My Path into Dating of the Shroud

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Sometimes small events in our lives can lead to our future focus and accomplishments. When I was 12 or 13 years old, my mother took me and my brother to Hudson's in downtown Detroit. At that time, it was the second largest department store in the United States next to Macy's in New York. It covered an entire city block and was 25 stories high, the tallest department store in the world. My mother took us to one of the upper floors filled with books and told us she would buy each of us one book of our choice. I chose a physics book which was written in simple terminology and concepts I could understand. After my paper route every Sunday morning, I gradually read through every chapter. The process of thinking through scientific evidence to explain various experimental results fascinated me. It reminded me of the brainteasers, both logical and mathematical, that were occasionally presented in my class at school. The challenge of solving mysteries excited me.

Another important event happened about the same time. Inserted in each Sunday paper was a magazine called *Parade*. As I flipped through one of its issues, I noticed a small grainy picture about 3 cm (1.2 inches) high of a strange face with long hair. A short description, perhaps only three or four sentences long, ended with, "The Shroud of Turin is believed by some to be Jesus' burial cloth". This astonished me. I had never heard of the Shroud of Turin and never considered his burial cloth could still be in existence. At the time, I thought this could not possibly be true, because if it were, it would be so famous everyone would know about it. I never forgot the picture and later decided I should investigate it further. A girl my age, on the other side of the country, also saw the picture in the magazine. Ten years later we met in San Diego and were married.

The last chapter in the physics book was on nuclear physics. It was the most interesting. As a result, I decided to make nuclear physics my life's work. This early decision guided my choices and motivated my studies. I chose to go to the University of Michigan because of its excellent nuclear engineering program. I completed BS and MS degrees then started my first job at General Atomics in San Diego, California.

At General Atomics I developed my skill in running various types of nuclear analysis computer software. I used this software to calculate the concentration of neutrons (neutrons per cm^3) in various types of advanced nuclear reactors (GCFR, HTGR, TRIGA). For a few years, while continuing my nuclear analysis of reactors, I also managed a small group involved in statistical analysis of nuclear measurements. As the speed of computers rapidly increased, I transitioned from using the simpler but more restrictive diffusion and transport theory software to the latest Monte Carlo theory software called MCNP (Monte Carlo N-Particle) developed at the Los Alamos National Laboratory in New Mexico. Previous nuclear software used equations to calculate the concentration of neutrons at points defined by the user, but MCNP operates by following one neutron at a time as it interacts with atoms in the various materials in the model.

The advantage of MCNP over the previous nuclear software is that it produces accurate results for models that include voids or near voids such as air inside a tomb surrounding a body. Due to gradual reductions in funding related to my work, I left General Atomics to become an independent consultant at various locations in the United States using MCNP to perform criticality safety calculations related to nuclear fuel production, storage, and disposal. I retired in 2011 after working 38 years in the nuclear industry. I did not realize at the time how useful this experience would be for research on the Shroud. It prepared me to run nuclear analysis computer software such as MCNP for analysis of the carbon dating problem and to understand basic statistical analysis of experimental measurements such as the 1988 carbon dating of the samples.

The 1988 Carbon Dating of the Shroud

During these busy work years, I started collecting information about the Shroud. The first book I read was "Is this the Face of Jesus? IT IS THE LORD" by Peter M. Rinaldi, S.D.B., 1972. I then read "Verdict on the Shroud, Evidence for the Death and Resurrection of Jesus Christ" by Kenneth E. Stevenson and Gary R. Habermas, 1981. This book included results of the 1978 Shroud of Turin Research Project (STURP), which convinced me it was likely the authentic burial cloth of Jesus. However, later carbon dating of the Shroud challenged this conclusion. In 1988, three samples were cut from the lower corner of the cloth for analysis. The paper reporting the results [1] was published in 1989 in the peer reviewed journal *Nature*, but the conclusion had leaked out earlier. When I learned the Shroud was dated from 1260 to 1390 AD with a 95% confidence, I was shocked and mystified. If this were true, then how could all the STURP evidence that pointed to its authenticity be explained? In bewilderment, I delayed reading the paper for a few years, but finally went to the library and found a copy in the back room. I carefully read it to understand how they had: 1) performed the C^{14}/C^{12} measurements, 2) analyzed the measurement data to arrive at the uncorrected average value for the three samples of 1260 ± 31 AD, and 3) obtained the corrected range of 1260 to 1390 AD with a 95% confidence.

