Fission Tracks in Crystalline Solids

Evidence for Accelerated Radioisotope Decay Within a Biblically Based Model

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Highlights

- Nuclear fission—atom splitting—is used to date ancient rocks.
- The various fission dating methods show results that are not only highly inconsistent with each other, they also don't match the dates secular scientists expect.
- It appears that neither fission dating nor the other dating methods have yet provided accurate results.

Have you ever pulled apart a large mass of taffy and watched it break into two approximately equal masses? This is an illustration of what happens in the subatomic world when a ^{238}U or ^{235}U atom undergoes *splitting*, or *fission*. Nuclear fission is often used to date rocks to millions or billions of years old. But are these methods valid?

The Basics of Nuclear Fission

There are two basic types of nuclear fission. The first is *spontaneous fission* in which the nucleus becomes unstable and splits into fragments without the intervention of an outside agent. The second is *induced fission* in which an outside agent (such as a moving neutron) induces the nucleus to break apart.

Sometimes a nucleus splits into approximately equal halves (e.g., $^{110}Pd + ^{110}Pd$) and sometimes into unequal parts (e.g., $^{92}Kr + ^{141}Ba$). In both cases, free neutrons are released. The yield of particular isotope fragments from this process can be approximately predicted using a formula developed by Rudstam[1,2] and adapted to a computer program called FREYA by Vogt and Randrup.[3]

How Is Nuclear Fission Used for Dating?

Crystals often contain trace amounts of radioactive atoms. When these atoms split, the resulting fragments, like tiny bullets, damage the surrounding crystal, leaving "tracks" of damage that show the trajectories of the fragments. Similar to radiohalos, these tracks are a permanent record of nuclear decay within crystalline solids. The phenomenon of nuclear fission is mostly observed in high mass nuclei such as ^{235}U and ^{238}U. Wagner, et. al.,[4] published a value for the spontaneous fission decay constant, i.e., $8.7 \pm 0.6 \times 10^{-17}$ yr^{-1} that is somewhat smaller than that obtained by Shultis and Faw.[5] Nasser, et. al.,[6] document the spontaneous fission decay constant for ^{238}U as 7×10^{-17} yr^{-1}. Clearly there is some ambiguity concerning the spontaneous fission decay constant for ^{238}U. One thing that does seem clear is that the spontaneous fission decay constant is over 7 orders of magnitude smaller than the alpha decay constant for ^{238}U of 1.55125×10^{-10} yr^{-1}.[7]

Much like alpha particles from ^{238}U decays, fission fragments leave tracks in any mineral where the phenomenon occurs. If the mineral stays below its annealing temperature, then those fission tracks will remain during that timeframe and can be counted under a microscope. The number of fission tracks counted then provides us with the number of ^{238}U spontaneous fission decays which have occurred since the last cooling event for the mineral (theoretically, when the crystal formed).

The total number of ^{238}U spontaneous fission decays (D) in a given volume of the mineral can be represented by:

$$D = {}^{238}U\left(e^{\lambda_f t} - 1\right) \qquad (1)$$

where: D = number of spontaneous fission decay events per cm^3 of the sample.
^{238}U = number of ^{238}U atoms per cm^3 in the sample at the present time.
and, λ_f = the decay constant for spontaneous fission decay of ^{238}U.

It should be noted that this equation is different from the foundational equation given in *Principles of Isotope Geology, Second Edition*.[8] That equation uses the alpha decay constant (λ_α) rather than the fission decay constant (λ_f). The author of *Principles* attempts to correct this by adding the fraction $\lambda_f / \lambda_\alpha$ as a multiplier of the parentheses. To first order this works, but becomes an increasingly bad approximation with increasing ages.[9] At 100 million years, the error is approximately 1% and at 1 billion years, just from this approximation, the error becomes approximately 8%.

In order to derive an age from the process of spontaneous fission decay in a mineral containing ^{238}U, several prerequisite conditions must exist during the formation and preservation of the mineral. They are:[10]

- The distribution of both ^{238}U and ^{235}U is uniform in the crystal counted.
- No other isotopes which undergo spontaneous fission are present in sufficient number to be a contributor to the observed fission tracks.
- Induced fission of ^{235}U due to thermal neutrons from the spontaneous fission of ^{238}U are not significant.

The condition concerning a uniform distribution of ^{238}U and ^{235}U throughout the mineral crystal examined could become problematic if the mineral cooled too rapidly to reach an isotropic distribution.[11]

The dating process for a particular crystal (mineral grain) begins with the counting of spontaneous fission tracks under a microscope. The density of spontaneous tracks is then approximately given by:

$$\rho_s = Dq \qquad (2)$$

where: ρ_s = number of fission tracks per cm^3.
q = fraction of tracks which cross the polished surface of the counted mineral grain.

