Carbon Dating of the Shroud of Turin to 1260-1390 AD is Not Explained by Normal Contamination

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Rev. 0, August 9, 2019

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Abstract

The 1988 carbon dating of samples from the Shroud of Turin produced a date a 1260-1390 AD. Those who believe the Shroud probably dates to the time of Jesus, i.e. about 33 AD, often explain this carbon date is due to normal contamination such as handling, intentional placing of materials such as wax on the Shroud, or carbon deposited on the Shroud from the fire in 1532. There are two reasons why these normal sources of contamination cannot explain a shift in the carbon date from about 33 to 1260-1390 AD:

1) A variety of cleaning methods, including acids, were used on the Shroud samples in 1988 but these various cleaning methods did not significantly alter the carbon dates.
2) To shift the carbon date from 33 to 1260 AD would require the carbon in the samples to be at least 60% due to the contamination which should be easily visible using a microscope. For carbon deposited by the 1532 fire to be the explanation, it would have to constitute 80% of the carbon in the sample. However, microscopic examination of the fibers indicates the contamination is minimal. The equations used to calculate these percentages are included.

The best explanation for the 1988 carbon dating of the Shroud to 1260-1390 AD is not normal contamination but instead is new C^{14} produced on the cloth by neutron absorption.

1. Introduction

In 1988, samples were cut from the corner of the Shroud of Turin and sent to three laboratories in Arizona, Zurich, and Oxford for carbon dating. Carbon dating is performed by measuring the C^{14} to C^{12} ratios for the samples, since C^{14} decays with a half-life of 5730 years but C^{12} is stable. The average date obtained by the three laboratories was 1260 ± 31 years (Ref. 1). This is the uncorrected value. When this value was corrected for the changing amount of C^{14} in the atmosphere, a range of 1260 to 1390 AD was obtained. This is stated to be a two-sigma range, which means there is a 95% probability that the true value falls within this range. But statistical analysis (Ref. 2-11) of the laboratory's measurements of the C^{14} to C^{12} ratios indicates these measurements were probably affected by a systematic bias that caused the samples to be "heterogeneous". This means the samples sent to the three laboratories were basically different from each other in their C^{14} to C^{12} ratios, even though they were located on the Shroud next to each other. This indicates that something had evidently changed the C^{14} to C^{12} ratios of the samples. Since the amount the C^{14} to C^{12} ratios were changed cannot be determined from the measurements, the measured carbon date (1260 ± 31, uncorrected, with a corrected range of

1260-1390 AD) should be rejected for dating the Shroud. Also, many believe other evidence indicates the Shroud should date much earlier than 1260-1390 AD (section 6C of Ref. 12 and sections 4 and 5 of Ref. 13).

2. Discussion

To explain why it was carbon dated to 1260-1390 instead of to the time of Jesus, i.e. about 33 AD, many Shroud researchers refer to various types of contamination as the cause of the anomalous carbon date. The usual types of contamination that are referred to include:

- Unintentional causes such as oils from handling, pollen, dirt, miscellaneous debris such as different types of fibers, etc.
- Intentional causes such as placing of wax, talc, etc. onto the linen to strengthen it.
- Carbon deposited from the fire in 1532.

In this paper, the word "contamination" is defined by the above items. Other proposals to explain the samples dating to 1260-1390 instead of 33 AD are:

- A bioplastic coating was produced on the fibers by bacteria.
- Newer fabric was interwoven with the original fabric at some unknown time in the past. This is the invisible reweave hypothesis.
- Carbon monoxide with a higher C^{14} to C^{12} ratio was absorbed onto the fabric.
- The C^{14} to C^{12} ratio of the samples was changed by isotopic fractionation due to the action of biological organisms.
- New C^{14} was produced on the Shroud by absorption of neutrons emitted in the burst of radiation that formed the image. This is the neutron absorption hypothesis (Ref. 14).

Though technically these might be considered contamination, most Shroud researchers probably do not think of these when they are talking about contamination, so they will not be included in the definition of contamination in this paper.

There are two reasons that this normal contamination, as defined above, cannot explain why the Shroud was carbon dated to 1260-1390 instead of about 33 AD.

