. Until recently it had not been demonstrated in the laboratory that the rate of nuclear decay could be changed by more than a few tenths of a percent even under extreme temperature, pressure, and chemical conditions [*Bosch et al.*, 1996]. So, the basic hypothesis of this minority view within the RATE group called for supernatural intervention by God to accelerate the decay rate at one or more periods within the mass-space-time continuum of earth history. This suggestion would be highly unpopular in the scientific community. Any reference to supernatural intervention is strictly taboo according to the conventional definition of the scientific method today. Even scientists who are Christians often react negatively to such explanations.

During the first phase of the RATE project when the literature review

was occurring and the research design was being developed, two other basic hypotheses were considered. Although these two hypotheses also had their ultimate source in supernatural action by the Creator, they were thought to have occurred at the very beginning of time or during the early Creation events of the Creation week. Subsequent processes which occurred following the initial supernatural creation by God could be studied by conventional scientific methods and would not be as controversial. The alternative hypotheses were considered in parallel with accelerated decay until the first RATE book was published. They were:

- large initial concentrations of daughter isotopes in the mantle which were mixed into the crust on Day 3 of Creation week, and
- large concentrations of daughter elements produced during Creation week which were later mixed into the crust by the Genesis Flood.

By the time the first book was published by the RATE group [*Vardiman et al*., 2000] the majority of the RATE group had decided that accelerated decay would be the primary research hypothesis, but that the other two concepts should be investigated as well. In fact, the final explanations offered by this study are actually a combination of all three hypotheses. Accelerated decay during several periods of earth history became the primary hypothesis because of the strong physical evidence the RATE group had accumulated that a large amount of nuclear decay had indeed occurred in the rocks themselves after their initial creation. This evidence suggested that most of the decay occurred during Creation week events, but also that a large amount must have taken place during the Genesis Flood. The RATE group considered the possibility that a substantial amount of decay might have occurred during the Judgment in the Garden of Eden, but then it was concluded that the implied levels of radiation and heating would have been so highly destructive to biology at that point in earth history as to render this possibility unlikely. The evidence for these conclusions comes from the physical presence of fission tracks, radiohalos, and residual He in rocks that contain U and other radioactive elements to be discussed shortly. Most creationists who had previously addressed these issues did not fully appreciate the evidences for radioactive decay beyond

the chemical presence of the daughter isotopes themselves. Most believed that the large quantity of daughter isotopes observed today was primarily God's doing during Creation, that is, the concentration of daughter isotopes was non-zero when time began. If this were in fact the case, then the problem could be solved simply by resetting the radioisotope clocks to account for this initial inventory of daughter isotopes. However, the physical evidence argues otherwise.

There are many independent lines of evidence that large quantities of daughter isotopes were formed since Creation and even since the beginning of the Flood! These findings and assertions are major departures from the previously-held understanding in creation science. They not only force creationists to discover a much more complex scenario for the decay of radioisotopes than has been considered in the past, but they also require us to link such an explanation to serious Biblical and scientific constraints. Either accelerated radioactive decay accounts for the large daughter isotope residues in a short period of time, or a large amount of decay occurred at conventional rates and the earth is old. The RATE group now believes that an old-earth concept can be refuted on Biblical as well as scientific grounds, and also offers a plausible explanation of how and when large quantities of nuclear decay occurred in a young-earth time frame.

Before launching into a summary of the technical results, however, a brief discussion needs to be given about why the young-earth time frame is supported by the Bible. The support for this viewpoint is fully presented in several sources such as **The Genesis Flood** [*Whitcomb and Morris*, 1961], **Scientific Creationism** [*Morris*, 1974], **The Genesis Record** [*Morris*, 1976], **The Young Earth** [*Morris*, 1994], and **Footprints in the Ash** [*Morris and Austin*, 2003]. A few of the arguments are:

- the Biblical text requires the days of Creation to be literal, 24-hour days;
- the genealogies from Creation to Christ listed in the Bible indicate earth's history to be thousands, not billions, of years; and
- many geological and geophysical processes argue for an age of the earth of thousands, not billions, of years.

This raises the question as to why the Bible should be taken literally when it deals with the age of the earth? It should be said at the outset that there are places in Scripture where some passages are intended to be taken figuratively or allegorically. In general, however, the RATE group takes the position that a passage should be taken literally unless there is clear evidence from the context that it is intended to be taken figuratively. For example, if a passage is poetic or it appears that the author intends for it to be an allegory, then more care should be taken during interpretation. Even in such allegorical passages, however, there may still be useful historical content. The RATE project reports on the historicity of Genesis 1:1–2:3 not only from radioisotope evidence, but also from internal grammatical evidence in the Hebrew text of the Bible.

2. Results from RATE

2.1 Helium Diffusion

The RATE group believes it has uncovered evidence that focuses the spotlight on the primary source of the discrepancy between the billions-of-years time frame of the conventional scientific community and the thousands-of-years time frame of the literal Biblical community. Dr. D. Russell Humphreys conducted a series of experiments and developed the supporting theory during the RATE project that allowed two independent clocks to be simultaneously compared [*Humphreys*, 2005]. One clock is based on the decay of a parent isotope (^{238}U) and the production of its two daughter products (^{206}Pb and ^{4}He). The other clock is based on the diffusion of ^{4}He from zircon where the daughter products appear. Because ^{4}He is produced as ^{238}U is transformed to ^{206}Pb and is a simultaneous daughter product, the diffusion of ^{4}He out of the zircon is tightly coupled to the radioactive decay process. Dr. Humphreys was aware that surprisingly large quantities of ^{4}He had been measured in zircons taken from a drill core extracted near the Jemez volcanic caldera, Fenton Lake, New Mexico, from Precambrian granodiorite [*Humphreys*, 2000]. Given the previously known

diffusivities of ^{4}He in other minerals, nobody expected to find much ^{4}He remaining in the zircon if the time period was 1.5 billion years since the rock crystallized. The high concentrations of ^{4}He, however, suggested that the zircons are very young, that the time period for the production of ^{4}He must have been short and the nuclear decay process must therefore have been accelerated. A photomicrograph of a zircon grain from the core used in the study is shown in Figure 1. Helium diffusion measurements were used to develop an independent clock to test the assumptions underlying the standard U-Pb radioisotope dating method.

Dr. Humphreys arranged for the rate of diffusion of He through zircon to be measured as a function of temperature in a laboratory well known for its He diffusion studies. Interestingly, although done for other materials, the measurement of He diffusion in zircon had never been unambiguously reported prior to the RATE project. Dr. Humphreys calculated the diffusion rates required to retain the observed amount of He still present in the zircons in the Precambrian granodiorite as a function of temperature. He calculated the diffusivity for a Creation model time of 6000 years and compared it with the diffusivity which would be necessary for the escape of the same amount of He for an

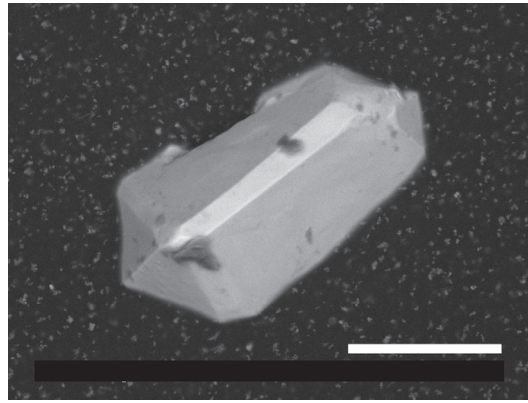

Figure 1. SEM photomicrograph of a zircon crystal containing ^{238}U, ^{206}Pb, and ^{4}He extracted from the Jemez granodiorite, Fenton Lake, New Mexico. Length scale in the lower right-hand corner is 30 μm. Photo courtesy of Mark H. Armitage.

