quantities and as a result it appears as though I underestimated the amount of heat produced by radioactive decay by approximately half.

So what implications does this have for my model? Well, the reality is that there exists a fairly high degree of uncertainty regarding the composition and characteristics of the earth at any significant depth. In my paper I used a 'best guess' for many of the parameters, based on my review of current scientific publications. For instance, in my paper I took commonly assumed concentrations of radioactive materials in the crust and mantle, but we don't have direct ways to measure those concentrations, and so (particularly for the mantle) my calculations could be assuming concentrations of radioactive materials that are somewhat too high. Furthermore, it is also possible that the earth's pre-Flood internal temperature was closer to 300 K than my assumed 500 K, which would accommodate somewhat more radioactively-produced heat. If the earth's present interior temperatures were also somewhat higher than my calculations and/or if there was less energy released by mantle separation than I assumed in this paper, these could also account for more heat.

In addition, although the heating of the earth may be the primary way that heat produced by radioactive decay can be accounted for, there may also have been other mechanisms involved:

- The intense global rain of the Flood helped radiate some of that heat into space.
- High-energy steam jets carried away some of the heat.
- Some heat was stored as potential energy as work was done to 'raise' the outermost parts of the earth as the earth expanded.
- Some of the energy was absorbed by other nuclear processes such as possibly the splitting of deuterium.
- The geological chemical reactions and changes to mineral crystalline structure that no doubt accompanied the Flood were on balance, endothermic (e.g. metamorphism).

I would like to see more research done in some of these areas. Even though my mathematical error underestimated the amount of heat produced by accelerated decay based on my assumptions about the earth, I believe it is still possible that this model involving the heating of the earth can essentially solve the heat problem associated with accelerated radioactive decay.

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Could most of the earth's U, Th, and K have been in the mantle prior to the Flood?

In his two-part article entitled 'A new magnetic field theory and Flood model',[1,2] Don Stenberg proposes a scenario for earth history that seeks to provide positive solutions to a number of problems associated with catastrophic plate tectonics (CPT) as well as with the Radioisotopes and the Age of the Earth (RATE) conclusions. Specifically, he proposes (1) that essentially all the earth's major heat producing elements (U, Th, K) prior to the Flood were in the mantle, and (2) that essentially all the nuclear transmutation or decay that has occurred during the solar system's history took place during the Flood.

Major problems swept away

In this proposed framework almost all the heat released by accelerated nuclear decay is absorbed by the mantle. This seems to solve one of the major difficulties associated with the RATE conclusions by providing a sink for the vast amount of heat released by some 4.5 Ga worth of accelerated nuclear decay. It also relieves the need to have some 4 Ga worth of nuclear decay take place before plants are created on Day 3 of Creation Week. It also sweeps away the problem of a high concentration of radioactive elements in the continental crust at the time of the Flood and high radiation levels arising from these elements as a consequence of the accelerated nuclear decay during the Flood. To be sure, these are not minor issues. I commend the author for seeking so earnestly to find solutions to them.

However, there are good reasons why the RATE team and those of us who have worked on the issues associated with CPT have not entertained Stenberg's two main theses in a serious way. The foremost ('elephant in the room') reason has to do with the actual record of radioisotope-decay history written within the rocks of the continental crust.

What does the record of radioisotope decay tell us?

Zircon, $ZrSiO_4$, a uranium-bearing primary mineral that is incorporated into the structure of an igneous rock when it crystallizes, has proved to be especially well suited in recording the history of nuclear decay.[3] These durable crystals can record a rock's nuclear decay history all the way back to when the rock originally crystallized, provided there has been no subsequent metamorphic event to interfere. Many of the continental granitic rocks outside the tectonic belts appear not to have experienced any significant metamorphism in their history. A compilation of U–Pb zircon ages from such granitic regions reveals that some 75% of the earth's continental area has a uniformitarian age greater than 1.5 Ga.[4] Age determinations by the RATE team for granitic rocks in New Mexico and Wyoming agree with these findings.[5] Zircons displaying more than 4.4 Ga have been reported from crustal rocks found in Western Australia.[6] Moreover, the same distribution of zircon ages as found in the granitic rocks themselves is also found in detrital zircon grains contained in the sands at the mouths of the major rivers of the world.[7]

When did this nuclear transmutation occur relative to the Flood?

