THE DATING OF THE SHROUD OF TURIN

CÉSAR BARTA GIL
Universidad Carlos III de Madrid

RESUMEN: La Sábana Santa ha sido datada por la técnica del Carbono 14 obteniéndose una fecha medieval. Si esta fecha fuese correcta la reliquia no podría ser de Jesucristo y toda la investigación perdería su interés. Aunque la técnica del Carbono 14 ofrece frecuentemente resultados positivos para la arqueología, hay también resultados insostenibles en un número significativo de casos y en la aplicación al caso de la Sábana Santa el análisis estadístico intrínseco de los datos brutos cuestionó la fiabilidad del resultado. Hay dataciones alternativas del Lienzo que han resultado compatibles con la vida de Cristo. Entre las posibles explicaciones de porqué pudo fallar la datación por C14 las que más sobreviven son la del remiendo y la de la radiación de neutrones.

PALABRAS CLAVE: datación; Carbono 14; Sábana Santa; irradiación neutrones.

The Dating Of The Shroud Of Turin

ABSTRACT: The Shroud of Turin has been dated by the Carbon 14 technique obtaining a medieval date. If this date were correct, the relic could not be of Jesus Christ and the whole investigation would lose its interest. Although the Carbon 14 technique (C14) frequently offers positive results for archaeology, there are also unsustainable results in a significant number of cases and in the case of the Shroud the intrinsic statistical analysis of the raw data cast doubt on the reliability of the result. Other alternative dating techniques applied to the Shroud align with the life of Christ. Among the possible causes of the failure of the C14 dating, the most survived ones are the mending and the neutron radiation.

KEY WORDS: Dating; Carbon 14; Shroud of Turin; Neutron irradiation.

Introduction

According to tradition, the Shroud of Turin is said to be a Christ's relic. It is a long, rectangular linen sheet about 4.3 x 1.1 m in size woven in a 3/1 herringbone twill (Raes, G. 1991). It shows a faint image of a Man with the wounds of the typical torture and crucifixion described in the Gospels. The irreproducible image is not the result of any substance added to the tissue, but of the discoloration of the tissue fibers themselves (Jumper *et al*. 1984). The true blood is indeed added to the tissue (Heller and Adler 1981).

This ancient cloth was exhibited in Lirey (France) around the year 1357 and since then, the cloth has been traced to the present day. Its previous existence is only assumed by some reliable clues. It was dated by the carbon 14 (C14) technique in 1988 and the result was to be medieval (1260-1390) (Damon *et al*. 1989a). This conclusion is disputed because it contradicts several arguments (Fernández-Sánchez 2024).

In this work the dating of the Shroud of Turin (denoted Shroud hereafter for brevity) will be analyzed, mainly by C14, although some alternative method will be also included.

Dating technique by C14 is supposed to be known and only a brief review of its fundaments is indicated. The amount of C14 that the living organisms acquire

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is reduced to half in organic materials every 5730 years, according to what has been agreed. The measurement of how much C14 remains in a biological object informs us of the time since its death. For example, when a vegetable is mowed, i.e., it dies. This technique was first applied to wood and then to bones, shells, and to vegetables as the linen of which the Shroud is made.

1. C14 Dating of the Shroud

A sample of the Shroud was taken from a corner (Figure 1). From that corner, a piece of around 8 x 2 cm was cut. This piece included a seam that joined the main cloth with a reinforcement fabric. The seam was removed. Half of the remaining sample was set aside as a reserve for future tests and controls, while the other half was distributed among the three laboratories best suited for carbon-14 dating using mass spectrometry (Figure 2).