evolution model time of 1.5 billion years (an age based on the measured amount of Pb present, but assuming today's rate of U decay to Pb). Figure 2 shows the results of these measurements and calculations plotted as the logarithm of diffusivity versus temperature. Temperature is plotted on the horizontal axis in a manner which permits theoretical relationships to appear as straight lines and produces an Arrhenius

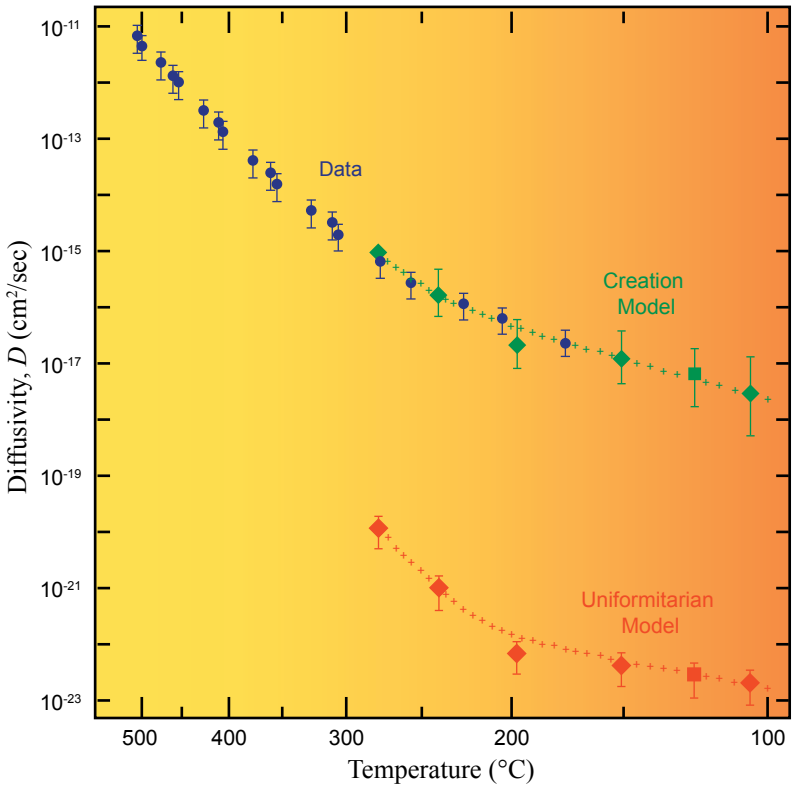

Figure 2. Comparison of diffusivity between Creation and uniformitarian models in zircon as a function of temperature. The upper dashed line shows the theoretical diffusivity needed for the Creation model of 6000 years. The lower dashed line shows the theoretical diffusivity needed for the uniformitarian model of 1.5 billion years. The red diamonds are calculated values of diffusivity using measured He concentrations and temperatures from *Gentry et al.* [1982], and the blue dots and green diamonds are from *Humphreys* [2005] for the same Jemez granodiorite.

diagram. Diffusivity is a measure of the rate at which He escapes from zircons. The Creation and uniformitarian models differ by a factor of about 100,000. The actual laboratory measurements of He diffusion through zircon fall on the Creation model line, well within the error bars. This is highly significant, because the method quantifies the disparity in the standard radioisotope and He diffusion methods for estimating the ages of rocks. The Creation model is more consistent with the measured diffusivities and estimates the age of the rock to be 6000±2000 years.

The physical presence of high levels of He in these U-rich zircons, given the measured He diffusion rate in zircon, is a strong argument that 1.5 billion years worth of U decay, at presently measured rates of U decay, has actually occurred within the last 6000 years. The RATE group believes the best way to account for the vast amount of U decay within the last 6000 years is by one or more intense episodes of accelerated decay.

2.2 Radiohalos

Not only does the decay of U produce He in the zircons where the radioisotopes occur, but α-particles which are ejected from the nucleii of atoms during decay, when the zircons are only about 1 μm in diameter, produce radiohalos in the surrounding biotite in which the zircons are embedded within granites. *Snelling* [2000] reviewed research on radiohalos, and *Snelling* [2005a] proposed a full explanation for their formation and their importance to accelerated decay.

The high-velocity α-particles produced by the decay of U cause damage to the crystal structure of the biotite outside the zircons as they race outward from a radioactive zircon. Alpha-particles are ionized and contain two protons and two neutrons. They become He atoms when they have decelerated greatly and captured two electrons to form a neutral atom. Many of the α-particles exit the zircon crystals and collide with the stationary atoms in the biotite surrounding the radioactive centers, producing discolored spherical shells of damage. Biotite occurs in thin sheets which can, with care, be peeled away

to reveal the discolored rings. By inspecting the sheets as they are removed several at a time, the sheet containing the largest diameter ring of discoloration and the radioactive center simultaneously can be located. The radius of discoloration and the number of rings can be used to identify the radioactive isotope which formed the radiohalo. Each radioisotope produces α-particles with distinctive energy levels which, in turn, reach different penetration distances in the crystal as they decelerate. Many millions of α-particles are required to form a ring which is intense enough to be seen under a microscope.

Figure 3 shows photomicrographs of ^{210}Po and ^{218}Po radiohalos (concentric circles near arrows). Polonium-210 releases α-particles with a single energy level creating a single ring surrounding a radiocenter. Polonium-218 releases α-particles to form ^{214}Po which releases α-particles at a different energy level to form ^{210}Po which in turn releases α-particles at a third energy level, creating a total of three rings. See *Snelling* [2000] for more details on radiohalo production by various radioisotopes.

The significance of Po radiohalos to the age-of-the-earth argument lies in their formation conditions and short half-lives. Three isotopes of radioactive Po occur within the ^{238}U decay chain—all with short half-lives. Polonium-210 has the longest half-life of 138 days. This means that whenever Po is formed it exists only for a brief time, on the order of only months, for the longest-lived isotope. Yet, radiohalos can only be formed in solid crystalline rock (such as granite) at temperatures below the annealing temperature of 150°C. The rings of discoloration can form only after the granitic magma has cooled to form solid mineral crystals. Radiohalos can be retained in the rock crystals only if the temperature remains below the annealing temperature. This means that conventional scenarios in which granite is slowly cooled from high-temperature liquid magma over hundreds of thousands or millions of years cannot form Po radiohalos. Yet, such radiohalos are commonly observed in granites all over the earth. Dark U radiohalos require at least 100 million years worth of decay to form and also to supply enough Po isotopes to generate Po radiohalos. But unless the U decay is accelerated, the supply of the Po isotopes will be too

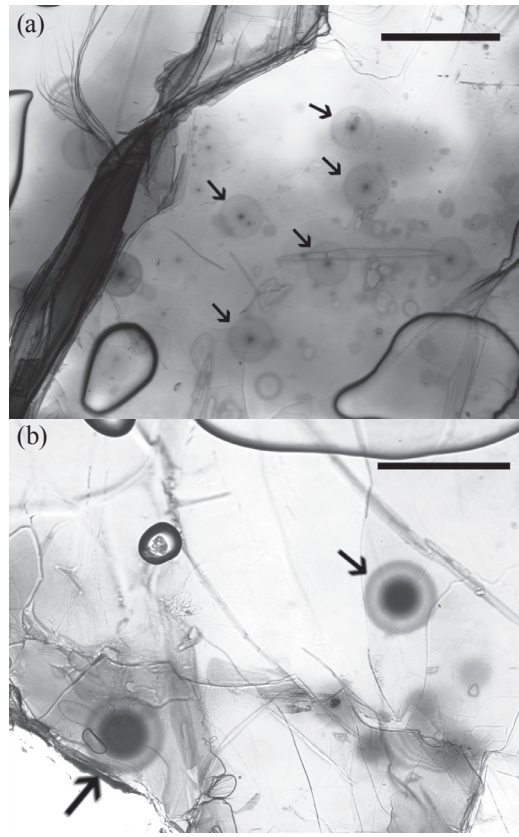

Figure 3. (a) ^{210}Po radiohalos. (b) ^{218}Po radiohalos. Length scale in the upper right-hand corner of each figure is 60 μm. Photos courtesy of Mark H. Armitage.

meager to produce the radiohalos. In other words, a lot of Po has to be produced very rapidly. Otherwise, there won't be enough Po to form the Po radiocenters. But at the same time the granites have to cool rapidly so that the rapid supply of a lot of Po isotopes is occurring at or below the annealing temperature of 150°C. Therefore, the cooling of granites and the formation of radiohalos must be rapid and decay rates must be accelerated. So, the rapid formation of granites and Po radiohalos are a strong argument for a young earth.