3. Reason 1 - Cleaning

The statistical analysis of the 1988 carbon dating of the Shroud is discussed in Damon, et al (Ref. 1). In Damon, under "Measurement Procedures", paragraphs 13 to 17 discuss the variety of mechanical and chemical cleaning methods used on the different samples by the three laboratories, including severe cleaning in ultrasonic baths and hydrochloric acid, sodium hydroxide, sodium hypochlorite, petroleum ether, and ethanol. The meaning of the results for the various cleaning methods is discussed under "Results", paragraph 21: "From these data it can be seen that, for each laboratory, there are no significant differences between the results obtained with the different cleaning procedures that each used." Because of the significant differences in the cleaning methods used, contamination on the samples was evidently not causing a significant change to the carbon dating. Thus, contamination as defined above would be insufficient to cause the Shroud to carbon date to 1260-1390 AD instead of about 33 AD.

4. Reason 2 – Required Fraction of Contamination

To shift the carbon date from about 33 AD to 1260 AD requires the amount of contamination to be so large that it should be easily visible using a microscope, and probably to the unaided eye. For example, for carbon deposited from the fire in 1532 to cause this shift in the carbon date, the weight of the carbon in the sample would have to be 80% due to carbon deposited from the fire and only 20% due to the carbon in the fabric. To shift the carbon date from about 33 AD to a year more recent than 1260 AD, such as 1390 AD, requires the weight of the carbon in the sample to be even more than 80% from the fire and less than 20% from the fabric. Even under the most conservative assumption, assuming all the contamination occurred in 1988, to cause this date shift from about 33 AD to 1260 AD, the weight of carbon in a sample would have to be 60% due to the contamination and only 40% due to the fabric. Microscopic examination of the Shroud threads and fibers indicates the amount of contamination cannot be this high, and in fact is minimal.

5. Required Contamination to Explain the 1260-1390 Date

The mathematical equations to derive the above values are given below. The general equation for the weight of C^{14} in a sample S decaying from an initial time "0" to a subsequent time "1" is:

$S_1 = S_0$ x exp[-ln(2) x decay time / half-life] Where from left to right:

- S_1 is the weight of C^{14} in a sample at the subsequent time 1.
- S_0 is the weight of C^{14} in a sample at the initial time 0.
- x means multiplication
- exp[a] means "e" to the "a" power with e = the base of the natural logarithms approximately equal to 2.71828.
- A negative is in front of ln(2) where ln(2) = natural logarithm of 2.00 = 0.69315.
- Decay time is the years between the initial time 0 and the subsequent time 1.
- The half-life for C^{14} is 5730 years.

For example, if the material decays through one half-life, then the equation simplifies to:

$S_1 = S_0$ x exp[-ln(2) x 5730 / 5730] = S_0 x exp[-ln(2) x 1.0] = S_0 x exp[-ln(2)] = S_0 x 0.5

This is as it should be, i.e. half the C^{14} remains when it decays through one half-life.

According to this equation, the fraction of C^{14} remaining after:

1988 – 33 = 1955 years of decay would be exp [-0.69315 x 1955/5730] = 0.78939

1988 – 1260 = 728 years of decay would be exp [-.69315 x 728/5730] = 0.91570

1988 – 1532 = 456 years of decay would be exp [-0.69315 x 456/5730] = 0.94633

This means if carbon deposited from the 1532 fire contaminated the Shroud, the weight of C^{14} in this contamination remaining after 456 years of decay would be .94633 times the original C^{14} in this contamination.

Thus, to get to a date of 1260 AD (for a mixture with 0.91570 of the original C^{14} remaining) by mixing fabric from 33 AD (with 0.78939 of the original C^{14} remaining) and contamination from 1532 AD (with 0.94633 of the original C^{14} remaining) can be solved by the equation:

0.78939(1-X) + 0.94633(X) = 0.91570 for a mixture of the two materials dating to 1260 AD.

where X = the weight fraction of newer (1532 AD) material in the sample, with the sample consisting of the combination of the original fabric, presumed to be from 33 AD, and the newer material in the fabric. This can be expressed as:

A(1-X) + BX = C, where A = 0.78939, B = 0.94633, and C = 0.91570. Solving for X:

A + (B-A)X = C

(B-A)X = C-A

X = (C-A)/(B-A)

Plugging the numbers in gives:

X = (0.91570 - 0.78939) / (0.94633 - 0.78939) = 0.80483.

This means if all the contamination came from carbon deposited from the fire in 1532 then over 80% of the weight of carbon in the sample would have to be carbon from the fire so that less than 20% of the weight of the carbon would be due to the fabric. The weight of the carbon deposited from the fire would have to be over four times the weight of the carbon in the fabric.