When I finished reading the report, I sat there for two or three minutes evaluating the issues, then it occurred to me the 1260-1390 date appeared contradictory. On the cloth, the nail wound was in the wrist, which caused the thumbs to be folded under the palms, contrary to paintings from this period. But how could carbon dating produce a date to 1260-1390 if the cloth was authentic, i.e., from about 33 AD? Fortunately, at that point in my life, I had several years' experience in performing nuclear measurements and statistical analysis of the measurement data. I also had 20 years' experience in performing computer calculations of neutron concentrations in nuclear reactors, so I was in the habit of thinking in terms of neutron interaction with matter.

Thinking logically, if the Shroud was Jesus' burial cloth, and if Jesus's dead body experienced a unique phenomenon while wrapped in the Shroud as the Gospels indicate, then the linen cloth could also have been affected. It occurred to me that perhaps such a unique phenomenon could have involved the body emitting radiation such as electromagnetic radiation (infrared, visible light, or ultraviolet) or particle radiation. This particle radiation could have included rapidly moving neutrons, protons, or electrons because a human body is made of atoms which contain these three particles. A 77 kg (170 lbs) human body contains about 2 x 10^{28} of each of these particles. If in the process of this unique phenomenon, radiation was emitted from the body as it was wrapped in the Shroud, and if every part of the body experienced this same process, then it would be reasonable to assume every tiny volume within the body emitted an equal amount of radiation, possibly including neutrons. Under this assumption, a larger volume within the body such as the abdomen would emit more neutrons than a smaller volume such as a toe, but they would both emit the same number of neutrons per cubic centimeter.

Thinking in terms of neutron interaction with matter, it quickly occurred to me that absorption of neutrons in various atoms would have produced new C^{14} in the fibers of the linen cloth. This new C^{14} would shift the measured carbon date forward, so the carbon dating process would produce an apparent date that was more recent than the true date. This concept was previously documented by Tom Phillips [2], though I was not familiar with his work at the time. To understand why neutron absorption would affect the results of carbon dating, it is helpful to understand the basics of the carbon dating process. Carbon dating is done by measuring the C^{14} to C^{12} ratio of samples from the item of interest. This is done because C^{14} decays with a 5730-year half-life, which means in 5730 years only half of the initial C^{14} would still exist. Since C^{12} is stable, i.e., does not decay, the C^{14} to C^{12} ratio of any material containing carbon will gradually decrease as the C^{14} decays. This permits the C^{14} to C^{12} ratio to be used as a clock to produce what is called the "carbon date", also referred to as the "radiocarbon date". After the C^{14} to C^{12} ratio is measured, the carbon date can be calculated assuming the C^{14} to C^{12} ratio only changed due to the decay of the C^{14}. But if new C^{14} atoms were produced on an item due to neutron absorption, then samples from the item would be measured to have a higher C^{14} to C^{12} ratio than it would have otherwise, so would produce a more recent carbon date than its true date.

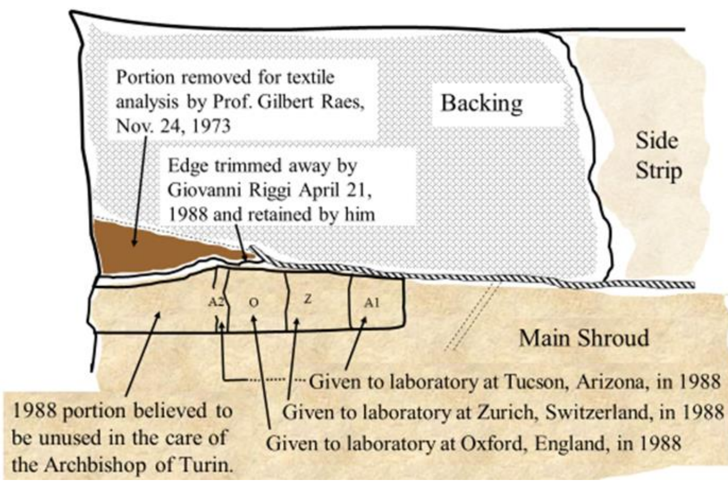
Since the Shroud was made of linen threads made from the long stems of the flax plant, it would contain much carbon. During the life of the plant, it would be taking in carbon (C^{12}, C^{13}, and C^{14}) during photosynthesis and an equilibrium C^{14} to C^{12} ratio would be established with the amount of C^{14} being lost by decay compensated by the amount of C^{14} being taken in by photosynthesis. When the plant was cut down, it would die causing photosynthesis to cease. The C^{14} to C^{12} ratio would then decrease due to decay of the C^{14}, so that measurement of the C^{14} to C^{12} ratio could be used to calculate when the flax plant was cut down. However, as pointed out above, if new C^{14} were produced in the Shroud by neutron absorption, then the experimentally determined carbon date would be more recent than the true date.