Gentry [1988], who first interpreted Po radiohalos as a unique

signature for instantaneous, recent Creation by God, believes that radiohalos occur only in Creation week granites. However, *Snelling* [2005a] reports on a survey of radiohalos in granites from many selected locations, some of which provide evidence that they were also formed in mountain-building episodes during and immediately following the Genesis Flood (see Figure 4). Note that the frequency of occurrence of radiohalos is relatively low for rocks conventionally older than 600 Ma and younger than 65 Ma. But, for rocks conventionally dated between 65 Ma and 600 Ma, which the RATE group believes are likely to be Genesis Flood rocks, the occurrence of radiohalos is often high.

The RATE team does not believe this interpretation detracts from God's supernatural intervention in the formation of radiohalos, because God was as intimately involved in the processes of the Genesis Flood as

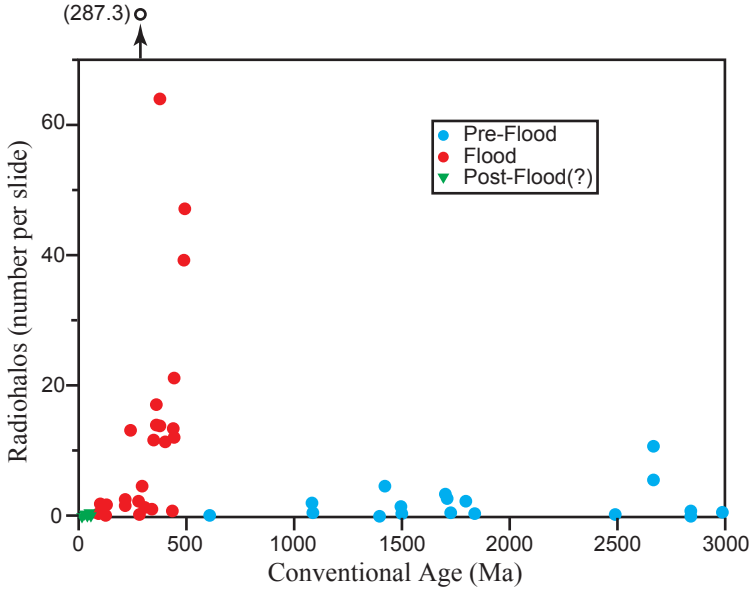

Figure 4. Plot of radiohalo occurrence in granites versus conventional age for three categories of granites—pre-Flood, Flood, and post-Flood(?). Arbitrary designations of pre-Flood were assigned to granites conventionally dated as 600 Ma or older, post-Flood(?) to granites 65 Ma or younger, and Flood for granites between 65 Ma and 600 Ma.

He was in Creation. However, the formation of Po radiohalos in granites associated with the Genesis Flood seems to require more explanation about the need to separate Po from U, and the possible mechanism because of the constraints of temperature and cooling rates.

Dr. Snelling proposes that radiohalos were formed only during catastrophic hydrothermal events when the rate of radioisotope decay was simultaneously accelerated. He found that Po radiohalos are associated with the occurrence of U radiohalos, and with the relative positions of the radiohalos in cleavages and near cracks and other lattice imperfections. Polonium radiohalos occur in greater frequency when U radiohalos are present upflow of the locations where the Po radiocenters can form and produce the Po radiohalos. Because Po is formed in a decay chain by the process of U turning to Pb, Po radiohalos appear to have been produced in an environment in which hot fluids were transporting and depositing intermediate radioisotopes at opportune sites within the crystals of biotite. The process appears to have been extremely rapid because of the magnitude of the decay and cooling necessary preceding the formation of the radiohalos.

It appears that the conditions necessary for the formation of Po radiohalos occurred only during global, highly energetic events like Creation and the Genesis Flood. In both events rapid, high-temperature processes occurred, based on the Biblical descriptions of massive cosmological and geological change. The descriptions of both events also suggest accelerated geological processes, and now the RATE group concludes there is evidence for accelerated nuclear decay processes as well. The production of Po radiohalos apparently is not occurring at the present time. It may be possible to find a local geological event today in which small quantities of water in contact with crystallizing magma may allow the slow transport of decay products through the resultant cooling rock, but we believe accelerated decay of the U to rapidly supply enough Po is also a condition for Po radiohalo formation. The rate of nuclear decay is obviously uniformly slow today. In addition, the widespread abundance of Po radiohalos in granites all over the earth would require events of global magnitude. We believe this only happened during Creation and the Genesis Flood.

2.3 Fission Tracks

Another direct evidence of nuclear decay in rocks is the formation of fission tracks by the disintegration of ^{238}U into high-velocity particles which leave small trails of destruction in zircon crystals as they speed away from the decay center. These tracks can be counted using special etching techniques and a computation of nuclear decay rates made in the zircons. *Snelling* [2005b] investigated the densities of fission tracks in several geological formations in Grand Canyon and nearby areas, and found that in most of the zircons the fission track densities matched the expected densities from the amount of radioactive material present in the rock units and their radioisotope "ages." In some of the zircon grains for which the densities did not agree, associated evidence indicated that the tracks had been erased by a process called thermal annealing—the reheating of the rocks enough for the damage trails to be erased by "healing" of the crystal structure. This elimination of the fission tracks may have been due to heating of the zircons by accelerated nuclear decay and during the Laramide uplift to form the Rocky Mountains and the Colorado Plateau at the end of the Genesis Flood.

For those zircons in which the fission track densities and radioisotope ratios agreed, more than 500 million years worth (at today's rate) of nuclear and radioisotope decay had occurred in the past. Taking the Biblical record as historically accurate, this decay must have occurred during the Genesis Flood year about 4500 years ago. Thus, the fission tracks in the zircons are physical evidence of accelerated nuclear decay.

2.4 Do Radioisotope Clocks Need Repair?

Do the different radioisotope clocks provide a consistent picture of the age of a rock or suite of rocks? If concordant ages were obtained, this would lend support to radioisotope dating. Therefore, a major effort of the RATE project was to compare the estimated ages from what would appear to be easily dated rocks by the whole-rock and mineral isochron methods. Rocks selected for radioisotope study were the Beartooth

andesitic amphibolite (northwestern Wyoming) and the Bass Rapids diabase sill (Grand Canyon, Arizona). Although *Austin* [2000] has shown previously that rock samples from Grand Canyon give isochron "ages" that conflict with each other and with historical evidence, he collected additional data for the RATE project with more highly controlled processing constraints in order to illustrate this discordance using both the whole-rock and mineral isochron techniques [*Austin*, 2005]. Isochron ages were computed from four different radioisotope pairs within the same rock samples. Yet, the four age determinations differed widely (~0.8 to ~1.4 billion years). If the conventional technique for obtaining "ages" from isochrons was accurate, all four estimates should yield the same "age," at least within small error bounds.

