The Carbon Dating Problem for the Shroud of Turin, Part 3: The Neutron Absorption Hypothesis

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Rev. 0, July 7, 2018
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Table of Contents

Abstract

In 1988, the C^{14} dating methodology was used (Ref. 1, i.e. Damon, et al.) to date samples from the Shroud of Turin to 1260 to 1390 AD. But research during the last 30 years has convinced leading Shroud researchers that the Shroud is much older than 1260 to 1390 AD, thus contradicting the results of the C^{14} dating. To solve this carbon dating problem for the Shroud, a three-part series has been written that covers: 1) background in Ref. 2, 2) statistical analysis in Ref. 3, and 3) the neutron absorption hypothesis, which is this paper. A more thorough statistical analysis (Ref. 3) than that originally done in Damon indicates that something (technically called a systematic bias) probably affected the measurement values, in addition to the normal random measurement errors. This systematic bias was neither identified nor quantified in Damon so that the resulting date of the measurements (1260 – 1390 AD) should not be regarded as necessarily accurate. There is much evidence to indicate that the image on the Shroud was caused by a burst of radiation from the body that was wrapped in it (Ref. 8 and 9). It is hypothesized in this paper that if neutrons were included in this burst of radiation, a small fraction of them would be absorbed in the trace amounts of N^{14} in the linen thus forming new C^{14} atoms by the (N^{14} + neutron → C^{14} + proton) reaction. This newly created C^{14} would be indistinguishable from the original C^{14} that was taken into the plant while it was alive, thus shifting the apparent C^{14} date in the positive direction by up to thousands of years. Computer calculations were performed using the MCNP nuclear analysis computer code to determine that if 2×10^{18} neutrons were emitted from the body it would have increased the C^{14} concentration at the sample location by 16%, which would have shifted the C^{14} date from 30 AD to 1260 AD. This number of neutrons is only one in every ten billion that would have been in the body that was wrapped in the Shroud. The MCNP nuclear analysis computer calculations were used to determine C^{14} dates for samples taken from anywhere on the Shroud. It was found that most locations would date to the future, assuming the usual equations are used to determine the date from the C^{14} concentration. Specifically, for material removed in 2002 from under the patches at the elbows, samples should date to about 3500 to 4500 AD (Figure 14). This neutron absorption hypothesis is the only hypothesis that is consistent with the four things that are known about C^{14} dating as it relates to the Shroud of Turin:

- Uncorrected date of 1260 AD at the 1988 sample location,
- Slope of the dates from the three laboratories of about 36 years per cm,
- The range of the dates for the 16 subsamples (1155 to 1410 AD), and
- C^{14} date of 700 AD for the Sudarium of Oviedo, which according to tradition is the face cloth of Jesus (John 20:7), and thus related to the Shroud.

1. Introduction

The Shroud of Turin has been in Turin, Italy, since 1578. On this burial cloth can be seen the image of a naked man (Figure 14) that was crucified exactly as the New Testament says that Jesus was crucified. Ancient tradition claims that this burial cloth is the authentic burial cloth of Jesus of Nazareth. To determine whether this could be true, more research has been done on the Shroud of Turin than on any other ancient artifact (Ref. 4 to 7). Scientific research on the Shroud during the 90-year period between 1898 and 1988 increasingly supported its authenticity,

but the C^{14} dating in 1988 produced a date range of 1260 to 1390 AD, with a 95% probability that the true date is within this range. The stated conclusion of this C^{14} dating of the Shroud in the abstract to Damon was that "The results provide conclusive evidence that the linen of the Shroud of Turin is medieval." But with 30 years of additional research, leading Shroud researchers now believe that the C^{14} dating of the Shroud is very flawed. The four primary reasons for this are:

1. The impossibility of forming the image on the Shroud during the Middle Ages.
2. The procedures used by the C^{14} dating laboratories were not consistent with the internationally established protocols for C^{14} dating of the Shroud.
3. Other dating techniques indicate that the Shroud is much older than the C^{14} date.
4. Detailed statistical analysis (Ref. 3) of the C^{14} dating measurements indicate that the data is not consistent due to the probable presence of a systematic bias, and thus the validity of the data is questionable.

It has been difficult to explain how the C^{14} dating methodology could have dated the Shroud to the Middle Ages instead of to the first century. Thus, we have two lines of evidence, one, based on history and science, supporting the authenticity of the Shroud, and the other, based on C^{14} dating it to the Middle Ages, strongly against authenticity.

How is this conundrum to be resolved? Resolution of these two lines of evidence (favoring and opposing authenticity) is accomplished through consideration of both sets of evidences and through detailed nuclear analysis computer calculations. Thus, whether the C^{14} dating of the Shroud samples to the Middle Ages disproves the authenticity of the Shroud cannot be properly judged without further statistical analysis of the C^{14} measurement data listed in Damon. This further statistical analysis (Ref. 3) concluded that there is a high probability that a systematic bias also affected the measurements, as well as the normal random measurement errors. Since this systematic bias was not identified or quantified in Damon, the accuracy of the C^{14} date measurements cannot be determined, so that the conclusion in Damon should not be accepted as necessarily valid.

But what would cause such a systematic bias in the measurements? The explanation that is consistent with everything that we know about C^{14} dating as it relates to the Shroud is that neutron absorption in trace amounts of N^{14} in the Shroud would have produced new C^{14} in the Shroud, which could have shifted the C^{14} date in the forward direction to the Middle Ages. Computer calculations on this neutron absorption hypothesis were performed using the MCNP nuclear analysis software. The results of these computer calculations are reported in this paper.

2. Proposed Explanations for the C^{14} Dating to the Middle Ages

Several explanations have been proposed as to why the C^{14} dating methodology produced a date of 1260 to 1390 AD for a sample of linen cut from the Shroud, when there is so much other evidence that it should date to the first century. These explanations proposed that the C^{14} date was shifted from the first century to the Middle Ages due to:

1. Neutrons that were emitted from the body while it was wrapped within the Shroud. These neutrons were subsequently absorbed by material in the Shroud to form new C^{14} on the Shroud. This was the first documented explanation (Ref. 10). This was proposed by Dr. Thomas J. Phillips and published as a letter to the British journal "Nature" in the same volume that published the statistical analysis of the 1988 C^{14} dating of the Shroud (Damon). Dr. Phillips is a particle physicist and at that time was working at the High-Energy Physics Laboratory at Harvard University in Cambridge, Massachusetts, USA. But this concept of neutron absorption in the Shroud shifting the C^{14} date to the Middle Ages was not investigated further at that time.
2. Contamination from handling or from things such as talc, wax, oils, etc., that may have intentionally or accidently been placed onto the area of the Shroud from which the samples were taken. However, the cleaning of the samples at the C^{14} dating laboratories should have removed these materials from the underlying linen, and no issues with contamination was evident during the progressive cleaning and dating process, so that any possible contaminants should have had an insignificant effect on the dating.
3. Absorption of carbon onto the linen from smoke that the Shroud was exposed to during the fire in 1532, or from other fires that the Shroud may have been in. However, this effect would not be sufficient to explain the magnitude of the date shift from the first century to the Middle Ages, and the cleaning of the samples at the laboratories should have removed any such contamination since smoke would have adhered to the outside of the fibers.
4. The high temperature that resulted from the 1532 fire, which might have changed the ratio of C^{14} to total carbon in the Shroud. This is called isotopic fractionation. However, such a change in the isotopic ratio would be much too small to explain the date shift from the first century to the Middle Ages. The ratio of C^{14} to total carbon in the Shroud must be changed by about 16% to account for the date being shifted from 30 AD to 1260 AD.
5. A bioplastic film that built up on the Shroud fibers due to bacteria growth. However, careful examination of the Shroud fibers indicated that bacteria buildup on the Shroud fibers was minimal so that this effect could not explain the magnitude of the date shift.
6. Carbon monoxide at a different C^{14} isotopic ratio being deposited onto the Shroud. Careful examination also found that this effect could not explain the magnitude of the date shift.
7. An invisible patch or reweave in the area from which the samples were taken, so that the C^{14} dating of these samples was dating a mixture of the newer added material and the older original material from which the Shroud was woven.