Most creationist geologists point to the widespread erosional discontinuity in the geological record commonly known as the Great Unconformity as marking the Flood's abrupt onset.[8] The age assigned to this unconformity is only slightly more than the U–Pb age of the earliest Cambrian rocks, which is 542 Ma.[9] But when did the transmutation responsible for uniformitarian ages between about 550 Ma and 4400 Ma in the rocks take place? Logically it must have been before the Flood. Moreover, the case seems strong that the earth's continents came into being during Creation Week. In Genesis 1:9 God declares, "Let the waters below the heavens be gathered into one place, and let the dry land appear." The dry land seems to equate to the continental portions of the earth's surface still in existence today. These regions are clearly distinguished by their layer of granitic crust, typically 35–40 km in thickness. These crustal rocks contain U and Th locked within primary minerals such as zircon and monazite and also abundant K in the primary mineral orthoclase, $KAlSi_3O_8$. Such primary minerals almost certainly had to be present from the time these rocks crystallized; that is, from Creation Week forward. This, of course, directly challenges Stenberg's conjecture that prior to the Flood essentially all the earth's inventory of U, Th, and K was in the mantle. Moreover, the only plausible interval during which such a large amount of nuclear decay before the Flood could have occurred is during Creation Week before God created plant life. This challenges Stenberg's second conjecture; namely, that essentially all the nuclear decay that has occurred during the solar system's history took place during the Flood.

The bottom line

The implication is that most of nuclear transmutation we find recorded in the earth's rocks accompanied God's creation of the physical earth, early in Creation Week, and not the Flood. The fact that most of today's large inventory of U, Th, and K in the continental crust is locked into its primary minerals strongly implies that these elements have resided within the continental crust—and not the mantle, since God, on Day 3 of Creation Week, declared, "Let the dry land appear."

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Don Stenberg replies:

I appreciate John Baumgardner's respectful and insightful reply to my article. As I said in my article, I have the highest respect for John as a person and great appreciation for how his efforts at RATE and his Flood modelling have greatly advanced our common cause. In stating why he and the RATE team previously considered and rejected some of the assumptions underlying my model, he gave essentially two reasons. The first reason was that zircon crystals seem to have undergone at least a significant portion of their accelerated radioactive decay in the crust, not in the mantle as I proposed in my paper. The second reason was that most Flood geologists agree that the geological event that produced the Great Unconformity, conventionally dated to ~550 Ma, is the beginning of the Flood. I believe there are answers to these objections, and I offer my following brief thoughts for consideration.

The first objection, the apparent decay of 1.5+ Ga of uranium into lead in zircons located in the crust, can be answered by pointing out that the conditions of zircon formation during an episode of accelerated decay are much different than assumed by uniformitarian geologists. Uranium decays through many other elements before finally decaying into stable lead, and during accelerated decay the relative abundances of those shorter half-life intermediate daughter products would be much higher in uranium than commonly assumed. Indeed, one of RATE's findings was that long half-life elements underwent a much more dramatic accelerated decay than shorter half-life elements. So the molten rock that produced the zircon crystals actually would have contained significant quantities of these intermediate isotopes. Many of these isotopes would have been incorporated into the zircon crystals during their formation along with the uranium, making it appear as though more uranium had decayed in place than really occurred. For example, one of the common 'impurities' in zircon crystals is Thorium, which is actually produced twice during the U-238 decay chain (as Th-234 and Th-230). Thus, much Thorium would have been produced by radioactive decay prior to the formation of the zircons and would have been incorporated into them as they formed. It is likely that other intermediate decay isotopes were also incorporated into zircon crystals but subsequently decayed to lead during accelerated decay. In sum, I believe that much of the radioactive decay recorded in these zircons actually took place in the upper mantle before they cooled and crystallized; much more than one would assume based on uniformitarian assumptions about zircon formation.