Radioisotopes which disintegrate by α-decay give higher estimates of age than ones that disintegrate by β-decay. *Austin* [2005] documented this strongly from both the Beartooth amphibolite (Wyoming) and the Bass Rapids diabase (Arizona). These well documented cases argue that conventional radioisotope clocks are in need of repair. We ask, "Which of the various radioisotope clocks can be trusted?"

Although the RATE group does not believe these absolute age values are correct, the data provide crucial information about the radioisotope decay process within earth history. In pointing out the disparities and discordances in radioisotope dating the RATE team concluded that radioisotope dating using conventional assumptions is invalid for accurately dating rocks. Not only has the RATE group documented that different radioisotope dating methods disagree with one another, but that the estimated "ages" must be wrong by many orders of magnitude. For example, because Biblical chronology as well as other RATE findings indicate the earth is no more than ten thousand years old, and whereas many rocks are dated more than one billion years old, standard radioisotope dating for such rocks is wrong by at least a factor of 100,000.

2.5 Isochron Discordance

Snelling [2005c] explored a wider sample of rock units for isochron

discordance and the role of inheritance and mixing of radioisotopes in the mantle and crust. He collected and analyzed in great detail samples from ten rock units which formed from recent times back to the early Precambrian (pre-Flood period). He tested the reliability of the four major radioisotope systems also used by *Austin* [2005] and similarly found a clear pattern of isochron discordance.

Snelling found that recently formed, often referred to as "young rocks," had inherited the radioisotope signatures of their mantle sources and there was evidence of open-system behavior. Contamination and mixing in crustal rocks had apparently occurred during their ascent from the mantle to the crust and while being intruded and extruded as magma. However, the overall systematic trend of "radioisotope ages" in the rock units in the geologic record indicated that accelerated decay was the dominant factor operating through earth history. Because all three assumptions of conventional radioisotope dating—known initial conditions, closed-system behavior, and constancy of decay rates—were shown to be subject to failure, the radioisotope methods cannot, and should not, be relied upon to produce absolute "ages" for the earth's rock strata. However, if the appropriate corrections are made, the chains of radioisotopes are almost certainly indicative of both the lapse of time and of other historical events, in particular, the Genesis Flood and Creation.

2.6 Composite Isochron Ages

Figure 5 displays a composite diagram of the isochron ages calculated by *Austin* [2005] and *Snelling* [2005c] from their samples in Grand Canyon. The isochron ages are plotted versus atomic weight for the four radioisotope pairs—^{40}K–^{36}Ar, ^{87}Rb–^{86}Sr, ^{147}Sm–^{144}Nd, and ^{238}U–^{206}Pb. Note that the α-decayers—^{147}Sm and ^{238}U—give consistently older isochron ages that the β-decayers—^{40}K and ^{87}Rb. The β-decayers have multiple decay paths and so-called forbidden decay modes which may explain part of this discrepancy. Whatever the process involved in speeding up the nuclear decay at various times in earth history, the amount of decay was apparently not the same for all isotopes. A dashed

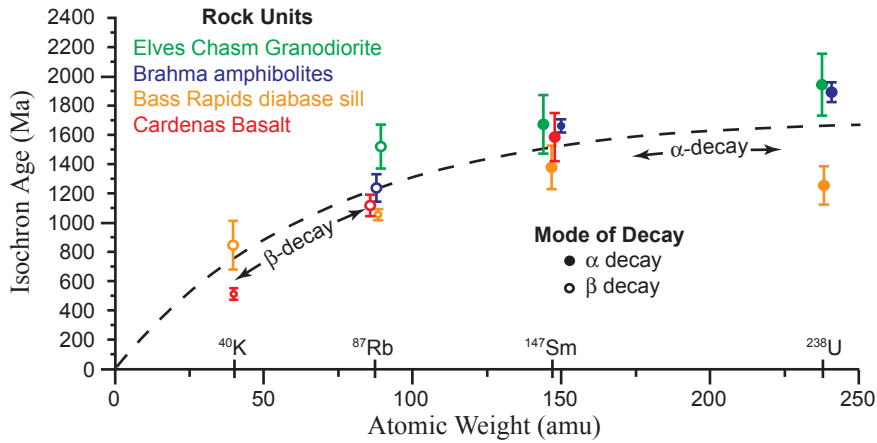

Figure 5. Composite plot of isochron age versus atomic weight for four radioisotope pairs and four Precambrian formations in Grand Canyon from *Austin* [2005] and *Snelling* [2005c].

trend line of isochron age parabolically increasing with atomic weight is drawn by eye on the diagram. The trend may be a hint about the process which causes different isochron ages in the same rock and could lead to a better understanding of accelerated decay. The RATE group recommends that decay rates be investigated for other radioactive elements with different atomic weights and decay modes.

2.7 Theoretical Considerations

Although the geological support for accelerated decay seems persuasive, most physicists will immediately object to positing any major change in nuclear decay rates because both theoretical and experimental considerations have shown that today they change by less than 1% even under extreme variations in temperature, pressure, and chemical conditions. However, some recent reports in the conventional literature show that if radioactive atoms with small energy releases (such as ^{187}Re with an energy release Q of 0.0025 MeV) are strongly ionized, that is, their electrons are stripped away to alter the electromagnetic field environment of its nucleus in a significant way, the likelihood of decay

can be greatly increased [*Bosch et al*., 1996]. This is not that surprising in terms of current nuclear theory, and it reinforces the conclusion that relatively small changes in the energy structure of the nucleus can alter the stability of the nucleus in dramatic ways.

Experiments to investigate the direct alteration of decay rates under such extreme conditions of temperature and pressure were beyond the financial capability of RATE. Certainly many nuclear experiments are even beyond the ability of the U.S. government at this time. So, the RATE project has focused on feasible studies of the relationship of various model parameters associated with α- and β-decay. For example, *Chaffin* [2005] has studied the shape of the potential energy barrier to α-particles exiting the nucleus of an atom. Because the shape of the potential energy distribution in the nucleus of an atom resembles the cross-section of a well dug in the ground, it is called a "potential well," as shown in Figure 6. Instead of height, the vertical dimension

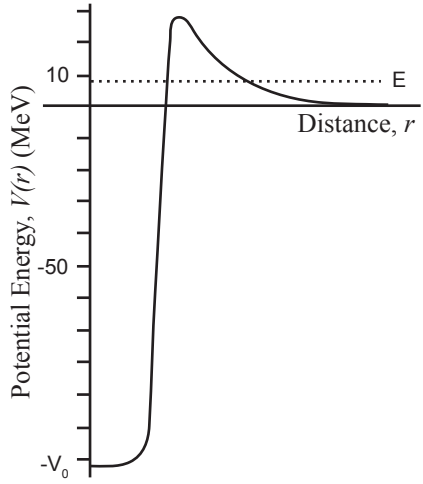

Figure 6. Potential energy seen by the α-particle versus distance from the nuclear center. The nuclear force dominates when the α-particle is inside the nucleus, but is short ranged and gives way to the electrostatic repulsion at large distances.The α-particle typically has a total energy E shown by the dashed line on the figure, and does not have enough energy to cross over the top of the barrier. If the depth of the potential well V_0 should change, then the α-particle's probability of escape is affected.

of a potential well is potential energy inside the nucleus of an atom. Dr. Chaffin has explored the effect of varying the potential well width and depth on α-decay rates. He has found that the quantum mechanical wave function for α-decay which represents a barrier to the escape of particles from the nucleus of an atom is highly sensitive to minor variations in its shape and depth. He has shown that small variations can cause the decay rates to vary by orders of magnitude.