Clearly there will be some ambiguity in determining q due to the fact that the fission fragments are emitted in all possible directions from each decay.

Next the concentration of ^{238}U needs to be determined. After the spontaneous fission tracks have been counted, the crystal is heated to "erase" the spontaneous fission tracks. It is then irradiated with thermal neutrons to induce fission in the ^{235}U contained in the crystal. Assuming both the ^{238}U and ^{235}U are uniformly distributed in the crystal, one can then write an equation to describe the density of the induced fission tracks (ρ_i):

$$\rho_i = {}^{235}U\varphi\sigma q \qquad (3)$$

where: ^{235}U ≡ the concentration of ^{235}U in the crystal in atoms per cm^3.
q ≡ is the same q as defined for the spontaneous fission tracks above.
φ ≡ is the thermal neutron flux in neutrons per cm^2.
σ ≡ is the cross section for induced fission on ^{235}U in cm^2.

Combining equations (2) and (3) and setting *I* equal to the presently known value for the ratio $^{235}U/^{238}U$ we obtain the age equation:[12]

$$t = \frac{1}{\lambda_f}\, ln\left[1 + \left(\frac{\rho_s}{\rho_i}\right)\varphi\sigma I\right] \qquad (4)$$

Using known numbers for the current values of λ_f, σ, and *I* and the measured values of φ, ρ_s, and ρ_i one can theoretically calculate the age (t) of the crystal when t is less than 500 million years. Uncertainties in the decay constant for spontaneous fission (λ_f) and measurement difficulties in establishing the neutron flux (φ) have led to a calibration effort to avoid these problems called the Zeta Calibration[12] method. In essence, this method uses crystals of known ages (dated by other isotopic methods) to replace φ, σ, *I*, and λ_f in equation (4) under the same irradiation conditions. However, under this methodology, fission track dating is no longer an independent determination of the age of a crystal. Please see reference 8 for the details of this methodology.

What Do the Data Suggest?

Important questions must be asked about nuclear fission dating methods. Are they reliable? Do they agree with each other? The Institute for Creation Research performed an extensive study on radiometric dating methods called *Radioisotopes and the Age of the Earth* (RATE).

A full summary of the fission track dating results from RATE can be found on pages 218 and 238 of reference 13, available online. The published ages are taken from various professional journals such as references 14 and 15. Table 1 in this article compares the results of three different dating models based on that data.

What do these results say about the secular models? Mostly they say the dating methods are inconsistent with each other. The U-Th-Pb and fission track data show a wide range of ages for Middle Cambrian rock strata and are thus highly discordant. Discordances are also observed within the fission track data from the Late Jurassic rock strata. Although the fission track data for the Early Miocene in the Cenozoic are clustered better than that for the Middle Cambrian and Late Jurassic samples, they still display some discordance.

This discordance means that the U-Th-Pb and fission track dating methods give wildly different dates for the zircon samples measured, most of which strongly diverge from the secular age expected for the Middle Cambrian rock. Similarly, the fission track dating for the Late Jurassic samples gives results that diverge from the expected geologic age.

Zircon samples from the Early Miocene samples give dates closer to those of conventional geology, but there is still some significant variation. About the only reasonable conclusion that can be drawn from the secular models is that the current dating models give highly differing results for the zircon samples from the same rock suite and, using the central age of the sample groupings,[5] there were between 125 and 200×10^6 years of decay, at today's decay rates, which occurred during the Middle Cambrian and Late Jurassic.

Within the framework of a biblically based model for creation, the data from reference 5 clearly show there must have been a period of accelerated decay sometime in the past, most likely during the Flood year. The decay rate of ^{238}U appears to have gradually increased from the Middle Cambrian through the Late Jurassic and then began to decrease on or before the Early Miocene until it stabilized at the decay rate we observe today. Note how the Early Miocene data show reduced decays as the decay rate may have slowed and stabilized.

In fact, the RATE results seem to suggest an ebb and flow of volcanic activity from the Middle Cambrian through the Late Jurassic systems[16] that carried zircon crystals experiencing varied amounts of accelerated nuclear decay to crustal rock during the early and midstages of the Flood. A model based on the Genesis Flood better explains these volcanic units if they occurred rapidly one after another during a short time frame while experiencing varying accelerated decay rates and significant mixing of the rock crystals contained therein.

Conclusion

Reviewing results of nuclear fission dating methods yields a simple result: They disagree with both each other and secular expectations on the ages of the geologic column. In addition to the many inherent problems with radiometric dating,[17] we can conclude that no dating method so far can yield accurate absolute-time results.