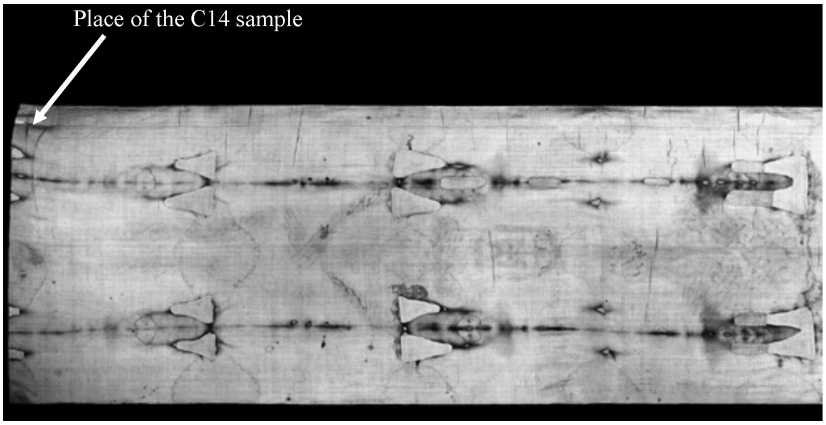

Figure 1
Place where was taken the sample of the Shroud for C14 dating.

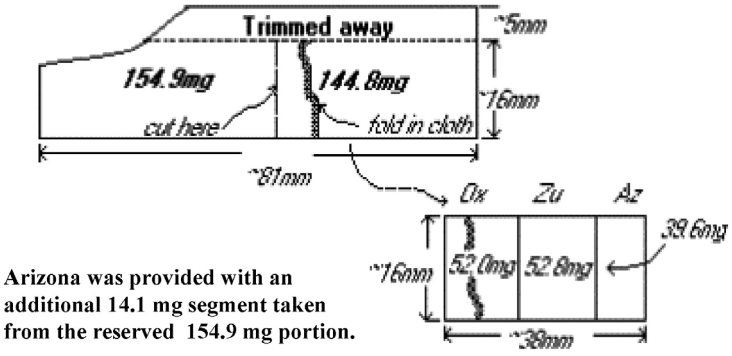

Figure 2
Distribution of the sample among the three laboratories for C14 dating.

The three laboratories were given about 50 mg of fabric. The piece initially intended for Arizona did not reach the required weight and had to be given a part of the reserve sample. Once the test was performed, the publication of the results unfortunately was not the standard, because it happened with an anomaly: before the results were published in a peer-reviewed journal, a press conference was convened in Turin and another in Oxford, from which journalists drew their headlines without the scientists having been able to assess the real data that had been used for the conclusion.

Only four months after the press conference, when the news had already appeared in all the headlines, is when the scientific article appeared with the data measured and the procedure applied. The conclusion of the article was that, with a 95% probability of reliability, the linen of the Shroud had been made between the end of the 13th and the 14th century (Damon *et al*. 1989b). That is to say: if it was medieval, it could not be from Jesus Christ, therefore, it was a forgery.

But once those data had been published, they began to be analyzed by the scientific community. Figure 3 shows the table as it appears in the original article of Nature, the prestigious scientific journal. It will be explained here a little more. The sample number 1 is the one that corresponds to the Holy Shroud.

Table 2 Summary of mean radiocarbon dates and assessment of interlaboratory scatter

Sample	1	2	3	4
Arizona	646 ± 31	927 ± 32	1,995 ± 46	722 ± 43
Oxford	750 ± 30	940 ± 30	1,980 ± 35	755 ± 30
Zurich	676 ± 24	941 ± 23	1,940 ± 30	685 ± 34
Unweighted mean*	691 ± 31	936 ± 5	1,972 ± 16	721 ± 20
Weighted mean†	689 ± 16	937 ± 16	1,964 ± 20	724 ± 20
χ^2 value (2 d.f.)	6.4	0.1	1.3	2.4
Significance‡ level (%)	5	90	50	30

Dates are in yr BP. d.f., degrees of freedom.
* Standard errors based on scatter.
† Standard errors based on combined quoted errors.
‡ The probability of obtaining, by chance, a scatter among the three dates as high as that observed, under the assumption that the quoted errors reflect all sources of random variation.