Dr. Chaffin has also studied models derived from string theory and Kaluza-Klein theory and considered how coupling constants in these models (numbers which specify how strongly a particle is associated with a force field it produces or to which it responds) relate to decay rates. These studies show that changes in decay rates may be connected to simultaneous changes in other basic constants. Early indications from double β-decay experiments in progress [*Barabash*, 1998, 2000, 2003] show that one or more constants involved in calculating β-decay half-lives may be variable. There are indications that any change in decay rate is likely to be dependent upon the type of decay of a given nuclear species. (This is consistent with the pattern of discordance between isochron "ages" of rocks found by Drs. Austin and Snelling.)

Although theoretical studies of nuclear decay are separate from the question of whether accelerated decay has actually occurred, these studies suggest that if certain variables are changed decay rates can be increased significantly. Small changes in some constants appear to be able to produce orders of magnitude changes in the decay rates. On the other hand, we acknowledge that theoretical and experimental studies may never with certainty be able to identify the primary mechanism God actually may have used. Because God is the eternal, all-powerful agent of Creation and the Genesis Flood, then He can simultaneously manipulate many possible variables in His Creation. With all our best efforts we might never discover exactly how or what He did to cause accelerated decay. However, we conceivably might be able from such studies to uncover some relevant interrelationships and estimate the magnitudes of certain parameter variations. We need to remember, however, that God is external and independent of His Creation, and during periods of intervention in the normal operation of His universe

He is not necessarily bound to follow what we call natural law. So, we do well to maintain an attitude of humility and carefulness in our attempts to understand such interventions on His part.

2.8 Radioactive Carbon

Most of the research pursued during the RATE project addressed the physics, geophysics, and geology associated with long half-life isotopes like U, Th, K, Rb, and Sm. Initially, research on short half-life isotopes such as ^{14}C was purposely excluded, because it was believed that the magnitude of the discrepancy between Biblical ages and ages of rocks estimated using long half-life isotopes was the much greater problem. Moreover, the literature revealed that many other young-earth researchers had already expended considerable effort on short-age isotopes. However, before the project had gone far into the research phase Dr. Paul Giem of Loma Linda University informed the RATE group that dozens of high-precision measurements were being reported indicating ^{14}C in coal and other ancient C-rich materials from deep in the geological record. These results were being reported in conventional journals like *Radiocarbon,* but were being interpreted as representing contamination from as yet undetermined sources. He suggested that the RATE project might wish to explore these reports and see if this evidence was relevant to its goals.

The RATE team decided that indeed ^{14}C deserved serious attention, and Dr. John Baumgardner assumed the leadership of this new project. He confirmed that about seventy independent measurements of ^{14}C using a new high-precision technique called accelerator mass spectrometry (AMS) had been reported in the standard radiocarbon literature for samples spanning most of the geological record. This method allows ^{14}C to be measured in much smaller concentrations than had been possible before, by counting ^{14}C atoms directly, rather than waiting for them to decay. *Baumgardner* [2005] collected the reports and graphed the results, as shown in Figure 7.

The average ratio of ^{14}C to total C concentrations in the samples relative to the modern carbon concentration for forty Phanerozoic

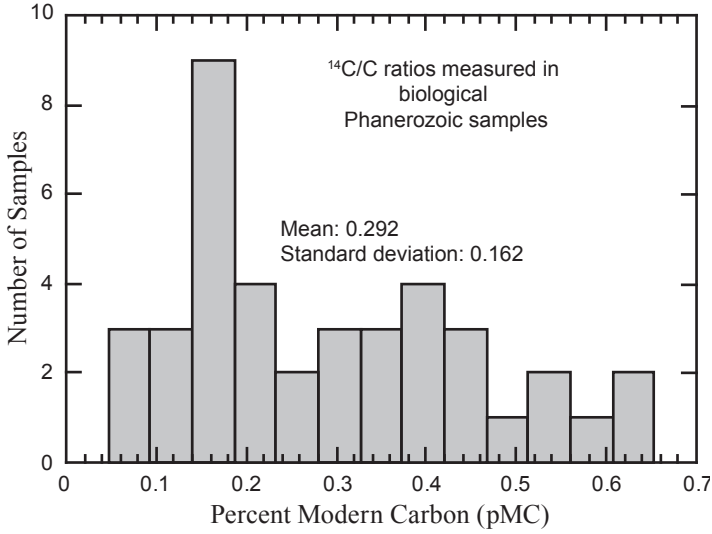

Figure 7. Histogram of measured $^{14}C/C$ in percent of modern carbon concentration for forty Phanerozoic biological samples as reported in the conventional literature [*Baumgardner et al.*, 2003].

(with uniformitarian ages 0.1 to 545 million years) biological samples was 0.292±0.162 percent modern carbon (pMC). In contrast, the average ratio for thirty Precambrian (greater than 545 Ma according to the conventional time frame) non-biological samples was 0.062±0.034 pMC. The average value of the $^{14}C/C$ ratio for biological samples would correspond to an age of about 50,000 years, provided one accepts that all the assumptions of conventional ^{14}C dating are valid. Even accepting the uniformitarian assumptions (which likely do not hold, given a recent global Flood), 50,000 years represents a glaring discrepancy with the uniformitarian ages of the reported samples, for example, of 300 million years for Pennsylvanian coal. But, uniformitarian assumptions are almost certainly inappropriate because, not only would a period of accelerated decay in the past have affected ^{14}C levels, but even apart from acceleration in decay rates, the Genesis Flood, by removing so much C from the biosphere, would invalidate the crucial assumption that the initial (pre-Flood) $^{14}C/$ C ratio was similar

to that of today's atmosphere. The RATE team concluded that even for a short half-life isotope like ^{14}C there is a major disparity between the uniformitarian age estimate and the actual age. The difference from the actual ages may not be as great as for long half-life isotopes, but is still important. In fact, partially because of this finding, the RATE group began to look for a theoretical mechanism of accelerated decay which would produce variable effects dependent upon half-life or possible decay modes (see *Chaffin* [2005]).

Dr. Baumgardner next sought to verify this remarkable result, namely, that samples considered tens to hundreds of millions of years old, given their position in the geological record, actually contain detectable ^{14}C. He obtained ten coal samples from the U.S. Department of Energy Coal Repository and sent them to a highly-regarded commercial laboratory for independent ^{14}C analysis. Moreover, because all of the non-biological samples reported in the literature showed measurable concentrations of ^{14}C as well, he acquired some diamonds and also had them analyzed for ^{14}C. Two criticisms were expected from the scientific community regarding these results from coal. It was expected that many old-age advocates would say that the high level of ^{14}C in the coal was a result of a faulty laboratory technique. However, after over twenty years of careful effort laboratories have reported that most significant sources of possible error have been eliminated. Actually, this process of identifying and correcting the errors in the AMS technique is the main reason for the scores of papers in the radiocarbon literature that deal with samples such as coal which the researchers assumed would be ^{14}C dead according to the conventional timescale. A second, expected criticism was that the source of ^{14}C in coal was *in situ* contamination. Coal has some level of porosity and water percolating through rock formations could conceivably bring some ^{14}C from today's biosphere into the coal seams. Finding measurable levels of ^{14}C in diamond, however, because diamonds are so hard and impervious to contamination, would be a powerful argument that the ^{14}C is actually intrinsic to the sample and not a result of contamination from the modern biosphere.