For the reasons stated above, explanations #2 through #6 should be rejected as capable of causing a shift in the C^{14} date from the first century to the Middle Ages. And reason #7 (invisible patch/reweave), though commonly adopted in presentations and on the internet, has significant evidence against it:

1. In back lighting, the lower left corner of the front image shows horizontal bands or striations in the linen that are continuous in the area from where the samples were cut from the Shroud. These horizontal bands are not in the backing cloth because a slight offset is visible in the bands where the 3-inch side piece is sown onto the main Shroud. This means that the horizontal bands are in the linen of the main Shroud. Dr. John

Jackson has pointed out that the continuity of these horizontal bands in the linen is conclusive evidence that there could not possibly be a patch or reweave in the sample area, for it would be impossible to retain these horizontal bands in the backlit image in doing a patch or reweave. Jackson states "… we must conclude unambiguously that there has been no reweave whatsoever surrounding the radiocarbon site." (page 175 of Ref. 7)

2. There is no historical or other evidence that indicates who might have made such an "invisible" patch or reweave on the Shroud, or when or where it might have been made. If there had been an "invisible" reweave in the sample area, it must have been done between 1260 and 1532, because 1260 is the earliest date of the C^{14} date range (1260 to 1390 AD) and the water stains in the sample area could not have occurred later than the fire in 1532 (Note 13 on page 458 of Ref. 7). Those doing a patch or reweave of the Shroud between 1260 and 1532 AD could have used a needle and thread or possibly a pair of tweezers but could not have used a compound microscope because it first appeared about 1620. It is not credible for a patch or reweave of a fine cloth such as the Shroud to be done so expertly that it could not be detected today either on the front or back side of the cloth by use of a modern microscope.
3. For the C^{14} dates from the three laboratories to show a slope of about 36 years per cm, the samples cut from the Shroud must have been a mixture of old material (~ 30 AD) and new material. The different dates from the three laboratories could then consist of different fractions of old and new material. But since each laboratory would have cut subsamples from the samples in various ways, it is very unlikely that all 16 measurements would include a combination of the old and new fabric. Rather, about half of the measurements should have dated only the old material or only the new material. The C^{14} dates for the 16 subsamples are not consistent with this.
4. When the samples for the C^{14} dating were removed from the Shroud in 1988, two textile experts (Professor F. Testore and G. Vial) were present to assure that the samples "came from a single site on the main body of the Shroud away from any patches or charred areas" (paragraph 7 of Damon). More recent examination of Shroud material remaining at the Tucson laboratory after completion of the 1988 C^{14} dating of the Shroud concluded that "we find no evidence to contradict the idea that the sample studied was taken from the main part of the Shroud, as reported by Damon. We also find no evidence for either coatings or dies, and only minor contaminants." (Ref. 11)
5. During the restoration of the Shroud in 2002, the backing cloth was removed from the Shroud so that experts could inspect both sides of the linen fabric around the radiocarbon sample site and all agreed that there was no evidence of a repair or reweave of the fabric. One of the world's leading experts on ancient textiles, Dr. Mechthild Flury-Lemberg, concluded regarding the "invisible" reweave theory that "There is no doubt that the Shroud does not contain any reweaving … Reweaving in the literal sense does not exist." (Ref. 12) "In any case, neither on the front nor on the back of the whole cloth is the slightest hint of a mending operation, a patch or some kind of reinforcing darning to be found." (Ref. 13)
6. Ian Wilson has written many books on the Shroud of Turin (Ref. 4, 5, and 14 to 16). In his latest book, he comments regarding this invisible reweave theory that "This argument lacks serious substance" (p. 22 of Ref. 5).

7. Mark Antonacci wrote his second book on the Shroud titled "Test the Shroud" in 2015 (Ref. 7). He dedicated Chapter 9 in this book to the question "Was the Shroud Invisibly Repaired?" Evidence that he cites to argue that the Shroud was not "invisibly" repaired in the radiocarbon sample area include the following:

    - "The Shroud was examined by scores of scientists and various experts in 1969, 1973, 1978, 1988, and 1997 …. but no repairs were ever discovered at this site." (page 171 of Ref. 7)
    - "In 1978, between 5,000 – 7,000 photographs of the Shroud were taken in various wavelengths and magnifications, but no photographs and microphotographs have indicated such a repair." (page 171 of Ref. 7)
    - Supposed evidence for a reweave in the sample area based on work by Ray Rogers, then a chemist at the Los Alamos National Laboratory, included subjective interpretations of what he saw through his microscope and "enormous leaps of logic to arrive at his unsupported and erroneous conclusions. Frequently, he failed to understand or ignored the basic facts that his samples came from a scorched area and were at the edge of a water stain." (p.170 of Ref. 7) Rogers claimed that he found evidence of a spliced thread from the Raes cutting, which was above the radiocarbon sample area, but "Rogers' photomicrograph of the Raes thread … shows no sign of a splice." (p.179 of Ref. 7)

8. The Shroud was in a fire in 1532. The holes and charred material that resulted from the burning of one corner of the folded cloth were patched two years later. The technology available at that time for patching of a thin fabric such as the Shroud is demonstrated by the nature of these patches. That these areas are patches is immediately apparent even to the casual observer because the fabrics don't match, and the threads used to attach the patches are easily seen. If a higher quality of fabric repair were available at that time such as an "invisible" reweave technique, it would much more likely have been used to repair these damaged areas near or on the image instead of being used to repair a far corner of the cloth well away from the image.

Thus, of the above seven explanations that have been proposed for why the Shroud was C^{14} dated to the Middle Ages rather than to the first century, the only remaining option is #1, i.e. that the C^{14} date must have been shifted from the first century to the range of 1260 to 1390 AD by neutron absorption in the Shroud. Therefore, according to the neutron absorption hypothesis, the primary reason that the Shroud was C^{14} dated to the Middle Ages was not because:

- The samples were contaminated by handling or from things such as talc, wax, oils, etc.
- The samples were contaminated by absorption of carbon onto the linen from smoke that the Shroud was exposed to during the fire in 1532.
- The high temperature from the fire in 1532 that changed the C^{14} isotopic ratio (the ratio of C^{14} to total carbon) in the sample area.
- A bioplastic film had built up on the samples due to bacteria growth.
- The sample area on the Shroud had been patched or rewoven with newer material.
- The area from which the samples were cut was a bad area.
- There was collusion, deception, or intentional fakery by anyone.

- There was any inadequacy in the handling or cleaning procedures.
- The measurement uncertainties were incorrectly determined.

Though some of the above may have had a small effect on the C^{14} dating, none of the above are the primary cause of the Shroud being dated to the Middle Ages. The Shroud was dated to the Middle Ages rather than to the first century primarily because the statistical analysis failed to recognize that the spread in the mean values from the three laboratories had only a 1.4% probability of being due to only random measurement errors (Ref. 3). This indicated a 98% probability that something other than random measurement errors was affecting the measured values. In statistical analysis terminology, a position dependent systematic bias was altering the measured values. According to the neutron absorption hypothesis, this systematic bias was caused by the natural distribution in the tomb of the neutrons that were included in the burst of radiation emitted from within the body that burned the image onto the Shroud. These neutrons would have produced new C^{14} on the Shroud by the (N^{14} + neutron $\rightarrow$ C^{14} + proton) reaction, thus shifting the measured C^{14} date in the forward direction. But there have been two problems in the consideration of this option:

1. People are not familiar with neutrons or neutron absorption, and
2. Detailed calculations of neutrons released from the body that were subsequently absorbed by the Shroud were not performed or reported until 2014 (Ref. 17).

3. Evidence for Radiation Emission from the Body

The problem with people not being familiar with neutrons or other forms of radiation is that they tend to reject any consideration of it relative to the Shroud because they think that it is strange. But we have all been surrounded by radiation our entire lives – we have just not been aware of it. Radiation emitted from the sun powers photosynthesis on the earth and allows us to see the scene in front of us when reflected photons of light enter our eyes. Much of our electronic equipment (cell phones, radios, televisions, microwave ovens) operate based on photons of electromagnetic radiation. Dental and medical X-rays use high energy photons of electromagnetic radiation. Decay of radioactive materials powers many items from our smoke detectors to our deep space probes. To solve the mysteries of the Shroud, we need to recognize the role that radiation has played in forming the image, shifting the C^{14} date, and perhaps even transporting the dried blood off the body and onto the Shroud where it appears to have re-dried.

To produce the image of the crucified man on the Shroud, three things were required:

1. A discoloration mechanism, for example a static discharge or a photo-chemical process,
2. Energy to drive the discoloration mechanism, and
3. Information to control the discoloration mechanism.

The content of the required information must be that which defines the appearance of a crucified man so that the discoloration mechanism would discolor certain fibers on the Shroud but not others, thus resulting in the image of the crucified man. This process results in the information content that defines the appearance of a crucified man being embedded or encoded into the

pattern of discolored fibers on the Shroud. When the Shroud is put on exhibit, photons of light reflect off the image in all directions including toward our eyes. These reflected photons by their intensity and direction carry the information content that is encoded into the pattern of discolored fibers from the Shroud to our eyes. This means that we can see the image of the crucified man because our brains have learned to interpret the information content that is in the pattern of discolored fibers on the Shroud as that of a crucified man (Ref. 8). This information content that defines the appearance of a crucified man must have come from the body that was wrapped within the Shroud, for that information was only inherent to the body, and not to the limestone walls of the tomb or the air in the tomb. Thus, the information that defines the appearance of a crucified man must have been communicated from the body to the Shroud, and then must have been communicated from the Shroud to our eyes for us to see the image. It was radiation (reflected photons of light) that communicated the information defining the appearance of a crucified man from the Shroud to our eyes so that we could see it. But what communicated the required information from the body to the Shroud? There are six ways that information can be communicated from one location to another:

1. By radiation such as photons of light or ultra-violet, or particles such as protons,
2. By waves in a medium such as sound waves in air,
3. By a flow of particles in physical connections such as a flow of electrons in wires,
4. By direct contact such as when your finger hits a key on the computer keyboard,
5. By diffusion of molecules as when you detect the presence of a skunk by its smell, and
6. By an electrostatic or gravitational field.