FIGURE 3

Copy of the original table of Nature n. 337, with the age in years of the Shroud (column 1) and the three control samples. Column 2, Tomb of Nubia (XII-XIII century A.D.), column 3, Egyptian linen (S. I a. C.) and column 4, pluvial cape of S. Luis d'Anjou (S.XIII).

The other three are samples of control. Laboratories applied the same procedures to all of them. The first three rows are the antiquity in years the laboratories obtained: about 700 years old for the Holy Shroud, that means it was from the 13th century. It could not be from Jesus Christ.

2. Critical review of the C14 dating of the Shroud

In the last row of the table (Figure 3) the authors of the dating indicated the significance level that is defined in the caption of the table: «*The probability of obtaining, by chance, a scatter among the three dates as high as that observed, under the assumption that the quoted errors reflect all sources of random variation*». The statistic value assigned to the Shroud, 5%, probably would be object of debate among the authors prior to the submission to the scientific journal. We can imagine something as «How are we going to publish that there is a 5% of significance level?». This 5% means that there is a 95% probability that some source of error was not taken into account. On the other hand, control samples showed higher significance levels. But, since there was a commitment to publish the statistical analysis, they had to agree to include it. They were honest enough to respect the commitment to publishing it. This 5% led to writing many critical articles in peer-reviewed journals over the following years until nowadays. Over the years, many critical articles in peer-reviewed journals highlighted the poor statistical reliability of this measure (Van Haelst 1997) (Giulio Fanti and Marinelli 1998) (Walsh, B. J. 1999) (G Fanti *et al*. 2010) (Van Haelst, R. 2010) (Riani *et al*. 2013) (Casabianca *et al*. 2019a) (Walsh and Schwalbe 2020) (Di Lazzaro *et al*. 2020). In fact, when the raw data were obtained (Casabianca et al. 2019a), their review verified that the significance level did not even reach 5%.

This low reliability does not mean that the Holy Shroud was made in the first century, it only means that the Carbon 14 dating is unreliable, and we do not know yet how old it is. The most honest conclusion would have been that there was an unexplained intrinsic discrepancy between laboratories. Therefore, we cannot trust it. In other words, the measure was invalid.

3. Some tentative explanations of potential causes of error

3.1. Contamination and fire

Some of the explanations to justify why a linen from the first century could have been dated in the 14th century by Carbon 14 include the fire (Kouznetsov, Ivanov, and Veletsky 1996) and the contamination. However, although qualitatively, they actually have a certain impact, they can only modify the dating by a few centuries but not up to 14 centuries. When the quantitative analysis is conducted, it is found that the known contamination of the Shroud, estimated at less than 15% (Morano, E. 1978), could justify an age reduction of

no more than 280 years. To justify the 14 centuries shift it would be necessary 64% of contemporary organic carbon contamination (Gove 1990). In the case of the fire, experiments that simulated the fire of 1532 showed that the shift was much less than 14 centuries (Moroni, M. 2000). These objections could only have changed the dating by up to 300 years, but they could never have justified the 1400-year difference.

3.2. Invisible mending

Others purported explanations that have survived are the patching and the neutron radiation. As for the patch, the scientist Raymond Roger also published in a high prestige journal that the characteristic measures he had made on fibers of the dated part had physicochemical differences with the same fibers of the main part (Rogers 2005a). It seems that the part dating did not correspond to the main cloth. This article will not analyze the patching explanation in depth. We only provide references that support this explanation (Rogers 2005b) (Benford and Marino 2008), other balanced that does not rule out its possibility (Meacham 2000) and, finally, others that refute this explanation (Flury-Lemberg 2003) (Freer-Waters and Jull 2010) (Bella, Garlaschelli, and Samperi 2015).