References

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2. Rudstam, G. et. al. 1990. Yields of products from thermal neutron-induced fission of 235U. *Radiochimica Acta*. 49 (4): 155.
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5. Shultis, J. Kenneth; Richard E. Faw (2008). *Fundamentals of Nuclear Science and Engineering*. CRC Press, 141. Table 6.2. https://en.wikipedia.org/wiki/Spontaneous_fission
6. Naeser, N. D., Naeser, C. W., McCulloh, P. H. 1989. The application of fission-track dating to the depositional and thermal history of rocks in sedimentary basins. In *Thermal History of Sedimentary Basins*. Edited by N.D. Naeser and T.H. McColloh. Springer-Verlag, Berlin, 157-180.
7. The decay constant (λ) is a mathematical way of expressing how many decays of a specific type occur in an assembly of a given radioisotope during a specific period of time. An assembly of ^{238}U atoms can undergo two different types of decay. They can decay by emitting an alpha particle or they can decay by spontaneously breaking apart into two or more different elements (fission). They are 10^7 times more likely to decay via alpha decay than they are by fission decay.
8. Faure, G. 1986. *Principles of Isotope Geology, Second Edition*. John Wiley & Sons, Inc., 344.
9. 9. If the expression in *Principles of Isotope Geology* and the correct expression both expand the exponential function by a Taylor series expansion, then the first term for the number of fission events are the same, i.e., $D = {}^{238}U \cdot \lambda_f t$. However the two expressions begin to differ in the second and subsequent terms of the series expansion. The second term for the correct formula would be $D = {}^{238}U \cdot \{ \lambda_f t + (\lambda_f t)^2/2! + \quad \}$ and for the formula in *Principles* $= {}^{238}U \cdot \{\lambda_f t + (\lambda_f \lambda_\alpha t^2)/2! + \quad \}$. We see that the two formulas have the same first term but different second, third and so on terms. This causes the formula in *Principles* to eventually give different results for the number of fission decay events per cm^3 in the zircon samples.
10. Snelling, A. A. 2005. Fission Tracks in Zircons: Evidence for Abundant Nuclear Decay. *Radioisotopes and the Age of the Earth*. L. Vardiman, A. Snelling, and E. Chaffin, eds. Institute for Creation Research, El Cajon, CA, 297.
11. Carnegie Institution for Science. 2018. Yosemite granite ‘tells a different story’ story about Earth’s geologic history. https://www.sciencedaily.com/releases/2018/06/180627160430.htm
12. Faure, G. *Principles of Isotope Geology*, 245.
13. Snelling, A. A. 2005. Fission Tracks in Zircons: Evidence for Abundant Nuclear Decay. In *Radioisotopes and the Age of the Earth: Results of a Young-Earth Creationist Research Initiative*. L. Vardiman, A. Snelling, and E. Chaffin, eds. El Cajon, CA: Institute for Creation Research.
14. Faure, G. 1986. *Principles of Isotope Geology*, *Second Edition*. New York: John Wiley & Sons, 271.
15. Nielson, J. E. et al. 1990. Age of the Peach Springs Tuff, southeastern California and western Arizona. *Journal of Geophysical Research*. 95 (B1): 571-580.
16. This conjecture is based on two factors: 1) that the decay rate began to accelerate in the upper mantle magma and progressed rapidly into the crust, and 2) that the violent upheavals during the early stages of the Flood mixed crystals with varying amounts of accelerated decay, thus generating the observed large age divergence of crystals from the Middle Cambrian and Late Jurassic. If true, this phenomenon would have had some dependence on location in the earth as well.
17. Cupps, V. R. 2019. *Rethinking Radiometric Dating: Evidence for a Young Earth from a Nuclear Physicist*. Dallas, TX: Institute for Creation Research.

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Sample Designation (# Samples)	Secular Time Frame	Secular Dating Method	Secular Date Range (x 10^6 yrs.)	Stratigraphic Age Range (x 10^6 yrs.)	Fission Track Age Range (x 10^6 yrs.)
MT-3 (6)	Middle Cambrian	^{238}U-Pb, ^{235}U-Pb, and ^{207}Pb-^{206}Pb	74.6–1621.2	509–497	68.4–473.5
MT-2 (20)	Middle Cambrian	*None*	*Not measured*	509–497	34.9–611.2
TT-1 (6)	Middle Cambrian	^{238}U-Pb, ^{235}U-Pb, and ^{207}Pb-^{206}Pb	86.0–1682.0	509–497	48.0–914.3
NMF-64 (20)	Mesozoic-Late Jurassic	*None*	*Not measured*	148–201	93.1–651.3
NMF-49 (9)	Mesozoic-Late Jurassic	*None*	*Not measured*	148–201	113.6–343.1
BMF-14 (20)	Mesozoic-Late Jurassic	*None*	*Not measured*	148–201	98.2–689.9
BMF-28 (19)	Mesozoic-Late Jurassic	*None*	*Not measured*	148–201	104.2–592.3
MMF-1 (20)	Mesozoic-Late Jurassic	*None*	*Not measured*	148–201	87.6–1036.2
MMF-4 (18)	Mesozoic-Late Jurassic	*None*	*Not measured*	148–201	114.6–233.5
PST-1 (20)	Cenozoic-Early Miocene	*None*	*Not measured*	~ 20	17.0–34.5
PST-2 (20)	Cenozoic-Early Miocene	*None*	*Not measured*	~ 20	16.4–27.3
PST-3 (20)	Cenozoic-Early Miocene	*None*	*Not measured*	~ 20	17.3–29.3

Table 1: Comparison of various dating methods from Snelling, Fission Tracks in Zircons.