In considering these six ways to communicate the required information content from the body to the Shroud (Ref. 8), it is concluded that only the first option can produce the finely resolved image that we see on the Shroud. Sound waves, diffusion of molecules, and electrostatic or gravitational fields could not produce a finely resolved image, there were no wires connecting every point of the body with every point on the Shroud, and it was not in contact with the body at every point, e.g. next to the tip of the nose. The only workable option is radiation. We conclude that radiation by its intensity and direction must have communicated the required information regarding the appearance of the crucified man (in terms of the body-to-cloth separation) from the body to the Shroud. And since the image on the Shroud apparently also includes the appearance of certain bones (some of the teeth, bones in the hands, some of the vertebra, and some of the cranial bones), the radiation was not just emitted from the surface of the body but must have been emitted from within the body. In other words, radiation of some type must have been emitted from within the body to carry the required information from the body to the cloth, so that that information could be encoded into the pattern of discolored fibers on the Shroud, so that we could see the image. This is just one reason for believing that radiation must have been emitted from within the body. A total of 17 reasons for believing that radiation was emitted from within the body are listed in the paper "Role of Radiation in Image Formation on the Shroud of Turin" (Ref. 9).

Many others have also concluded that a burst of radiation was emitted from the body as it was wrapped within the Shroud. In Giulio Fanti's 2015 book "The Shroud of Turin, First Century After Christ", he said "To explain all the particular features of the Shroud image, other researchers like O. Scheuermann [128], G. B. Judica Cordiglia [83], J. B. Rinaudo [123], and E.

Lindner [95] supposed the presence of a radiation source coming from the internals of the body wrapped in the Shroud …" where the bracketed numbers are references in his book. He also said "Summing up, the radiation hypothesis … is the most reliable because …. it allows one to obtain a result that gets close to the peculiar features of the Shroud." (pages 28-29 of Ref. 18) In Mark Antonacci's 2015 book "Test the Shroud at the Atomic and Molecular Levels", Chapter 5 is titled "All Signs Point to a Unique Form of Radiation – From the Body". His conclusion is that "only radiation can account for all of the unique body image attributes on the Shroud of Turin." (Ref. 7) Finally, Ray Rogers' claim that formation of "the image could not have involved energetic radiation of any kind" (Ref. 19) upon review (Ref. 20) has been found to not be justified by the evidence presented in his paper.

It might be pointed out that in the Biblical account of Jesus, it is claimed that there were occasions when radiation such as light was apparently given off by his body. One example is the transfiguration (Matthew 17:1-9, Mark 9:2-10, Luke 9:28-36) where Peter, James, and John observed Jesus' face to shine "like the sun" and "His garments became radiant" "as white as light" (NASB). Another example is when Jesus appeared to Paul on the road to Damascus (Acts 9:3-19). Paul saw Jesus as a "light from heaven" that was so brilliant that it created "something like scales" over Paul's eyes which blinded him. Paul regained his sight days later when the scales "fell from his eyes". If these accounts are historically accurate, as Christians believe, then it should not be surprising if radiation, possibly including neutrons, was given off in the disappearance of Jesus' body from within the Shroud in the tomb. I'm not suggesting that neutrons were necessarily emitted from Jesus' body in his transfiguration or in his appearance to Paul on the road to Damascus. I am only saying that if a brilliant light was emitted from his body on these two occasions, then we should consider the possibility that a burst of radiation could have been emitted from his body when it disappeared from within the shroud, and we should consider the possibility that this burst of radiation included neutrons.

There are many good and convincing reasons that radiation must have been emitted from within the body as it was wrapped within the Shroud. With this perspective, it becomes much easier to believe that neutrons were emitted from within the body, for we have no reason to reject the possibility that neutrons could have been included in the radiation that must have been emitted from within the body.

4. Evidence for Neutron Emission from the Body

The evidence that a burst of radiation was emitted from within the body as it was wrapped within the Shroud was discussed in the previous section. Since we know of no reason that would preclude neutrons from being included in this radiation, we ought to consider the possibility that neutrons were also emitted from within the body. When it is assumed that a burst of neutrons was homogeneously (uniformly) emitted from within the body, three mysteries related to C^{14} dating and the Shroud can be explained. Explaining three mysteries by one assumption indicates that this assumption probably has much merit to it. The three mysteries that can be explained by the assumption that neutrons were emitted from within the body are summarized below:

- In 1988, the Shroud was C^{14} dated to 1260 ± 31 AD (uncorrected), which translates to a two sigma (95% probability) range of 1260 to 1390 AD when corrected for the changing C^{14} concentration in the atmosphere. If radiation was emitted from within the body, and neutrons were included in this radiation, then a small fraction of these neutrons would have been absorbed in the trace amount of N^{14} that was naturally in the Shroud to form new C^{14} atoms in the Shroud by the (N^{14} + neutron → C^{14} + proton) reaction. This new C^{14} would have been indistinguishable from the remaining C^{14} that was brought into the flax plant while it was alive, thus shifting the apparent C^{14} date in the positive direction. Based on nuclear analysis computer calculations using the MCNP program, if about 2 x 10^{18} neutrons were released from within the body, then the C^{14} date for the sample from the bottom corner of the Shroud would have been shifted from about 30 AD to 1260 AD. The weight of the man that was wrapped in the Shroud has been estimated to be about 170 to 175 pounds. It can be calculated that the atoms in the body of a 170-pound man contain about 2 x 10^{28} neutrons. This means that emission of only one neutron in every ten billion (1 x 10^{10}) that are in the body would be sufficient to shift the date from 30 AD to 1260 AD. The three dating laboratories and those that did the statistical analysis of the experimental results, not suspecting that the Shroud had experienced a neutron absorption event, simply reported the average value for the C^{14} date (1260 ± 31 AD, uncorrected). It should be noted that there are two other reactions that produce C^{14} (C^{13} + neutron → C^{14} + a gamma, and O^{17} + neutron → C^{14} + He^4 which is an alpha particle) but production from neutron absorption in N^{14} is much more significant.

- The average C^{14} dates reported by the three laboratories did not agree well with each other. Statistical analysis of the measurement data indicates that the spread in the mean values from the three laboratories had only a 1.4% probability of being due to random measurement errors alone (Ref. 3). This indicates that there is a significant chance that these differences were caused by something else as well. When these average values from the three laboratories are plotted as a function of the distance of the sample from the end of the Shroud, a slope or gradient of about 36 years per cm is apparent in the data (Figure 3 of Ref. 3). If neutrons were homogeneously (uniformly) emitted from within the body, then the natural shape of the neutron distribution in the tomb will cause this slope in the C^{14} dates, depending on how the Shroud was wrapped around the feet.

- The Sudarium of Oviedo, which ancient tradition indicates is the face cloth of Jesus, has been C^{14} dated to about 700 AD. Based on the MCNP calculations, if 2 x 10^{18} neutrons are released from within the body while it was wrapped within the Shroud, and if the face cloth, after being removed from his face, was placed on the right bench in the tomb just in front of the back bench as shown in Figure 1, then enough new C^{14} would have been produced in the face cloth to shift the date from about 30 AD to 700 AD. This is shown in Figure 13 by the yellow highlighted area on the right-side bench. Figure 13 is from slide 39 of Ref. 17.

The only hypothesis that has been suggested that can explain the above three mysteries related to C^{14} dating is neutrons emitted from within the body as it was wrapped within the Shroud. The invisible reweave hypothesis was conceived to explain the first mystery (the 1260 date for the Shroud). For the invisible reweave hypothesis to explain the second mystery (the slope of about

36 years/cm), a second assumption must be made regarding the fraction of the old cloth that was replaced with new cloth as a function of the distance from the end of the cloth. The invisible reweave hypothesis does not explain the third mystery of why the Sudarium of Oviedo was C^{14} dated to 700 AD. The invisible reweave hypothesis would also predict that many of the measurements should be to about 30 AD which is not the case.

5. Objections to the Neutron Absorption Hypothesis

Objection 1. Radiation emitted from within the body could not produce the high-resolution image that we see on the Shroud. When an atom emits radiation, the radiation is emitted in any direction with equal probability, so that any point on the Shroud would be receiving radiation from many different points in the body so that only a blur would result.

Response 1. When we follow the evidence on the Shroud where it leads, without being constrained by a philosophy of naturalism, the conclusion is that the image is a radiation burn. Since, as correctly stated in the objection, radiation is normally emitted in any direction with equal probability and thus could not form a high-resolution image, the radiation that caused the image (probably charged particles and/or ultra violet) must have been emitted only vertically, both vertically up and down to form good resolution front and dorsal images but without side images. This radiation could not have been perpendicular to the surface of the body for then there would be images of the side of the body on the cloth, and distortion of the front and back images. This vertically collimated radiation could have been similar to the coherent radiation emitted from a laser. A laser emits electromagnetic radiation, i.e. photons, usually in the visible or ultraviolet energy range that is "coherent" in the sense that the wavelengths of all the photons are in-phase with each other so that there is no tendency for the beam to spread out. As commented by others, the burst of radiation from the body that formed the image on the Shroud was like millions of lasers within the body all pointed vertically up and down, and all emitting simultaneously in an extremely short burst of radiation. It is recognized that this radiation being emitted only vertically is outside of our current understanding of science, but then a high resolution negative image formed by a dead human body on a cloth that contains 3D information content is also outside of our current understanding of science. This is explained further in "Role of Radiation in Image Formation on the Shroud of Turin", Ref. 9.