3.3. Neutron irradiation

This article will provide more analysis of a lesser referred hypothesis regarding the radiation of neutrons, which merits further study. The radiation of neutrons would certainly be an exceptional phenomenon that some scholars often neglect a priori (Currie 2004); however, this hypothesis was already proposed in the same issue of Nature in which the dating was published (Phillips 1989). If the dating is to be trusted, the neutron irradiation hypothesis must be considered as well.

Physicist Philips said that a radiation of neutrons could have altered the dating by carbon-14 (Phillips 1989). And indeed, from a physics point of view, it is known both theoretically and experimentally that this can happen. In fact, experiments have confirmed the effect, and they have even provided approximately what dose of neutrons is needed to modify the dating by 1400 years (Lind *et al*. 2010). Actually, these doses can be described as quite low because they barely modify the physicochemical structure of the linen (Barta *et al*. 2025).

Generally, people wonder where the neutrons come from. However, this is a subsequent question, which would only arise once the evidence of neutron irradiation is found. Some nondestructive techniques are proposed to elucidate the possible neutron irradiation on linen (Barta, Fernández-Álvarez, and Ruiz-Navas 2024). Only in case of evidence of such a neutron irradiation, the question of the origin will have to be considered. If there is no evidence of such irradiation, it would never be necessary to answer the question of the origin of neutrons.

About the origin of the alleged neutrons, the American nuclear engineer, Robert Rucker, proposes the hypothesis that the neutrons come from the wrapped body (Rucker, R. 2014). Rucker had worked in the nuclear reactors industry developing models for dynamic nuclear reactors and he applied his experience to calculate definite values of the C14 increment along the Shroud, assuming a quantity of neutrons emission proportional to the corporal mass density of the wrapped body. Rucker also had to make assumptions about the interactions of those neutrons with the surrounding: the air, the rock wall and the slab. Those neutrons that go down, and towards the wall, can bounce and return back to the Shroud (Figure 4). He assumed that the slab was made of limestone like the one in Jerusalem.

Figure 4

According to Rucker's hypothesis (Rucker, R. 2014), the body emitted neutrons that interacted with the wall and slab and transmuted elements in the Shroud that increased the C14 depending on the relative position with respect to the body part. The figure is for illustrative purposes only.

According to the Rucker's model, thermal neutron doses have a gradient. In his model, he determines that where there is more body mass, there is more dose. For example, in the center of the torso there must be more dose than near the feet or head. Moreover, at the dorsal side, where the neutrons bounce against the slab, there must also be more dose than at the frontal part where

the neutrons escape through the air. The intensity of the emission, as a single factor, is tuned so as to give the measured concentration of C14 at the part of the feet where the sample was taken giving a 14th century dating. Then, the model provides a dose for every part of the rest of the Shroud. The among of C14 in many part of the Shroud would be higher than that corresponding to the living organisms and the algorithm providing the age would give a future period. If several samples were dated by C14 throughout the Shroud, the resulting age would go beyond the present day into the coming centuries (Figure 5).