There are three mechanisms by which new C^{14} can be produced by neutron absorption, but the most common (96% of the total) for the Shroud is the [N^{14} + neutron produces C^{14} + proton] reaction. Thus, if a large number of free neutrons, i.e., neutrons not bound in the nuclei of atoms, were released into the tomb, then a small fraction of these neutrons would have been absorbed in the trace amount of nitrogen in the cloth fibers. This would produce new C^{14} in the Shroud, which would shift the carbon date forward. To shift the carbon date forward by neutron absorption from the time of Jesus, about 33 AD, to 1260-1390 AD only requires the C^{14} concentration in the samples to be increased by 16.9%.

As I continued to focus on the paper [1], the next question was how I could use the data in the paper to test the possibility that neutron absorption would explain a shift in the carbon date from

33 AD to 1260-1390 AD. I knew that in 1988, the samples were cut from the lower corner of the cloth. Since carbon dating is a destructive process, separate samples were cut from the Shroud so one could be sent to each of the three laboratories in Tucson, Arizona, in Zurich, Switzerland, and in Oxford, England. To send at least 50 mg to each laboratory, two pieces (A1 and A2) were sent to the laboratory in Arizona. The pieces were cut from the cloth next to one another, so had slightly different locations as shown in Figure 2. This difference in location could have caused a variation in the number of neutrons absorbed by each piece, which would have shifted the carbon date forward by a different amount for each sample.

Figure 2. Samples Were Cut from the Lower Corner of the Shroud in 1988



With my experience in calculating neutron concentrations (neutrons per cm^3), I thought I could make a reasonable estimate of the neutron concentration in the Shroud that would result if every cubic centimeter of the body released the same number of neutrons, as I assumed above. Based on my experience, I believed the neutron concentration in the cloth would be greatest toward the center of the body and would decrease toward the head and toward the feet. Later computer calculations proved this to be true. The important point is that the neutron concentration should have varied across the area cut from the cloth in 1988. According to this concept, the neutron concentration should have been greater across sample A1 sent to Tucson than across sample O sent to Oxford (Figure 2). This would have created a greater amount of new C^{14} on the Tucson sample than on the Oxford sample, which would have shifted the carbon date further forward for the Tucson sample than for the Oxford sample. Thus, the Tucson sample would carbon date more recently than the Oxford sample, with the Zurich sample carbon dating in between.

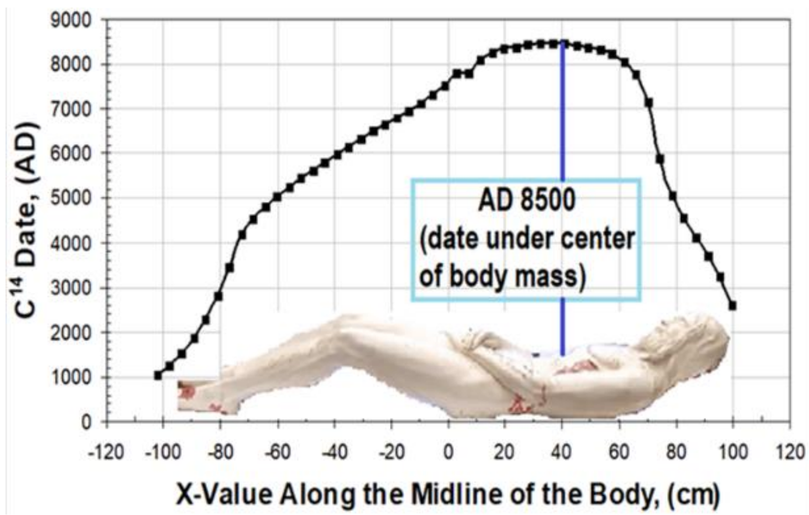
With this prediction, I excitedly turned back to the paper to check the carbon dates they had experimentally determined. I found the measured carbon dates agreed with this prediction, with the Oxford sample the oldest (1200 AD ± 30), the Zurich sample in between (1274 AD ± 24), and the Tucson sample the most recent (1304 AD ± 31). This fulfillment of my prediction encouraged me to believe that the explanation of the Shroud's carbon dating to 1260-1390 was neutron emission from the body and neutron absorption in the Shroud.