Objection 2. The radiation did not have to be emitted from within the body. The radiation could have originated in the walls of the tomb due to an earthquake or a lightning strike.

Response 2. We can see the image of a crucified man on the cloth because the information that defines the appearance of a crucified man is encoded into the pattern of discolored fibers on the Shroud. This information could only have originated in the body, and only been communicated from the body to the cloth by radiation (Ref. 8). If the radiation was initially emitted in the walls of the tomb from an earthquake, a lightning strike, or any other mechanism, then information that defines the appearance of a human body must still be communicated from the body to the cloth. This means that the radiation that was emitted in the walls must have entered the body from outside the body and then in some way

communicated the required information from the body to the cloth, doing so in a totally vertical manner in order to form the high-resolution images. No one has theorized how this could happen within our current understanding of science. Thus, assuming the radiation was initially emitted in the walls of the tomb does not make the mechanism understandable.

Objection 3. What caused the radiation to be emitted from within the body?

Response 3. This objection is often phrased in the form of a question, but the purpose of the question is often to disprove that radiation could be emitted from the body. To answer the question, it must be remembered that the method that is being used is to follow the evidence on the Shroud where it leads. This evidence leads us to believe that the image is a radiation burn formed by a burst of radiation emitted from within the body. But the evidence on the Shroud is not sufficient for us to discover what caused the radiation to be emitted from the body. The evidence that we can gather from the Shroud is limited in this sense. But our process of following the evidence where it leads is not invalidated because the evidence does not answer all our questions. It should also be realized that this objection is based on a presupposition of naturalism – that things can only happen according to the laws of physics as we currently understand them, so that if a phenomenon can't be explained within our current understanding of the laws of science, then it is assumed it can't be real or true. But who knows what the ultimate laws of the universe are? And who knows how science will progress in the future? We must be careful to avoid rejecting the evidence to maintain our presuppositions.

Objection 4. The neutron absorption hypothesis is not science because it does not explain how the radiation was emitted from within a dead body.

Response 4. There are different types of science for different purposes. What is being done in this document is not experimental science because it does not propose a cause for the burst of radiation emitted from within the body and it does not propose repeated experiments in the laboratory to examine this cause for the radiation. What is being done in this document is forensic science, where the evidence is examined to determine the most likely explanation for it. This methodology is like a detective at a murder scene, or cosmologists doing computer simulations trying to figure out how the solar system or our galaxy was formed. In none of these examples can the original cause be repeated in a laboratory.

Objection 5. Your methodology and conclusions are the result of religious bias motivated by a desire to prove the resurrection of Jesus.

Response 5. Everyone has worldview presuppositions which they use, usually without being aware of it, to help them understand reality. In our work in science, we must try to be aware of our own presuppositions and consider the justification for the presuppositions of others. In our work on the Shroud, we must seek the truth above all else, and let the "chips" fall where they may. Books and other sources that argue for the truth of Jesus' resurrection base their arguments almost entirely on the historicity of the New Testament documents, and very seldom even mention the Shroud of Turin. So, Christian belief in Jesus' resurrection will not be falsified if the Shroud is proven to not be Jesus' burial cloth.

Since the authenticity of the Shroud ultimately doesn't matter to Christianity, the Christian can view the evidence for the Shroud objectively. And it should be realized that this objection may arise out of anti-Christian bias and a desire to deny evidence for the resurrection of Jesus. All Shroud researchers should be careful to consider how their presuppositions are influencing their judgment of the evidence.

6. Nuclear Analysis Computer Calculations

After consideration in Section 4 of the evidence for neutron emission from within the body, and consideration in Section 5 regarding objections to this hypothesis, we are now ready to consider the detailed computer calculations that modeled such an event.

The MCNP (Monte Carlo N-Particle) computer software program (Ref. 21) was developed at the Los Alamos National Laboratory in Los Alamos, New Mexico, USA, over many decades. It has been approved by the US Department of Energy (DOE) and the US Nuclear Regulatory Commission (NRC) for use in the nuclear industry for calculations related to nuclear reactor design, criticality safety, radiation shielding, radiation detector design, medical treatment, etc. This approval process was based on comparison of thousands of experiments performed in nuclear facilities with the results of MCNP calculations. MCNP is a common nuclear analysis computer program and is used to solve a wide array of problems related to neutrons and other sub-atomic particles.

In early 2014, the MCNP nuclear analysis computer program was used to model the C^{14} dating problem for the Shroud by performing detailed calculations for the neutron absorption hypothesis that was originally suggested in 1989 (Ref. 10). This hypothesis states that the C^{14} date was shifted from the first century to the Middle Ages by neutrons emitted from the body as it was wrapped in the Shroud, and that these neutrons were subsequently absorbed in the linen threads to produce new C^{14} atoms in the Shroud. In a long series of MCNP calculations, the body was modeled in the MCNP computer program wrapped in a linen burial shroud laying on the back bench in a tomb as it would have been cut out of the limestone in Jerusalem in the first century. The tomb was modeled with a left bench, a right bench, and a back bench around the "pit" or stand-up area. Figure 1 shows a cut-away three-dimensional view of the tomb as it was modeled, with the locations indicated for the body, Shroud, and the face cloth. A small entrance was modeled with a circular stone placed in front of the entrance. The body wrapped in the Shroud was modeled on the back bench because John 20:5 says that when John bent down outside the tomb and looked through the entrance to the tomb, he could see the "linen wrappings". Due to the small size of the door and the lack of any light sources in the tomb, he must have bent down well back from the entrance, so that he probably could not see the side benches – only the back bench. Seeing the linen wrappings on the back bench means that the body was probably placed there. The head was modeled to the right because most people are right handed. If the head was placed to the left in the tomb, then there would be a right-left reversal of the calculated results.

Figures 2 through 8 were produced from the input to the MCNP computer program to show the model of the tomb that was used in the MCNP calculations. In these figures, the gray color represents the limestone, the off-white represents air, and the peach color represents the body.

Figures 4 and 7 show the top and front views of the body inside the Shroud. The body was modeled using simple geometrical figures. The Shroud was modeled as a box around the body and was open at the bottom end. This modeling is simplistic but was judged to be sufficient to obtain an initial solution to the problem. Figure 8 shows a close-up detail of how the Shroud was modeled around the body.

Assumptions used in the MCNP calculations are listed in Table 1. The main assumption is that the thermal neutrons were emitted homogeneously (uniformly) from within the body and isotropically (uniformly) in all directions, so that the same number of neutrons would be emitted from every volume, i.e. every cm^3, within the body. Based on this assumption, MCNP calculated the neutron distribution shown in Figure 9. The top curve in Figure 9 is for neutrons of all energies and is plotted along the centerline of the body on the section of the Shroud that was under the body, i.e. along the centerline of the dorsal image.

The neutron distribution in Figure 9 was used to calculate the distribution of neutrons absorbed in N^{14} in the Shroud (Figure 10). And the data in Figure 10 was used to calculate the C^{14} dates that would be measured for a sample taken from any point along the centerline of the back (dorsal) image. The result is shown in Figure 11. If the outer portions of the cloth at the bottom of the Shroud were wrapped under the feet, then the second point from the left on Figures 9, 10, and 11 would be the location from which the samples were taken in 1988. In Figures 9, 10, and 11, the zero value on the x-axis is at the mid-height of the body, with the head toward the right and the feet toward the left. The peak of the curve in these figures does not occur at the mid-height of the body, over the zero value on the x-axis, but is shifted toward the right, i.e. toward the head, so that the maximum in the curve is over the abdomen/chest area, where the center of mass for the body would be located.

Figure 11 is important because it shows that the predicted C^{14} dates are quite variable across the Shroud because the neutron distribution across the Shroud, as shown in Figure 9, is quite variable. Specifically, it shows that with the second point from the left normalized to 1260 AD, which is the average of the measured values obtained by the three laboratories, the maximum C^{14} date along the midline of the dorsal image would be about 8500 AD! This is the date that is predicted to be measured for a sample removed from the dorsal image along the centerline of the body at the abdomen/chest area, assuming the normal equations would be used to calculate the date from the measured amount of C^{14}. It is predicted that these equations would give this future date because the C^{14} dating laboratory would measure a significantly higher C^{14} isotopic ratio (the ratio of C^{14} to C^{13} and C^{12}) in the sample than would be possible from the normal C^{14} isotopic ratio that would be in a plant such as flax while it was growing. Normally, the dating laboratories measure a lower C^{14} isotopic ratio due to decay of the C^{14} atoms so that a date to the past is calculated, but if they measured a higher C^{14} isotopic ratio, then use of the same equations would give a date to the future, as predicted in this paper.