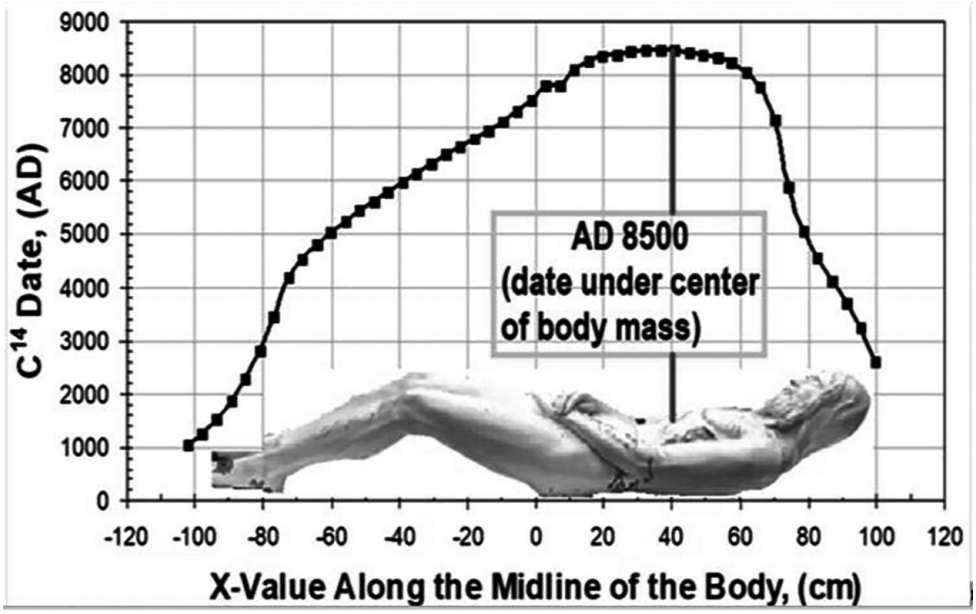

Figure 5

Date corresponding to the increment of C14 due to the neutron irradiation coming from the body according to the model of (Rucker 2022). Note that most of the cloth facing the dorsal part of the body would give calendar dates in the future.

Although obtaining permission for new C14 dating using several samples is very unlikely because the technique is destructive, non-destructive techniques already performed or to be proposed could provide clues in favor of the hypothesis or against it to rule it out.

Among the data already obtained, there are at least two that can support the hypothesis of neutron irradiation. First, there is the geometric arrangement of the three samples that were dated. The date obtained for each samples was

not exactly the same. In fact, those dates were more different than the allowed intrinsic error which led to a level of signification ≤ 5%. Arizona presents a margin of error incompatible with that of Zurich and Oxford. In other words, there is no overlap between measurements. The remarkable finding was that the further away the sample was from the body, the older they appeared to be. The closer the sample was to the body, the more modern it appeared matching that predicted by the Ruckers's model (see Figure 6). There is a hint of a trend between age and position and the gradient confirms that it could have been a radiation of neutrons. On the other hand, this fact argues against the mending hypothesis because the assumed added modern matter for repairing would increase towards the edge just to the opposite direction of what is observed.

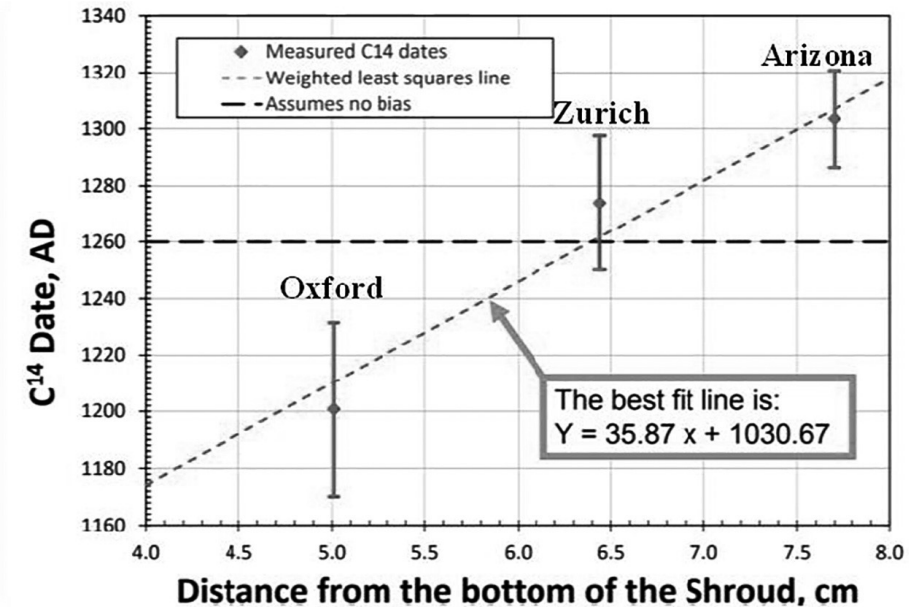

FIGURE 6

Date corresponding to the samples of the three laboratories according to their the position in the Shroud. The associated margin of error shows how much the Oxford sample is incompatible with the other two.