The average ratio of $^{14}C/C$ in the ten coal samples analyzed by Dr. Baumgardner was 0.25 pMC. For five diamonds from deep mines it was

0.04 pMC and for seven diamonds from alluvial environments it was 0.12 pMC, all notably greater than the background measurements of which the machines are capable. The independent coal measurements made by the RATE project agree closely with the earlier measurements reported in the radiocarbon literature. However, the new measurements in diamonds add a whole new dimension to the issue. If the level of ^{14}C detected in diamonds holds up as more diamonds are analyzed, the disparity relative to the standard timescale is even greater. Diamonds are thought to have been formed in the earth's mantle 1–3 billion years in the past according to conventional thinking. Yet, if they contain ^{14}C at reproducible levels near to what have been measured thus far, implying an age of 50,000 years or less, what could have been the source? Regardless of the source, it would have had to have gotten there very recently in terms of the uniformitarian timescale. One explanation for the ^{14}C in diamonds is the *in situ* transformation of ^{14}N, a trace contaminant in diamonds, into ^{14}C by bombardment with neutrons. However, the concentrations of neutrons measured in mines and other crustal environments today are many orders of magnitude too small to produce the measured concentrations of ^{14}C. On the other hand, the neutron levels that would have occurred in crustal environments during an episode of accelerated nuclear decay during the Flood do appear to be sufficient to account for the ^{14}C levels in diamonds the RATE project measured.

Because the 5730 year ^{14}C half-life is so short relative to the billions of years of the conventional timescale, the presence of measurable quantities of ^{14}C in coals and diamonds is another compelling indicator that the earth is young. Most of the ^{14}C in coals was probably sequestered when the material which formed the coals was buried during the Genesis Flood. Even with uniformitarian assumptions this had to be less than 50,000 years ago. The source of ^{14}C in diamonds is not yet clear, but whatever its source, it has since been trapped without contamination and the date of its introduction also must be less than 50,000 years ago. Because the Flood likely renders the uniformitarian assumption for the initial ^{14}C level incorrect, this age estimate almost certainly represents an upper bound.

2.9 Historical Reading of Genesis 1:1–2:3

Most of the efforts of RATE were dedicated toward research on rocks and discovering how the radioisotopes in them produced the daughter products observed today. However, because RATE depended so heavily on the Bible as the primary source of information for earth history, some of the effort was spent on evaluating the foundational premise that the primary passages of the Bible text relating to the earth's physical history are to be understood literally.

Recent trends in the evangelical community are troublesome, because an increasing number of conservative Bible scholars are teaching that the Creation and Genesis Flood accounts are mythical in essence and therefore should not be the basis of scientific investigation. To address this issue RATE commissioned Dr. Steven Boyd to conduct a linguistic and statistical study of Biblical Hebrew text to identify characteristics that objectively distinguish narrative passages from poetic passages [*Boyd*, 2005]. Our hope was that from this effort he would be able to demonstrate definitively that the authors of the key Creation and Flood passages were indeed writing literal, historical accounts, not figurative poetry meant merely to convey theological ideas.

He tabulated Hebrew verb forms for numerous narrative and poetic passages throughout the Old Testament. He targeted the preterite, imperfect, perfect, and waw-perfect. In general, narrative passages display high frequencies of preterites and moderate frequencies of imperfect and perfect verb forms. Poetic passages evidence almost the opposite, with low frequencies of preterites and moderate to high frequencies of imperfects and perfects. More particularly—as Figure 8 shows—the relative frequency of preterites for narrative is so different from that for poetry that it alone should be able to classify passages as narrative or poetry.

Dr. Boyd conducted a statistical experiment by randomly selecting a joint sample drawn from the two types of passages from Scripture and testing a distribution of the preterite verb form. He was able to demonstrate from his study, as shown in Figure 9, that the Creation account in Genesis 1:1–2:3 can be objectively identified as a narrative

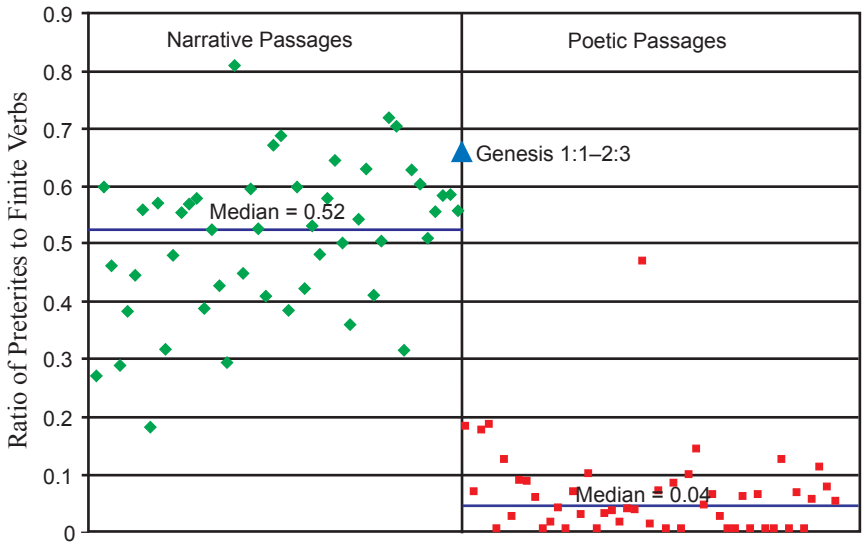

Figure 8. Side-by-side scatter plot of preterite verb forms in narrative passages versus poetic. The green diamonds are the narrative passages of the joint sample. The red squares are the poetic passages. The horizontal blue lines are the median for each sample. Genesis 1:1–2:3 (the blue triangle) is also plotted for comparison.

text with an extremely high statistical confidence level. Furthermore, he showed that Biblical narrative texts compel the reader to believe in their historicity. Genesis 1:1–2:3 should be read therefore as history and taken literally. This study reinforces the underlying premise of the RATE project that building a scientific model from Scripture is consistent with the linguistic character of the texts themselves.

3. Unresolved Problems

There are, of course, many questions and issues which the RATE project has not resolved. Although the problems were discussed at numerous times during project deliberations, adequate time and resources were not available to solve them. Some of them would have led the project astray from its main interests, and some required expertise which the RATE group did not have.

3.1 The Theological Problem

One important issue for many people is the apparent problem of nuclear decay of any sort occurring during Creation week (let alone accelerated decay), given the statement at the end of the sixth day in Genesis 1:31, "*Then God saw everything that He had made, and indeed it was very good*." If nuclear decay occurred at any point during the six days of Creation, it would seem at first that there would be a conflict in the definition of "good." The term "decay" is normally thought to be "bad." So, the issue is, if unstable nuclei of elements such as U or K were "decaying" into Pb, He, and Ar during the Creation week, would this process be compatible with the statement that, "…

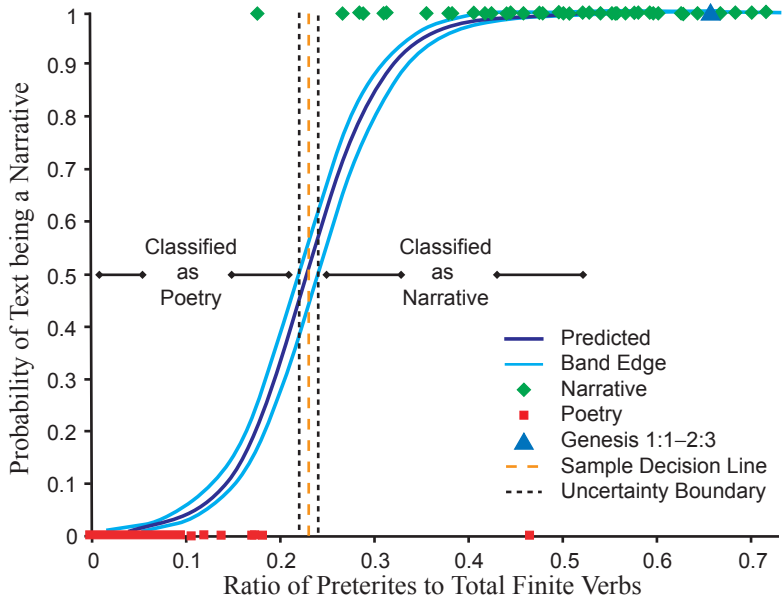

Figure 9. Plot showing the band of possible logistic curves derived from random samples from the total population of texts. The vertical distance between the light blue lines at a given ratio of preterites to finite verbs is a 99.5% confidence interval for the probability that a text with that ratio is a narrative.

everything that He had made … was very good." The RATE group does not have a conclusive answer to this question, even after eight years of consideration. However, we have several thoughts concerning the issue.