As indicated above for Figure 11, if it is assumed that the Shroud was wrapped under the feet then the second point from the left in Figure 11 is the location from which the sample was cut in 1988 for the C^{14} dating of the Shroud. The MCNP calculations are normalized so that the second point from the left is at a C^{14} date of 1260 AD, as shown on Figure 11. This second point from the left shows that there is a very significant slope to the curve at that point. The slope of a curve

is defined as the ratio of the change in the y-value to the change in the x-value at that point, i.e. slope = $\Delta y / \Delta x$. Since the C^{14} dating process involves burning of the sample, the three C^{14} dating laboratories (Oxford, Zurich, Tucson) had to be sent separate samples, so that though the samples were cut from the Shroud right next to each other, there was enough difference in their location that the effect of the slope in Figure 11 can be detected in the average C^{14} date measured by each laboratory (Ref. 1 and 3).

7. Prediction of Results for Future C^{14} Dating of the Shroud

Figure 12 indicates the areas on the Shroud and on the side benches where MCNP calculated the C^{14} dates, and Figure 13 gives the C^{14} dates calculated by MCNP in the pattern defined by Figure 12. These results were reported in Ref. 17 based on the assumptions in Table 1. When interpreting the values in Figure 13, it should be remembered that the model that was input into MCNP modeled Jesus' head to the right and his feet to the left, as in Figures 3, 4, 6, and 7. The C^{14} dates on Figure 13 can be used to predict the dates that would be obtained by the C^{14} dating methodology for samples removed from any location on the Shroud, but of primary interest is the charred material removed in 2002 from under the patches on the Shroud. Based on the MCNP results in Figure 13, the C^{14} dates for the charred material can be predicted as shown in Figure 14. The values in Figure 14 are the raw or uncorrected C^{14} dates, i.e. C^{14} dates prior to being corrected for the changing C^{14} concentration in the atmosphere, and assume that the standard equations are used to calculate the date from the measured C^{14} isotopic ratio. Many of the dates in Figures 13 and 14 are in the future. This results from the prediction that neutron emission from within the body will, for many locations, result in a C^{14} isotopic ratio that is greater than the nominal value of one part per trillion (1.0×10^{-12}), which is the approximate C^{14} isotopic ratio for living plants.

A simplified form of the equation that is used for the C^{14} dating methodology is:

$$N = N_o \, e^{C(T/5730)}$$

Where N = number of C^{14} atoms remaining in the material
N_o = number of C^{14} atoms in the material initially, i.e. when the plant was cut down
C = ln (0.5) = -0.69315
T = age of the material in years

So that:

For a zero age (T = 0): $N/N_o = e^0 = 1.0$
After one half-life of 5730 years (T = 5730): $N/N_o = e^{-0.6913*1.0} = 0.500$, and
After two half-lives of 11460 years (T = 11460): $N/N_o = = e^{-0.6913*2.0} = 0.250$

The above equation can be applied to the future dates shown in Figure 14 as follows.

Let Y = predicted year (AD) of the sample = 1950 -T

Then the age of the material in years T = 1950 – Y, where 1950 is the reference year for C^{14} dating.

So that: $N / N_o = e^{C(1950 - Y)/5730}$

Inserting the dates from Figure 14 into this equation gives the ratio (N / N_o) of the C^{14} that will be measured relative to a plant that was just cut down. For dates to the past relative to 1950, the ratio (N / N_o) will be less than 1.0 since the C^{14} in the material will be decaying after the plant is cut down. But a date to the future relative to 1950 will be associated with a ratio (N / N_o) that is greater than 1.0. The C^{14} dating methodology does not measure the date directly. Rather, it measures the ratio (N / N_o) and then calculates the date from the ratio. For example, in Figure 14 the prediction for the second point from the top on the right side is that the C^{14} dating laboratory will measure the ratio (N / N_o) to be 1.412, and then from this ratio a date of 4800 AD would be calculated from the equation. Figure 14 is given in terms of the date, even when the date goes into the future, to facilitate comparison with the 1260 AD date obtained for the radiocarbon samples taken from the bottom corner of the Shroud. But the dating laboratories will actually be measuring the C^{14} isotopic ratio of the sample relative to the C^{14} isotopic ratio of new material that has not undergone decay, i.e. N / N_o in the above equation.

The distribution of the C^{14} dates in Figure 14 is explained as follows:

- The values are higher near the elbows than near the knees because the elbows are closer to the center of the body mass and so would be closer to where more neutrons would be emitted, assuming the neutrons are emitted homogeneously (uniformly) from the body. This would cause more neutrons to be absorbed near the elbows which would cause a greater shift in the predicted C^{14} dates.
- The values are higher near the back (dorsal) image than near the front image because neutrons reflected from the limestone bench below the dorsal half of the cloth would have caused a higher fraction of the neutrons to pass through the dorsal half of the cloth multiple times, thus causing a greater shift in the predicted dates.
- The values on the right side of the image are higher than on the left side of the image because the locations on the right side of the image would have been closer to the back wall of the tomb, assuming the head was toward the right side as the body lay on the back bench in the tomb. This is because neutron reflection from the limestone wall at the back of the tomb would have caused a higher fraction of the neutrons to pass through the right side of the cloth multiple times, thus causing a greater shift in the predicted dates.

8. Conclusion

Many evidences indicate that the image on the Shroud was caused by a burst of radiation that was emitted from within the body while it was wrapped within the Shroud (Ref. 8 and 9). We have no reason to reject the possibility that neutrons were also included in this radiation. And if this radiation burst included neutrons, then the C^{14} date for a sample taken from any location on the Shroud would be shifted in the positive direction by up to thousands of years. This would be primarily due to neutrons absorbed in N^{14} in the Shroud which would produce new C^{14} in the

Shroud by the (N^{14} + neutron → C^{14} + proton) reaction. The distribution that neutrons would naturally take (Figure 9) in the tomb would alter or bias the measurement results in a systematic (not random) way, depending on the prior location of the samples on the Shroud.

On the hypothesis of neutrons being emitted from within the body, calculations were performed with the MCNP nuclear analysis computer program which showed that this hypothesis can explain the four things known about C^{14} dating as it relates to the Shroud:

- Why the samples taken from the corner of the Shroud in 1988 gave a date of 1260 to 1390 AD (corrected for changing C^{14} concentration in the air) rather than a date to the first century.
- Why results from the three C^{14} dating laboratories agreed so poorly with each other, indicating a slope or gradient to the C^{14} dates of about 36 years per cm.
- Why the range of C^{14} dates (1155 to 1410 AD) was obtained for the subsamples, and
- Why the Sudarium of Oviedo, which is believed to be the face cloth of Jesus (John 20:7), was C^{14} dated to 700 AD.

These successes indicate that the MCNP results for other locations on the Shroud should probably be reliable. The MCNP calculations predict that most locations on the Shroud will give a C^{14} date that is far into the future (Figure 14)! Since these computer calculations give the best explanation for how the 1988 C^{14} dating could date the Shroud to the Middle Ages, it is proposed that C^{14} dating be done on the charred material removed in 2002 from under the patches on the Shroud. If there is agreement between the experimental results for these locations and the computer predictions in Figure 14, it should be concluded that the C^{14} dating done in 1988 was affected by neutron absorption in the Shroud that resulted from neutrons emitted from within the body while it was wrapped in the Shroud. This would prove that there was an event in which the body emitted a significant number of neutrons – about 2×10^{18}, which is about one neutron in every ten billion that would have been in the body. Such an event is beyond or outside of our current understanding of science, consistent with the reported disappearance of the body (John 20:6-9) from within the Shroud in the tomb.

9. References

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Biographies

Robert (Bob) A. Rucker earned an MS degree in nuclear engineering from the University of Michigan and worked in the nuclear industry for 38 years. He organized the International Conference on the Shroud of Turin (ICST-2017) held July 19-22, 2017, in Pasco, Washington, His website is www.shroudresearch.net . Send comments, questions, or corrections to robertarucker@yahoo.com .

Kevin N. Schwinkendorf earned a doctoral degree (PhD) in nuclear engineering from the University of Washington (Seattle) and has worked in the nuclear industry for over 30 years, primarily in the areas of reactor physics and nuclear criticality safety. He has contributed papers to the journal *Nuclear Science and Engineering* and is currently employed at Columbia Basin Consulting Group working on Generation IV reactor designs. He can be contacted at Kevin.N.Schwinkendorf@hotmail.com .

Table 1. Assumptions for the Nuclear Analysis Calculations

Basic assumptions:

1. It is assumed that a sufficient number of neutrons (2.1×10^{18}) were emitted homogeneously (uniformly) from within the body to cause the C^{14} date for the 1988 samples to be shifted from about 30 AD to 1260 AD. In other words, the MCNP calculations were normalized to the only experimental value available – the 1260 AD date for the lower left corner on the Shroud.
2. The trace amount of nitrogen in the Shroud is assumed to be 0.065 weight percent. The neutrons emitted from within the body when absorbed in this nitrogen in the Shroud would create new C^{14} atoms in the Shroud by the (N^{14} + neutron → C^{14} + proton) reaction. This new C^{14} would have shifted the C^{14} dates for all locations on the Shroud in the forward direction, including shifting of the date for the 1988 samples from about 30 AD to the uncorrected C^{14} date of 1260 AD.