As noted above, the model yields a lower dose along the half having been on the frontal part of the body than that in the dorsal part due to the bouncing of neutrons against the slab. There is also a slightly lower dose at the feet than at the head and at both edges, much less dose than at the torso (Figure 7 upper part).

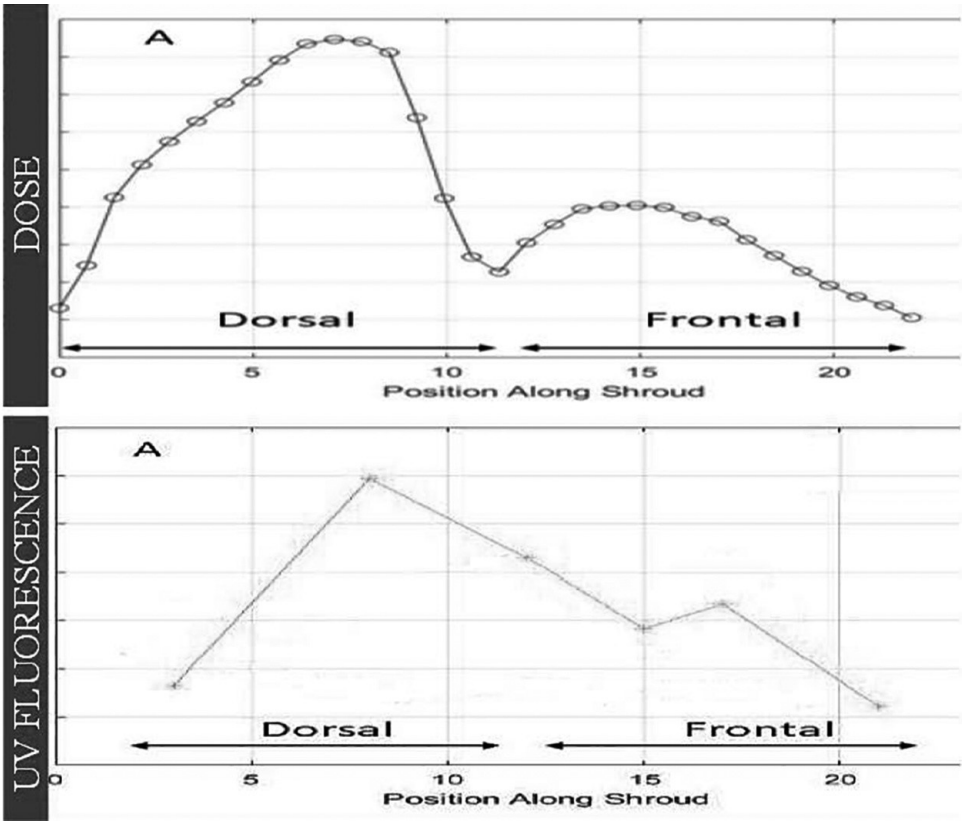

Figure 7

Upper figure: Profile of the dose predicted from the model along the central part of Shroud. Lower Figure: Intensity of the UV fluorescence recorded in 1978 and processed by McAvoy.

This profile could have had some observable effect. For indeed, there is something remarkable. McAvoy published the ultraviolet (UV) fluorescence along the Shroud processing data taken in 1978 (McAvoy 2021) and he observed that the UV fluorescence also has a profile that follows the prediction of the dose. Less fluorescence at the feet, more at the torso and maximum at the dorsal part (Figure 7 lower part). McAvoy wondered if neutrons could modify the UV fluorescence of linen, and he made irradiate linen fabric for increasing neutron radiation. He obtained that there is indeed a correlation between the more doses, the more UV fluorescence (McAvoy 2021).