First of all, it is evident from Scripture that indeed physical changes in the earth occurred when God cursed the ground in Genesis 3:14–24. It would seem consistent for nuclear decay to have occurred at any time from the curse onwards, because this passage implies that everything was then no longer "good." So, could it be that all the nuclear decay from which we observe evidence occurred during and following the curse? The most energetic earth processes described in the Bible seem to have occurred during Creation and at the Genesis Flood. If a large amount of nuclear decay occurred at the time of the curse, there is no explicit mention in the Biblical text of major physical disruptions to the earth itself. Of course, this is an argument from silence and the Bible does not always provide all the details. Scripture does indicate that the serpent was cursed, that woman would have pain in childbirth, that man would now have to till the ground, that Adam and Eve were driven from the Garden and away from the tree of life, and that they and their offspring began to die physically. But, nothing is mentioned about tectonic or geological upheavals. If this was indeed the case, then there would be no apparent conflict with Scripture.

However, the magnitude of the nuclear decay and the heat such decay would release seem to the RATE group to be too great to have occurred only since that judgment. A significant portion of the decay could have occurred during the Genesis Flood, but there still seems to be a need for another period of time during which it could have occurred. The only other likely period seems to be early in the Creation week, particularly during the first three days. During the first two days and part of the third day of Creation there was as yet no life on the earth. Any radiation, heat, or other by-products of these nuclear disintegration or transformation processes would not have been a problem for plants and animals.

The processes God used to create and form the earth were probably more energetic than anything we can imagine today, even in light of

the May 18, 1980 Mount St. Helens eruption and the December 26, 2004 Asian tsunami. Scripture describes these processes only in very cursory terms. However, there is a sequence to the events. Mass, space, time, and light were formed on the first day, the atmosphere on the second day, and seas, dry land, and plants on the third day. Before the plants were formed there could have been rapid nuclear processes and the transformation of various elements into others.

Is it possible that the apparent conflict here is only semantic? Would the problem go away if we used the term *nuclear transformation* instead of nuclear decay? The basic problem is that we do not have enough information about how God managed these processes. And, even if we had more information, how would we describe them in current scientific terms? All of these events were supernatural, if not in kind, at least in terms of energetics and speed. So, it seems possible to us that some, even most, of the daughter products we observe could have been formed during the early Creation week, and the process was not viewed by God as "bad" at all. Some who still have a problem with the term "nuclear decay" being "bad" could alternatively interpret the considerable quantity of the daughter products we observe today simply to be the result of God's supernatural creative work with no reference to any specific process. What we call daughter elements would have played a "very good" role in the pre-curse period, as well as after the curse. For instance, Pb is a very useful metal.

3.2 The Heat Problem

If God caused a period of accelerated decay during the Genesis Flood, it would have generated a massive pulse of heat in the earth. The RATE group estimates that the heating would have been equal to that produced by about a half billion years of decay at today's rates. But, it would have been generated over the period of only one year of the Genesis Flood. The heat would have melted the crustal rocks many times over unless there was some mechanism for simultaneously removing it quickly. How did the earth survive such a massive dose of heat without vaporizing the oceans and melting the rocks? How did

Noah and his family survive such an environment on the Ark?

A primary piece of Biblical evidence that heat was not a problem is the fact that Noah and his family made it through the year of the Genesis Flood without being cooked! Sometimes we forget the obvious. Or, we choose to ignore the statements of Scripture which can guide our technical considerations. From the simple fact that Noah, his family, and the animals survived and left the Ark at the end of the Genesis Flood we can infer at least one of several possibilities:

- no accelerated decay occurred;
- no large amount of heat was generated by the accelerated decay; and
- God supernaturally protected Noah and his entourage by rapidly removing the large amount of heat that was produced by some unknown mechanism

That accelerated decay occurred during recent earth history was a major conclusion of the RATE project. Evidence provided from several lines of research in this book overwhelmingly supports this conclusion. All nuclear processes we know today generate heat. It is highly likely that accelerated decay generated heat in the crust of the earth proportional to the amount of acceleration. This implies a large amount of heat was generated over a short period of time recently in the crust of the earth. The RATE findings of abundant Po radiohalos in granite implies that a huge amount of nuclear decay took place while this rock was cooling in order to generate the radiohalos. On the other hand, rapid cooling of the granitic plutons in which they are found is also required [*Snelling and Armitage*, 2003]. The implication is that most of the heat from the rapid nuclear decay had to be removed by some extraordinary process.

Baumgardner [2000] earlier had described a long-standing mystery concerning the strong correlation between surface heat flow from crystalline rocks at the earth's surface and the abundance of radioactive elements these rocks contain. He showed that a simple explanation involves a recent burst of radioactive decay such that the surface heat flow is dominated by heat from this event, not from heat conducted from deeper in the earth. Yet, when the actual amount of accelerated decay is taken into account, as indicated by fission track data, for example, the implication is again that most of the heat from this episode of

accelerated decay requires removal by some process other than thermal conduction.

The RATE group believes from these arguments that

- a large amount of nuclear decay occurred during the Genesis Flood and during the early part of Creation week as well;
- a large pulse of heat was also generated by this accelerated decay; and
- some mechanism removed this heat as it was being produced.

The removal of heat was so rapid that it likely involved a process other than conduction, convection, or radiation. For example, the cooling of granite plutons would have taken thousands of years by conventional thermal diffusion. Of course, God was directly involved in all of these events, so it is possible that He employed some supernatural process which does not occur today or cannot be detected. However, He commonly uses natural law to do His work on earth, and so we believe it may be possible to discover how He did it.

For example, *Humphreys* [2005] has offered a volumetric cooling mechanism based on relativistic principles. It appears to be consistent with the magnitude of the cooling needed as well as the cosmological language of the *"stretching of the heavens"* contained in Scripture. It involves the stretching in four dimensions of the space we experience in three dimensions and the consequent loss of energy on the part of photons and particles as the expansion of the fabric of space proceeds. Humphreys' postulated explanation represents only a beginning attempt to understanding the complicated events of the Genesis Flood and may not, in fact, be the correct mechanism. But his hypothesis has many attractive explanatory features and only a few known difficulties.

One difficulty is the distribution of volumetric cooling within the earth. The cooling probably could not have been uniform, but instead must have been dependent on some complex function of another variable like absolute temperature. It would have needed to vary strongly in some manner to avoid too much cooling in certain locations such as the oceans. Had the granite plutons with their high concentrations of radioactive elements cooled at sufficiently high rates to form and persist as crystalline rock, then the oceans would have frozen solid had

they cooled by the same amount. Likewise, Noah and his family on the Ark would have been in danger of freezing. Of course, the concept of a complex cooling rate being dependent on temperature is not unusual. We know, for example, that Planck's radiation cooling law is a function of the absolute temperature to the fourth power. If such a relationship were to be applied to volumetric cooling, hot objects would cool orders of magnitude faster than cool objects.

The heat problem will eventually, through the research it spawns, actually yield crucial insight as to the mechanism behind accelerated decay itself. For example, the Ice Age following the Genesis Flood or subsurface ice layers may have been results of such an effect. *Baumgardner* [2000] has shown that there is a major problem in explaining the distribution of temperature in and near plutons without invoking some non-conventional heating and cooling mechanism. The RATE project did not have time to pursue this issue to any significant depth. We encourage others with the requisite physics background to investigate this problem and explore these largely uncharted waters.