Assumptions used in the MCNP nuclear analysis computer program:

1. The tomb was modeled in the MCNP computer program as it would have existed in Jerusalem in the first century. It was modeled with benches cut into the limestone on the left and right sides and at the back of the "pit" or standup area in the tomb. The tomb was modeled with a small entrance and a circular stone in front of it with a 4.0 cm gap between the stone and the entrance.
2. The sample that was cut in 1988 for the C^{14} dating of the Shroud was cut from the bottom left corner of the Shroud. For the MCNP calculation, it was assumed that when the body was wrapped in the Shroud in the tomb, the bottom of the cloth near the feet was tucked under the feet, so that the sample area used for C^{14} dating was located under the feet along the midline of the body at the time of the radiation burst.
3. The neutrons were emitted homogeneously (uniformly) from within the body.
4. The neutrons were emitted isotropically (uniformly) in all directions.
5. The neutrons were emitted at a thermal energy, i.e. emitted without additional energy but rather just left behind in thermal equilibrium with the surrounding atoms at normal room temperature. The peak of the energy distribution for neutrons at this thermal energy is 0.0253 ev (electron volts).
6. The body was wrapped within the Shroud and laid facing up on the back bench in the tomb with the head facing to the right. The direction that the head was facing is important because neutrons tend to reflect back toward the Shroud from the limestone wall at the back of the tomb. With the head to the right, the right side of the body is closer to the back wall of the tomb, so it receives more reflected neutrons passing through the Shroud, so its date is shifted further into the future. If the head were facing to the left, then the dates for the left side of the Shroud would be shifted further into the future.
7. The body was assumed to be uniform in composition with a density of 0.99 grams/cm^3.
8. The side wall of the tomb is located 20 cm from the bottom extreme position of the feet. This assumption is important because neutrons are reflected back toward the Shroud from the limestone wall below the feet on the left side of the tomb.
9. The nominal atom fraction of C^{14} atoms in carbon is one part per trillion (1.0×10^{-12}).
10. The half-life for decay of C^{14} atoms is 5730 years.