Also, by the above equation, if the Shroud was contaminated by modern material in 1988, then the fraction of C^{14} remaining in 1988 after 1988 – 1988 = 0 years decay would be exp [-0.69315 x 0/5730] = 1.0, as it should be.

Thus, under the most conservative assumption, i.e. that gives the smallest fraction of contamination, assuming all the contamination is from modern material in 1988, then B = 1.0 so:

X = (0.91570 - 0.78939) / (1.0 - 0.78939) = 0.59973

This means that, even under this most conservative assumption, 60% of the weight of the carbon in the sample would have to be due to contamination, and only 40% could be due to the fabric. This level of contamination would be easily visible using a microscope, and probably with the unaided eye.

6. Required Increase in the C^{14} to C^{12} ratio to Explain the 1260-1390 Date

The uncorrected value obtained from the 1988 carbon dating of the Shroud was 1260 AD. If the Shroud was made in 1260 AD, by the time the carbon dating experiments were performed in 1988, the C^{14} to C^{12} ratio would have decreased by the following fraction:

$\exp[-\ln(2) \times (1988-1260)/5730] = 0.915702$, as previously calculated in section 5.

If the Shroud was made in 33 AD, by the time the carbon dating experiments were performed in 1988, the C^{14} to C^{12} ratio would have decreased by:

$\exp[-\ln(2) \times (1988-33)/5730] = 0.78939$, as previously calculated in section 5.

If the C^{14} content in the Shroud samples was increased by 16% [(0.915702 / 0.78939) = 1.16001] in 33 AD, then in 1988 it would appear the samples were from 1260 AD:

$1.16001 \times \exp[-\ln(2) \times (1988-33)/5730] = 0.915702$

This value (0.915702) is the same as for the Shroud being made in 1260. Thus, if the C^{14} to C^{12} ratio for the Shroud was increased by 16% in 33 AD, carbon dating of it in 1988 would produce an apparent date of 1260. This is important because the neutron absorption hypothesis (Ref. 14) postulates that the 1988 carbon date of 1260-1390 AD is best explained by neutron absorption to produce new C^{14} in the Shroud, with this event occurring in about 33 AD. In the above considerations, the uncorrected date of 1260 was used instead of the corrected range of 1260-1390 to avoid complexities.

According to the above, the quantity of C^{14} is required to increase by 16% to shift the carbon date from 33 AD to 1260 AD if the neutron absorption occurred in 33 AD. At the other extreme, if the neutron absorption occurred in 1988, at the time of the carbon dating, then the required increase can still be determined from the ratio 0.915702 / 0.78939 = 1.16001. Thus, no matter when the neutron absorption occurs between 33 and 1988, the required increase in C^{14} is 16%.

7. Options for Explaining the 1260-1390 Carbon Date

If the Shroud is from the time of Jesus, i.e. about 33 AD, normal contamination cannot adequately explain why it was carbon dated in 1988 to a range of 1260-1390 AD. For normal contamination to cause this large of a shift in the carbon date would require the carbon of the samples to be mostly due to the contamination, which should have been easily seen using a microscope.

What then is the most likely explanation for the 1988 carbon date of 1260-1390 for the Shroud? The possibility of a plastic coating on the fibers due to the action of bacteria can be rejected on the same basis as normal contamination. There are significant objections to the invisible reweave hypothesis as the explanation for the 1260-1390 date (section 2 of Ref. 14 and chapter 9 of Ref. 15). Carbon monoxide absorption into the threads, with the carbon having a higher C^{14} to C^{12} ratio than normal, has not been accepted as the explanation due to many problems, and if true, should have changed the carbon dates for many other items. Isotopic fractionation and neutron absorption are considered below.