3.3 The Radiation Problem

If God caused an episode of accelerated decay during the Genesis Flood, how could Noah and his family and all the plants and animals on the Ark have survived the massive dose of radiation such nuclear decay would have unleashed? At first glance, a simple solution to the problem seems to be readily available. The waters of the Genesis Flood covered the entire earth and thereby provided an absorptive layer between the Ark and the crust of the earth where most of the radiation was being generated. The occupants of the Ark would have been protected from the radiation, similar to shielding in a gigantic swimming-pool reactor.

However, at second glance there is a problem. It turns out shielding from the increased radiation dose from outside the Ark is not sufficient. Noah and his family may have had sources of radiation within their own bodies. For example, plants and animals today contain ^{40}K, which is radioactive. If nuclear decay rates were accelerated to the levels the RATE group believes occurred during the Genesis Flood, the radiation

dose from similar levels of ^{40}K within Noah's body likely would have been lethal. One solution has been offered that possibly could mitigate this problem—namely, that the ^{40}K we measure in plants and animals today is the result of the Genesis Flood itself. The RATE team believes an attempt should be made to test for ^{40}K in the bodies of pre-Flood insects which were trapped in amber during the Genesis Flood and were thereby protected from subsequent contamination.

4. Conclusions

RATE began its eight-year research project with the intention to investigate radioisotope dating and determine if there was an explanation for the disparity between the conventional estimates of an old earth and the Biblical statements of a young earth. Initially the RATE team had no preconceived ideas regarding what might be found in the data. In fact, because the scientific community is so convinced in the great antiquity of the earth, the team was concerned that it might possibly run up against overwhelming evidence against a Biblical time frame. However, the RATE team was committed to conducting the first major creationist effort to investigate theoretically and experimentally a young-earth explanation of nuclear decay processes, no matter where the evidence led. The RATE team intended to offer a positive, scientific alternative for a thousands-of-years scenario rather than simply critiquing the conventional billions-of-years scenario. The team believed this problem was so important, so central to the current wide-scale defection of society from the literal teachings of the Bible and the creationist model of origins, that the team was willing to stake the scientific reputations of its members on the outcome of this effort. Many supporters agreed with this assessment, based on the widespread prayer support and financial backing the RATE project received.

The first conclusion reached through the literature search and early discussions was that whatever happened in earth history, a large amount of nuclear decay has occurred. The evidence includes the presence of large amounts of radiogenic Pb in minerals that do not normally contain Pb. Large concentrations of fission tracks—linear patterns of

crystal damage in rocks caused by high-energy particles ejected from nuclear fission centers—are ubiquitous throughout the rock strata of the earth. Radiohalos—spherical patterns of discolored crystal surrounding nuclear decay centers—are present in most granitic rocks. The formation of radiohalos required a large amount of radioactive decay for the radiohalos to be detectable. And, finally, the measured presence of relatively large quantities of ^{4}He in zircons was, in itself, evidence for a large amount of nuclear decay.

The conclusion that a large amount of decay has occurred had been denied or ignored previously by many creationists. However, the evidence is overwhelming. The magnitude of the nuclear decay indicates that, independent of initial conditions, the equivalent of billions of years worth of nuclear decay has occurred during earth history.

How then should a young-earth advocate proceed? The only remaining avenue available appeared to be to question the assumption that nuclear decay rates have been constant. This approach was adopted by the RATE group as the preferred avenue for research, given the evidence for massive nuclear decay.

Although there were many subprojects to confirm preliminary and auxiliary concepts developed by the RATE group, there were four that provided direct evidence for accelerated decay—

- He diffusion,
- radiohalos,
- isotopic discordance, and
- ^{14}C in coal and diamonds.

These were summarized briefly in the previous section and are discussed in great detail in the appropriate chapters of this book. Three general geophysical conclusions were drawn from the RATE research:

- **A large amount of radioactive decay has occurred.**
- **Nuclear decay processes were accelerated during episodes in earth history.**
- **Conventional radioisotope dates are therefore incorrect by large factors.**

In addition to the geophysical issues, a study was also conducted on the reliability of Scripture as a basis for interpreting earth history.

Passages in the Old Testament were studied regarding their narrative versus poetic content. Because the highly statistically significant results of this study and the findings that the geophysical results were consistent with a literal interpretation of the Bible, two hermeneutical conclusions were also made:

- **Creation and the Genesis Flood are genuine historical events.**
- **Scripture is scientifically reliable.**

5. Recommendations

The RATE project has advanced an entirely new approach to resolving the conflict over the age of the earth. It identified several lines of evidence supporting the case for episodes of accelerated nuclear decay in the earth's past. Such evidence undermines a key assumption that underlies all uniformitarian radioisotope methods for estimating the ages of rocks. However, the experimental and theoretical RATE research needs to be confirmed and extended greatly. For example, trends in isochron "ages" of rocks need to be explored more widely by including additional isotope pairs with different half-lives and types of decay characteristics; He concentrations and the rate of diffusion in zircons need to be measured in a larger suite of rock samples containing a larger range in U concentrations from different geological settings; geological distributions of radiohalos and fission tracks need to be investigated more thoroughly, not only in granites, but also in metamorphic rocks; many more coals, diamonds, and other "old" geologic samples need to be analyzed for their ^{14}C content; and theoretical processes that influence the rate of nuclear decay need to be studied more comprehensively to identify mechanisms by which the decay processes can be accelerated.

Three major problems with accelerated decay pointed out previously, namely "the theological problem," "the heat problem," and "the radiation problem" need further work and consideration. The RATE group is confident that these issues will be solved because the evidence is so strong that accelerated decay has occurred, but at the time when RATE ended in 2005, their resolution had only begun.

There are many other issues and interesting projects which were only begun or considered during RATE which need further work. For example, the abundance of daughter products from long-lived radioisotopes in meteorites from space needs much more attention. These elements are used conventionally to infer cosmological processes involved in the formation of the earth and to estimate its age as a whole. The studies conducted by RATE on rocks from the earth do not yet adequately address the issue of the age of meteorites.

The point is that many of the strands of research started by RATE need to continue. The viability of the concept of accelerated decay has not yet been demonstrated to the satisfaction of many even within sympathetic creationist circles, let alone to the wider scientific community. Although the RATE team has already received some encouragement at technical presentations and hopes to receive more positive response from articles in conventional journals in the future, it does not expect the findings currently in hand by themselves to be adequate yet to precipitate a full-fledged revolution in thinking about the age of the earth. Such ingrained concepts as an old earth and constant rates of nuclear decay will not be overturned merely by the preliminary evidence and explanatory framework RATE has been able to assemble thus far. It will take continued efforts on the part of many more scientists and much greater levels of funding to build an irrefutable case for accelerated decay before it will be entertained with any seriousness by skeptics. This issue is at the core of a naturalistic world-view, not only in the physical sciences but, also, in the life sciences. Many years of additional research and reporting will likely be needed in order to make an enduring impact. The research started by RATE should be continued and expanded.

In the meantime, as the evidence accumulates, initial dissemination of these groundbreaking results should be made in creationist publications and to Christians in general to encourage them regarding the reliability of the Bible. Research on the age of the earth may, with God's help, be one of the most important methods for encouraging the church to work to return recognition and honor back to the Creator and Savior and away from naturalism. Although the technical issues are complex, the concept and implications for belief in the Bible are easily seen

by the layman. Confidence in what the Bible says on these matters in important because, as Christ told Nicodemus, *"If I have told you earthly things and you do not believe, how will you believe if I tell you heavenly things?"* (John 3:12).

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