<u>Computer Calculations</u>

Though I realized this in about 1992, I was busy with my other responsibilities. Also, the nuclear analysis computer codes I was working with in the 1980s and 1990s were not adequate to model a human body in an air-filled limestone tomb, and the computers were too slow to perform calculations with the more flexible Monte Carlo codes. It took many years to resolve these issues. In 2014, I finally had time to run a long sequence of nuclear analysis computer calculations with the MCNP (Monte Carlo N-Particle) software on my desktop computer. In these calculations, I modeled a human body, using simple geometrical volumes, wrapped in a linen cloth in an air-filled limestone tomb as it would have been constructed in first century Jerusalem according to archeologist Leen Ritmeyer (https://www.ritmeyer.com/2010/11/27/the-tomb-of-jesus/comment-page-1/). I ran over 400 MCNP calculations to cover the range of uncertainties involved, with each calculation taking between 6 and 13 hours on my desktop computer. In these calculations, I specified that MCNP follow 30 million neutrons to make the calculations accurate. The results were consistent with my expectations discussed above. They were first presented at the Shroud conference in St. Louis in 2014 and are shown in Figure 3.

This solution to the carbon dating of the Shroud is called the neutron absorption hypothesis, and is documented in my paper 25, with a simplified version in paper 30, on the research page of my website www.shroudresearch.net.

Figure 3. Carbon Date Calculated by MCNP on the Dorsal Image Along the Centerline of the Body



Conclusion

If the image on the Shroud was formed by a process that included radiation from the body, as many Shroud researchers believe, and if neutrons were included in this radiation, then absorption of neutrons in the linen fibers could explain the carbon dating of the Shroud to 1260-1390 AD. I believe this is the best explanation for the 1260-1390 date because it is the only hypothesis that can explain the four things we know about carbon dating as it relates to the Shroud: 1) a carbon date of 1260-1390 at the sample location, 2) an increase in the carbon date of about 36 years per cm (91 years per inch) at the sample location, 3) the distribution and range of the carbon dates obtained for the various subsamples, and 4) a carbon date of 700 AD for the Sudarium of Oviedo, which is believed to be the face cloth of Jesus and thus related to the Shroud. Relative to the time of Jesus, the carbon date for the Sudarium (700 AD) was shifted forward less than the carbon date for the Shroud (1260-1390 AD) because, according to the Gospels, it was located a distance from the body (the source of the neutrons) whereas the Shroud was wrapped over the body. The invisible reweave hypothesis, under the right assumptions, can explain #1 and #2 but not #3 and #4.

References

1. P.E. Damon, and 20 others, "Radiocarbon Dating of the Shroud of Turin", *Nature*, February 16, 1989.
2. Thomas J. Phillips, "Shroud Irradiated with Neutrons?", Nature, Vol. 337, No. 6208, page 594, February 16, 1989, published in the same edition of *Nature* as Damon.

Short Resume

Robert (Bob) A. Rucker earned BS and MS degrees in nuclear engineering from the University of Michigan and professional engineer's certificates in nuclear engineering and in mechanical engineering. He worked in the nuclear industry for 38 years in advanced nuclear reactor design, statistical analysis of measurement data for fissile material inventories, and criticality safety for fissile material production, handling, and storage. He has been researching and promoting the Shroud since 2014. He performed nuclear analysis computer calculations using the MCNP (Monte Carlo N-Particle) software to solve the C^{14} dating problem for the Shroud and organized the "International Conference on the Shroud of Turin" (ICST-2017) held July 19-22, 2017, in Pasco, Washington. This conference speakers included by 28 Shroud researchers from Italy, Spain, France, Mexico, Australia, and the US and produced 34 hours of PowerPoint presentations and panel discussions. The author's papers are available on the research page of his website www.shroudresearch.net . He can be contacted at robertarucker@yahoo.com .