8. Isotopic Fractionation

Another option sometimes used to explain the 1260-1390 carbon date is isotopic fractionation. This is the process by which certain physical and chemical processes, often related to biological organisms, could alter the isotopic fractions of carbon from the standard values. However:

- In the analysis of the 1988 carbon dating of the Shroud discussed in Damon (Ref. 1), the stated carbon date of 1260-1390 included a correction for the isotopic fractionation of C^{14} based on the measured isotopic fractionation of C^{13}.
- The measured isotopic fractionation of C^{13} in the 1988 samples, as reported in Damon, was -25.0 per mille for Tucson (25.0 parts per thousand, i.e. 2.5%, less C^{13} than the standard), -25.1 for Zurich, and -27.0 for Oxford. This gives an average of -25.7 per mille for the three laboratories, which means that there was an average of 2.57% less C^{13} than the standard, with the standard being the carbon isotopic fractions in the Cretaceous belemnite formation at Peedee in South Carolina, USA (Ref. 20). The recommended convention for carbon dating measurements is to adjust the results to a C^{13} isotopic fractionation base value of -25.0 per mille, which means that the average C^{13} isotopic fractionation of -25.7 is only 0.7 per mille (0.07%) more negative than the base value. The effect of isotopic fractionation should be approximately proportional to the difference in mass, and the mass difference between C^{14} and C^{12} is twice the mass difference between C^{13} and C^{12}. This is stated in Ref. 20: "The extent of isotopic fractionation on the 14C/12C ratio … is approximately double that for the measured 13C/12C ratio." Based on this, the C^{14} isotopic fractionation for the 1988 carbon dating measurements should cause a reduction in the C^{14} isotope of only about 0.14% (twice the 0.07% for C^{13}) relative to the base value that carbon dating measurements are usually normalized to. This is significantly smaller, and in the opposite direction, compared to the 16% increase (see section 6) in the C^{14} that is required to shift the carbon date from about 33 to 1260 AD.
- Isotopic fractionation does not explain the slope in the measured dates reported by the three laboratories (about 36 to 38 years per cm, Figure 3 of Ref. 10) when compared to the measurement uncertainties. In statistical analysis terminology, the explanation for this slope is that the samples were heterogeneous because their C^{14} to C^{12} ratios were altered by a systematic bias that was a function of the distance from the bottom of the cloth.
- Isotopic fractionation does not explain the inconsistency between the range of the measured dates (540 to 795 years before 1950, Table 6 of Ref. 10) when compared to the

measurement uncertainties (Ref. 10). Again, in statistical analysis terminology, the explanation for this inconsistency is that the samples were heterogeneous because their C^{14} to C^{12} ratios were altered by a systematic bias that was a function of the distance from the bottom of the cloth.

- If isotopic fractionation shifted the date for the Shroud from about 33 to 1260-1390 AD, then the carbon dates for many other items should also have been significantly changed.

9. Conclusion

The most likely explanation for the 1988 carbon dating of the Shroud to 1260-1390 is not normal contamination, or any of the other proposed explanations discussed above, but that neutrons were included in the burst of radiation emitted by the body that caused the image (Ref. 16, 17, 18, and section 5 of Ref. 19). Absorption of a small fraction of these neutrons in the trace amount of N^{14} in the threads would have produced new C^{14} atoms by the [N^{14} + neutron $\rightarrow$ C^{14} + proton] reaction, thus increasing the sample's C^{14} to C^{12} ratios by the required 16% calculated above in section 6. This is the neutron absorption hypothesis (Ref. 14). This hypothesis was first suggested by Tom Phillips (Ref. 21) in 1989 in a letter to the editor in the same edition of *Nature* that contained the original statistical analysis of the 1988 carbon dating of the Shroud (Damon, Ref. 1). Neutron absorption is the only hypothesis that is consistent with everything that we know about carbon dating as it applies to the Shroud, i.e. the date, slope, and range of the data from the 1988 carbon dating of the Shroud and the 700 AD carbon date for the Sudarium, which is believed to be the face cloth of Jesus. Based on MCNP (Monte Carlo N-Particle) nuclear analysis computer calculations (Ref. 14), the required 16% increase in the C^{14} to C^{12} ratio at the 1988 sample location would have required emission of about 2 x 10^{18} neutrons if homogeneously emitted from the body. This is about one neutron for every ten billion that would have been in the body (section 4 of Ref. 14), based on the estimated weight of 170 to 175 pounds for the body.

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Biography

Robert A. Rucker earned an MS degree in nuclear engineering from the University of Michigan and worked in the nuclear industry for 38 years primarily in nuclear reactor design, nuclear criticality safety, and statistical analysis for quality control of nuclear material inventories. He holds Professional Engineering (PE) certificates in nuclear engineering and in mechanical engineering. He organized the International Conference on the Shroud of Turin (ICST-2017) held July 19-22, 2017, in Pasco, Washington. His papers can be downloaded from the research page of his website at http://www.shroudresearch.net/research.html. Send comments, questions, or corrections to robertarucker@yahoo.com.