Figure 1. 3D View of the Tomb Showing Locations of Shroud and Face Cloth

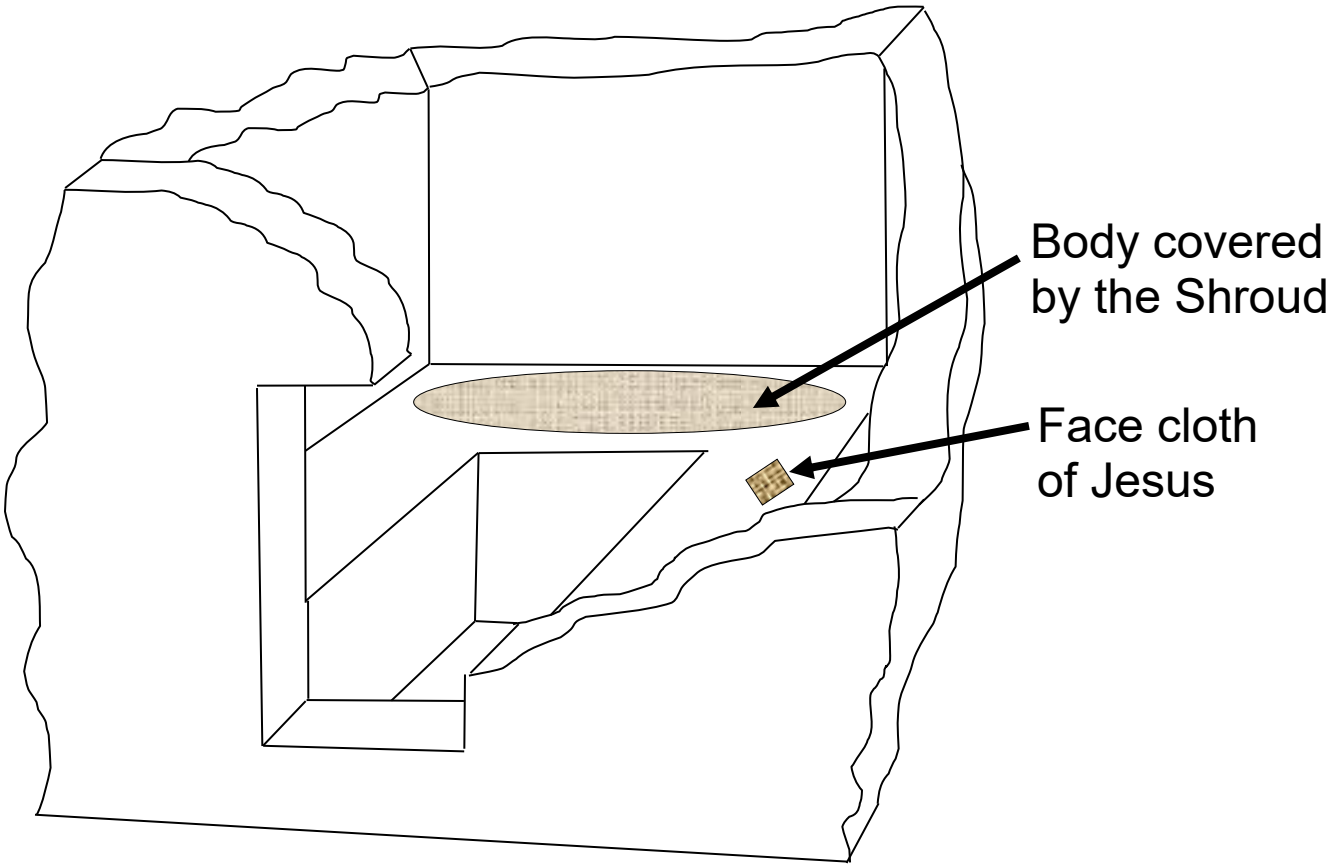

Figure 2. View from Above, Cut Below the Top of the Benches

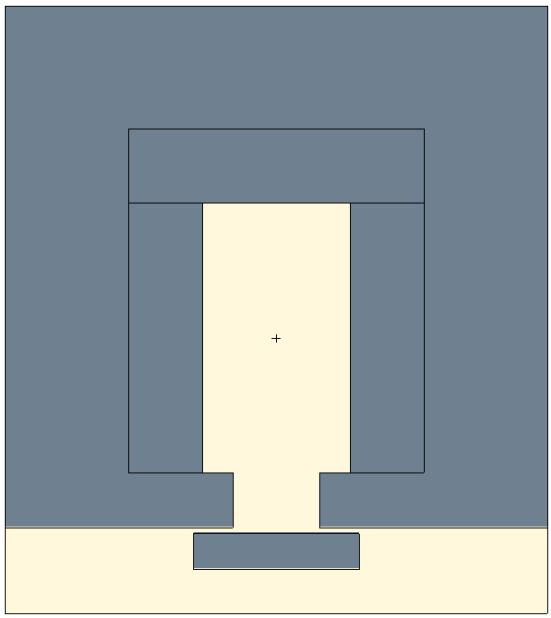

Figure 3. View from Above, Cut Above the Top of the Benches

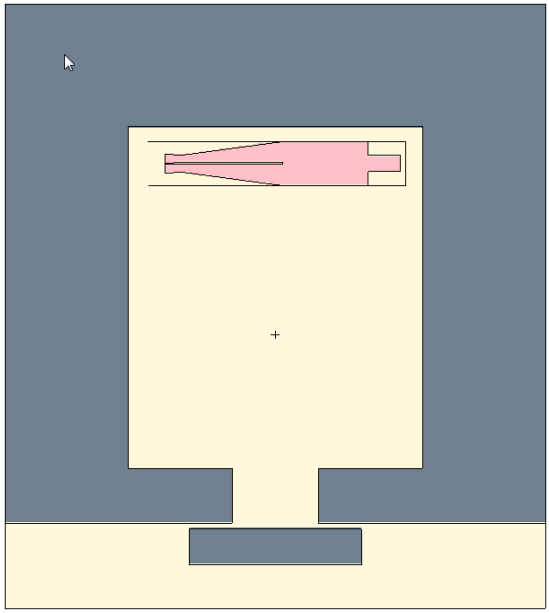

Figure 4. Close-up of the Body in the Shroud, View from Above

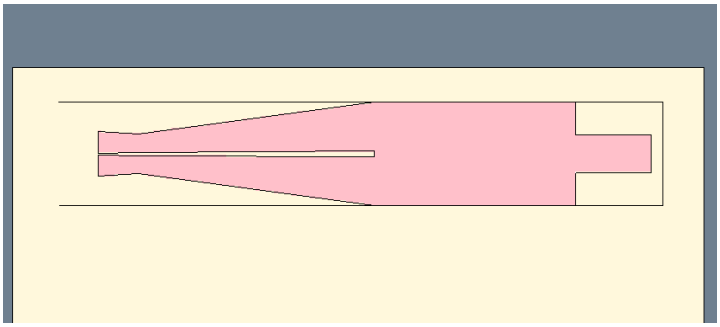

Figure 5. Side View Through the Tomb, Body is on the Back Bench

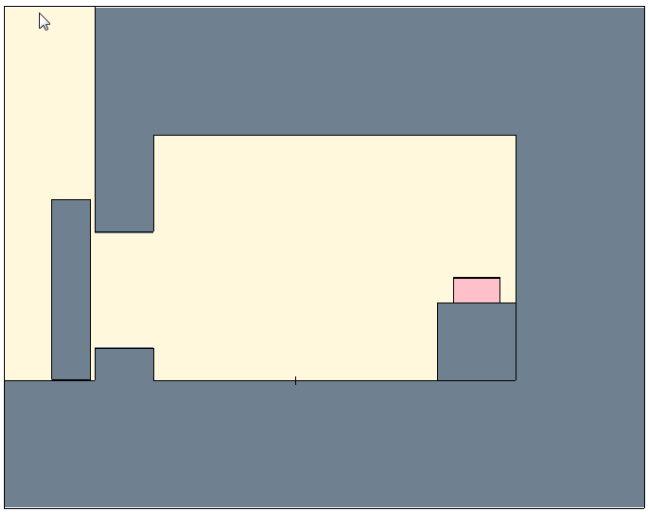

Figure 6. View from the Front, Includes Walls, Floor, and Ceiling

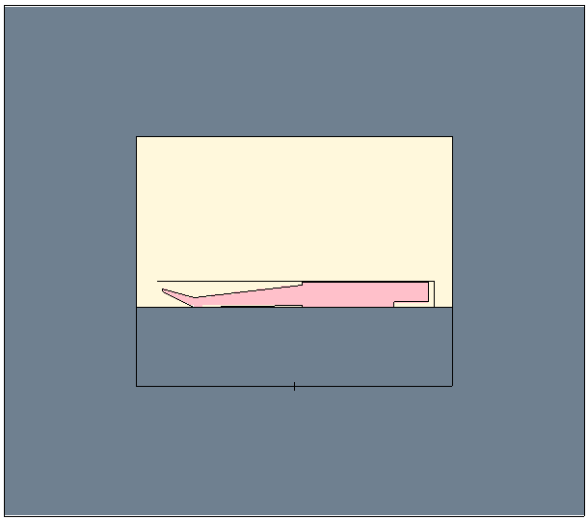

Figure 7. Close-up of the Body and the Shroud, View from the Front

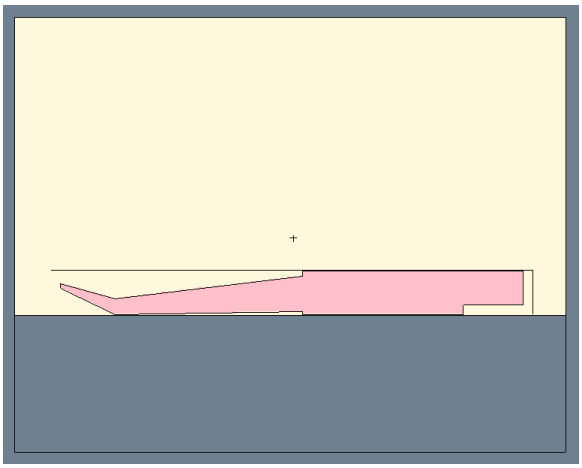

Figure 8. Close-up of a Corner of the Body Surrounded by the Shroud

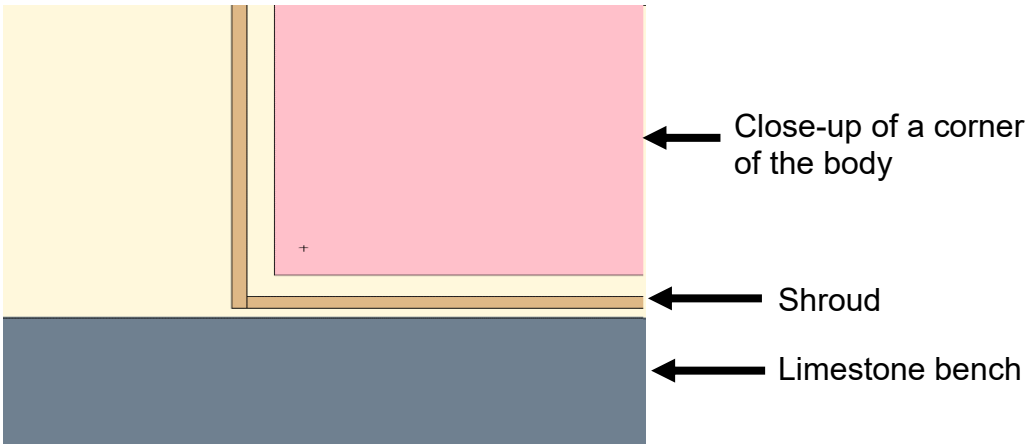

Figure 9. Distribution of Neutrons on Centerline of the Dorsal Image, With the Feet to the Left and the Head to the Right

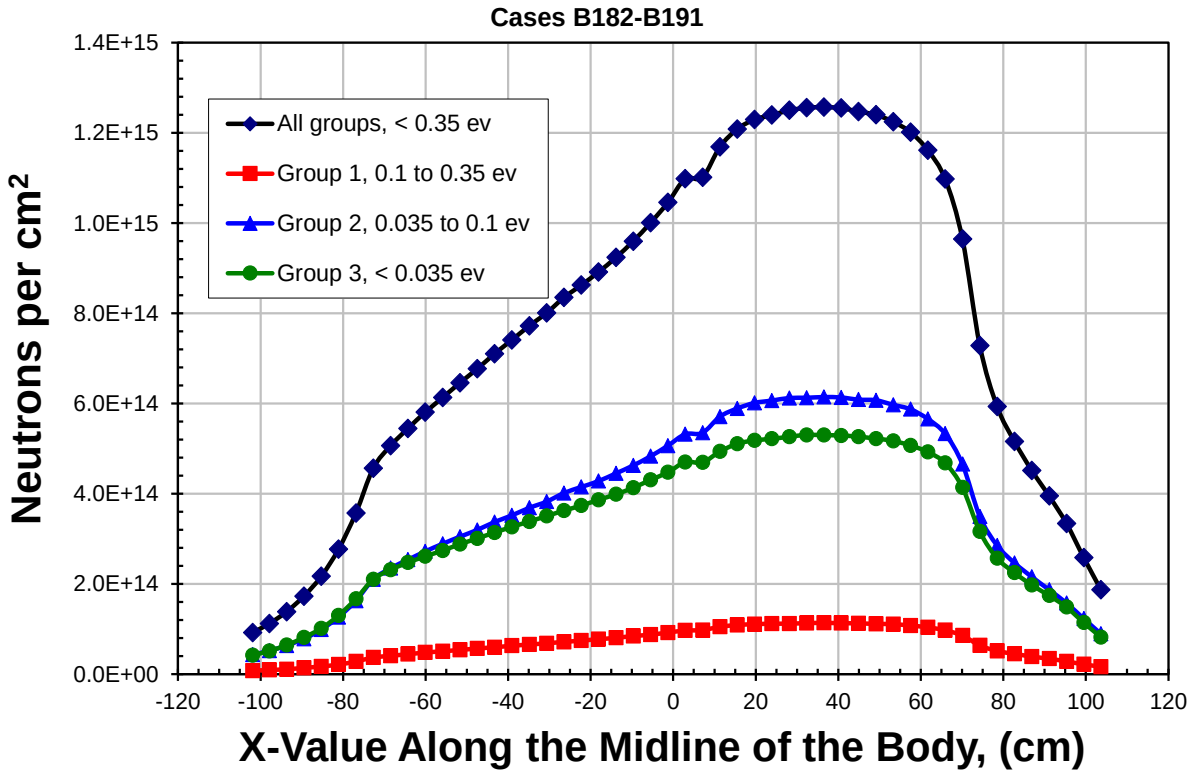

Figure 10. Distribution of Neutrons Absorbed by N^{14} Along the Centerline of the Dorsal Image, Feet to the Left & Head to the Right