But that doesn't fully answer the objection. This is because, although in both of our models there had to be a rapid cooling of oceanic crustal rocks during and after the Flood, I am arguing that many of the rocks which make up the continental crust cooled rapidly as well. But perhaps the intense global rain that accompanied the Flood can take care of that problem. A simple calculation which, taking the highest recorded rate of rainfall on Earth, and then applying that over the whole Earth for a whole year, yields a maximum amount of heat transferred out of the crust via water heating and boiling/evaporating and condensing as rain of ~3×10^{29} J. The amount of energy needed to cool the entire crust from 5000 K to 400 K is 'only' ~7×10^{28} J. So there would be some cooling capacity from intense global rain left after that cooling to remove some heat due to accelerated radioactive decay in the crust near the end of the Flood. But this energy must have ultimately gone somewhere—could it have left the planet as electromagnetic radiation? [1] I suggest that future creationist research be directed toward the question of how it would have been possible for the atmosphere to support intense global rainfall—I believe this is the final piece of the heat problem puzzle.

The second objection points out an important distinction between our models. Baumgardner believes that the Great Unconformity (~550 Ma conventionally dated) was caused by the initiation of the Flood. However, there are reasons to treat this claim with caution. My biggest difficultly with it is that it places the life, death, and fossilization of certain life-forms such as stromatolites[2] (~3.5 Ga conventional) before the creation of the first life, namely plants, on Day 3 of creation. I view this as a significant weakness of Baumgardner's interpretation of the Great Unconformity as the beginning of the Flood.[3] In my view, these stromatolites were most likely buried near the beginning of the Flood, possibly by underwater mud slides. So I believe it is evidence that the Flood began shortly after a single large (~4.5 Ga apparent) accelerated decay episode began. As I pointed out in my paper, a major weakness of Baumgardner's related assertion that ~4 Ga of accelerated decay took place prior to Creation Day 3 is that this decay would then have preceded the creation of the moon, but moon rocks have been conventionally dated to about 4.5 Ga, showing that they have experienced approximately the same amount of accelerated decay as the earth has in total.

So then, is there an explanation of why we see radioactive isotopes in the crust today that is consistent with my model? I believe so. First, if the earth was solid before the Flood, then it would not have been necessary for ~35-km-thick continental crust to have been 'floating' on the mantle; the land areas wouldn't have been floating on anything; they would be sitting firmly on the underlying solid rock (Psalm 104:5–9). But then, during the Flood, I am proposing that much material containing radioactive isotopes was added to the crust. Thus, radioactive isotopes in the present crust do not present a problem for my model. Indeed, my paper tried to explain how this was possible and I proposed that a significant portion of the granitic crust actually separated out from the mantle during the Flood when the earth 'melted' (Amos 9:5–6, Psalm 46:1–6). Thus, the presence of radioactive elements in the crust right now does not mean that they were there from Creation; known physical and chemical laws[4] operating during the Flood could have brought about what we observe today.

How then do I interpret the Great Unconformity, as seen for instance in the Grand Canyon? First, I interpret the basement rocks of Grand Canyon as early- to mid-Flood igneous rocks, which were overlain by the Grand Canyon Supergroup sedimentary rocks sometime mid Flood. Then, I believe there was a powerful collision of continents during one of the Wilson supercontinent cycles, which I believe took place during the Flood; this collision caused these rocks to tilt at a high angle and they quickly eroded, similar to an episode of mountain formation. Finally, in the mid to late Flood the sedimentary 'Paleozoic' rocks were laid on top of these tilted layers. This reconstruction fits my model well, and I believe it avoids some of the problems with alternate models as mentioned above and in my paper.

In conclusion, I appreciate Dr Baumgardner's reply, but I do not believe that his objections are actually problems for my model. I hope that my response has clarified my model, and that it has contributed to the ongoing search for a Flood model that does a good job of handling all of the data we have.

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