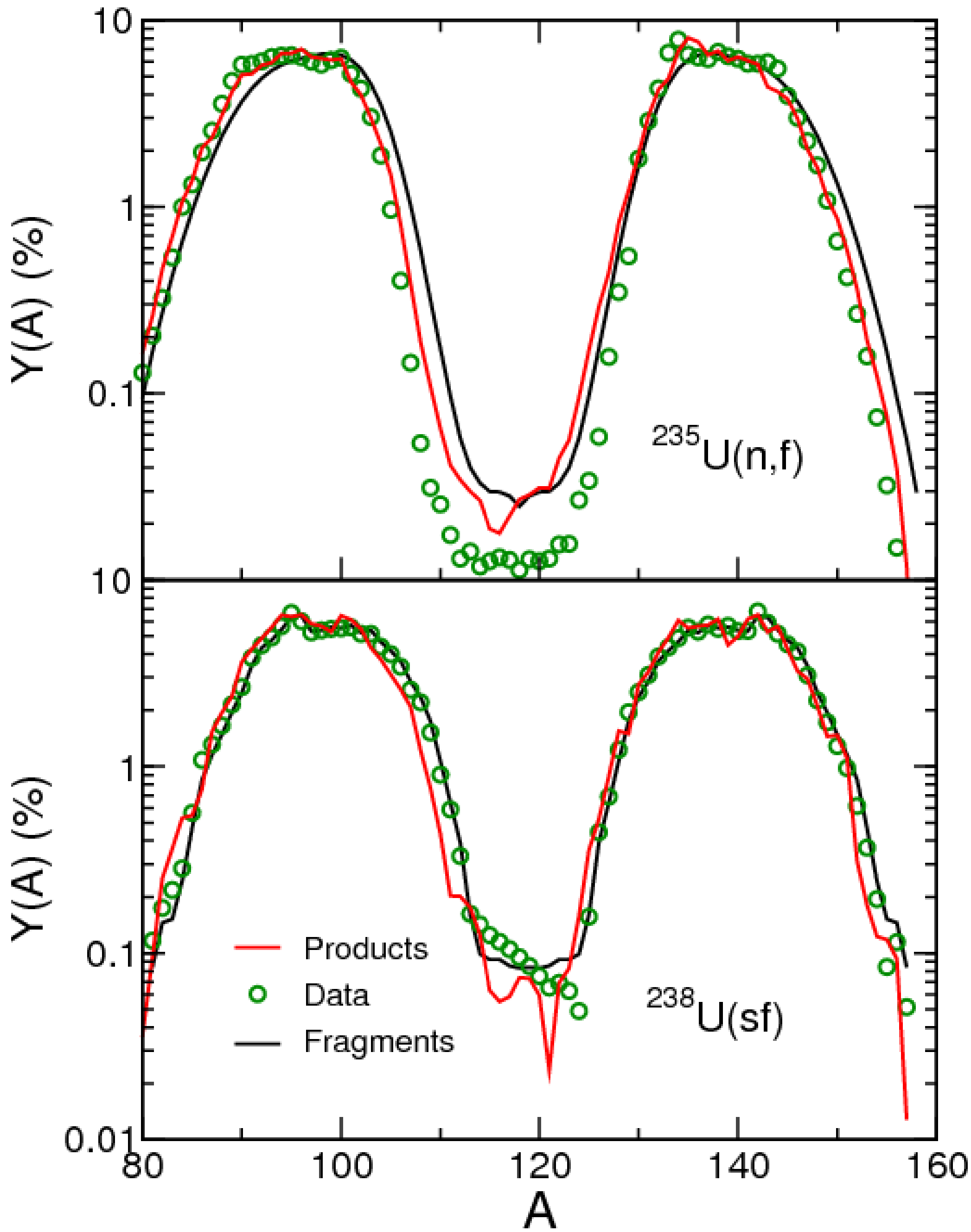

Figure 1: Predictions from the Rudstam formula for approximate production of various isotopes from fission of ^{235}U and ^{238}U compared to actual experimental data. Actual experimental data is shown as hollow green dots. The black curves are the 5-Gaussian fits to the fragment distributions while the red curves are the results after neutron emission. A is the atomic mass number and Y(A)(%) is the percent yield from each fission reaction for a given isotope with mass number A.