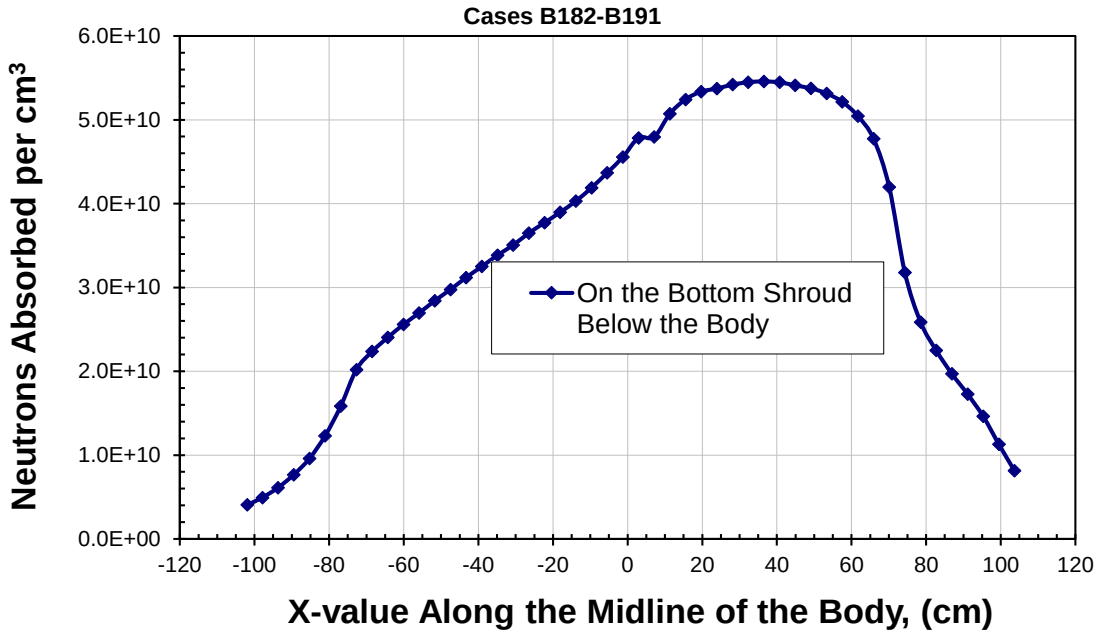

Figure 11. C^{14} Date for a Sample Taken from Along the Centerline of the Dorsal Image, with Feet to the Left & Head to the Right

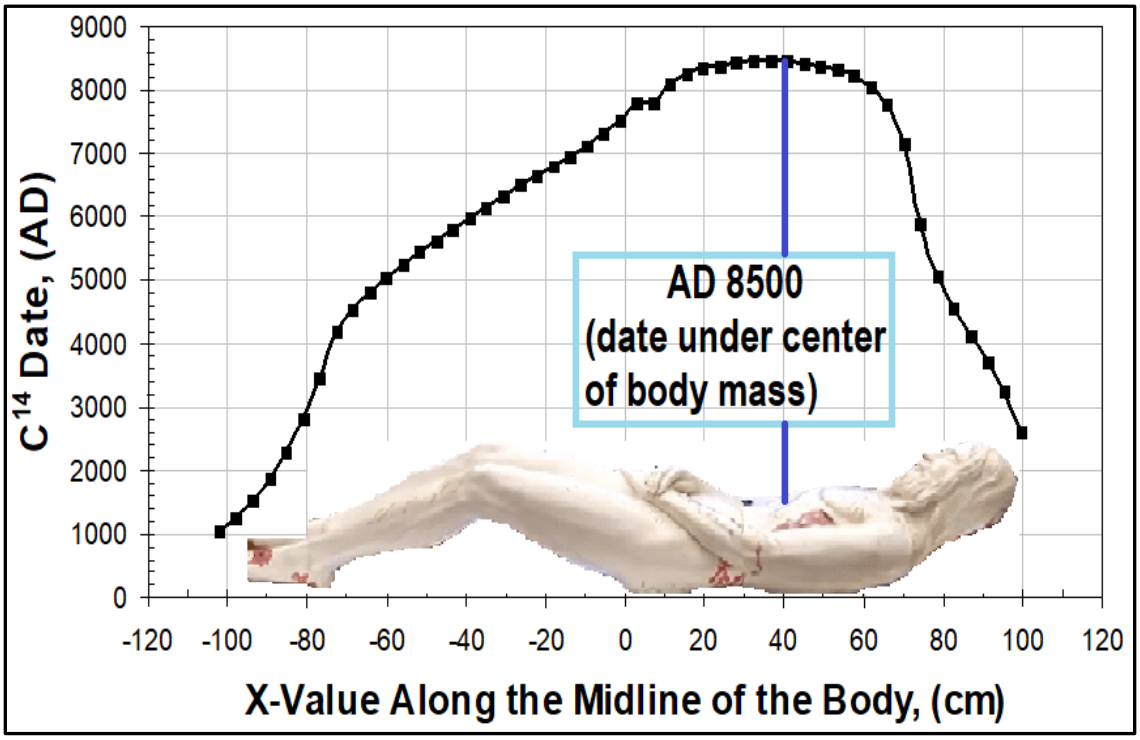

Figure 12. Location of Dates Shown in the Next Figure

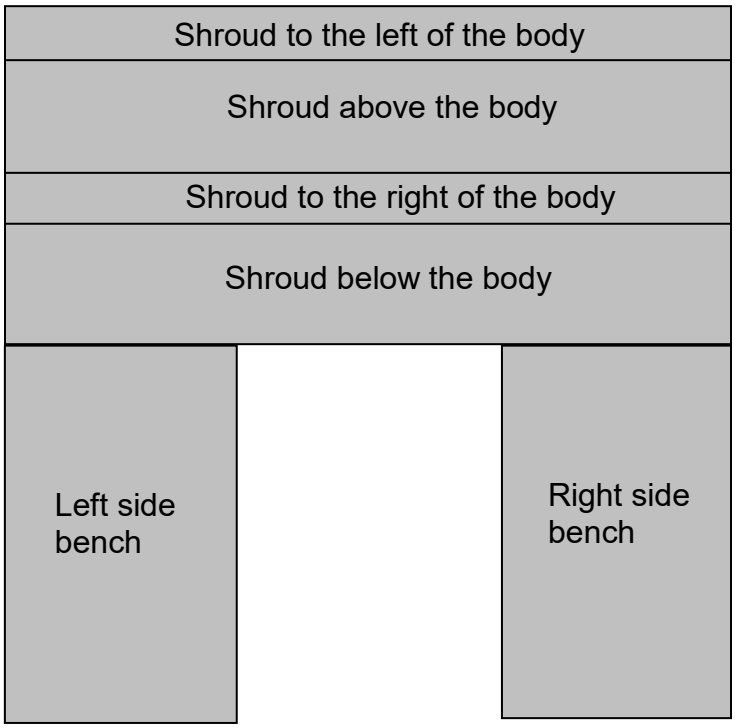

Figure 13. C^{14} Dates (AD) Calculated by the MCNP Computer Program

Uncorrected C-14 Date (AD), Cases B182-B191								Uncorrected C-14 Date (AD), Cases B182-B191								
828	1017	1262	1542	1871	2252	2669	3085	3459	3676	3716	3719	3619	2954	2326	1683	
824	1018	1202	1367	1542	1740	1976	2290	2836	3136	3171	3174	3130	2611	2156	1627	
875	1086	1272	1436	1638	1841	2075	2408	2762	3012	3038	3033	2995	2525	2068	1571	
983	1267	1477	1733	2044	2396	2783	3248	3534	3818	3862	3861	3785	3157	2348	1756	
1067	1388	1618	1918	2293	2713	3133	3626	3750	3994	4048	4033	3958	3546	3057	2280	
1005	1300	1541	1821	2159	2546	2937	3396	3654	3951	3984	3980	3912	3269	2547	1913	
904	1154	1381	1612	1871	2141	2441	2829	3130	3392	3424	3409	3322	2825	2423	1826	
866	1110	1363	1613	1884	2204	2590	3089	3897	4316	4379	4341	4166	3416	2620	1952	
877	1123	1447	1831	2294	2813	3379	3954	4514	4819	4884	4849	4632	3746	2802	2025	
958	1265	1659	2144	2692	3430	4326	5262	6141	6556	6620	6583	6320	4799	2994	2065	
1197	1869	2985	4031	4950	5714	6341	6943	7603	8056	8147	8096	7811	5970	3679	2378	
1317	2452	4260	5130	5745	6281	6779	7334	7909	8343	8459	8404	8115	6381	4235	2677	
1143	1770	2880	3909	4819	5572	6200	6805	7477	7923	8023	7977	7697	5853	3468	2197	
894	1136	1454	1853	2320	2997	3841	4760	5699	6081	6168	6161	5936	4462	2623	1789	
581	637	693	754	838							1507	1364	1200	1060	925	
557	601	638	682	747							1095	1022	947	876	802	
532	569	599	627	679							888	843	803	760	700	
506	543	566	588	630							764	734	704	678	636	
486	514	536	554	588							680	660	640	616	577	
458	490	504	523	546							619	599	579	562	534	
442	466	480	494	516							568	550	533	520	490	
419	441	455	468	491							522	508	496	485	459	
405	423	434	444	465							491	478	464	455	429	
384	408	416	425	447							460	448	439	429	411	
371	393	401	412	426							440	432	420	409	391	
356	374	385	393	411							424	411	401	392	374	
343	363	372	383	402							410	398	387	376	356	
322	344	359	370	391							401	387	374	357	333	

This is a top view looking down on the left bench, the right bench, and the back bench in the tomb. The locations of the above regions are shown in Figure 12 and are correlated to Figures 1 and 2. These values are the predicted C^{14} dates that would be measured for samples taken from linen cloth laying on the top surfaces of these benches in the Tomb. When the normal equations for C^{14} dating are used, the above dates into the future are obtained when neutron absorption causes the quantity of C^{14} in the sample to be greater than what would be expected for currently living plants.

Figure 14. MCNP Predictions of C^{14} Dates for Charred Material