The intensity of the dose according to the Rucker's model should be higher on the side closer to the wall than on the side facing the access to the slab where there was no wall (Figure 8 left). The profile of the UV fluorescence

analyzed by McAvoy corresponds to the longest longitudinal dimension of the Shroud (Figure 7 bottom). But McAvoy also included the intensity of the UV fluorescence on both right and left sides of Shroud (Figure 8 right). The UV fluorescence is higher on the right side of the Shroud. The right side in the Shroud refers to the side of the chest wound of the Man of the Shroud. If neutrons increase C14 and UV fluorescence, the higher fluorescence on the side of the chest wound must require that this side of the Shroud was placed close to the wall and the other side would be the one facing the access to the slab.

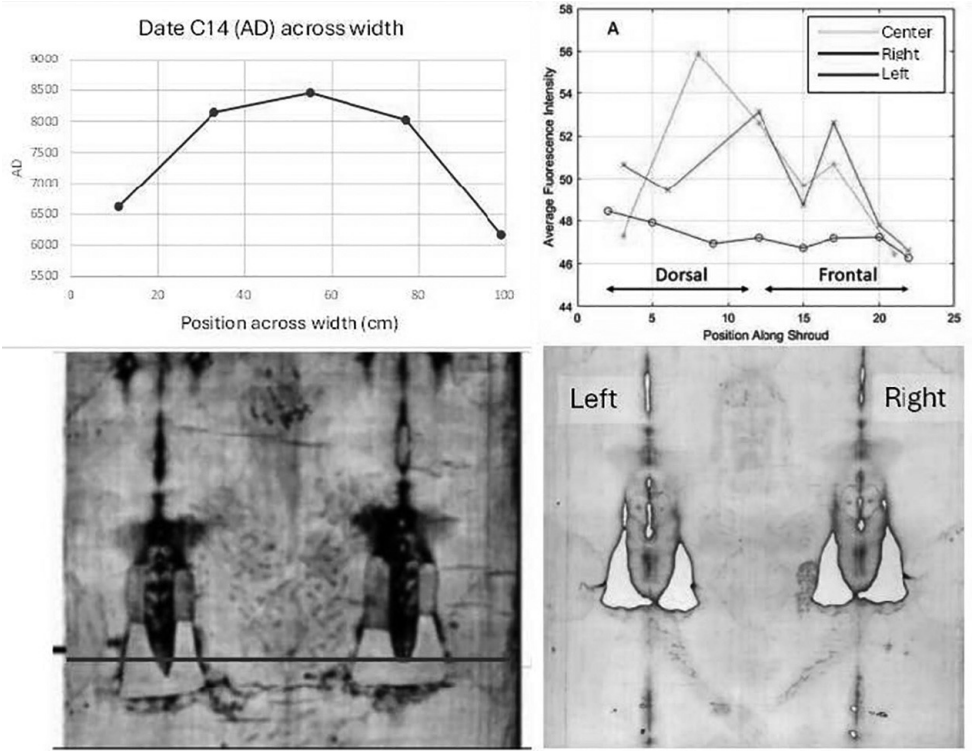

Figure 8

Left: Profile of the dose predicted from the model across the Shroud. Right: Intensities of the UV fluorescence on the center, right and left areas of the Shroud. Right is the side where is the chest wound of the Man of the Shroud.

Is it possible to determine whether the spear wound was on the side of the wall or on the side of access to the slab? A possible clue is proposed here: the «belt of blood» crossing the lumbar area must have dropped on the Shroud when the corpse was placed on it. Once the corpse approached the slab face up by the access side of the slab, the wound of the chest would drop blood staining first the edge of the Shroud near the access side of the slab and continue staining

the Shroud along the path below the trajectory of the wound of the chest and stopping staining just where the wound was finally left. The «belt of blood» overlaps a burned area, and it is not easy to distinguish the edge of the blood stripe. But when it is looked closely, the blood trail stops at the edge of the body on the side of the wound but goes further along the opposite edge (Figure 9).

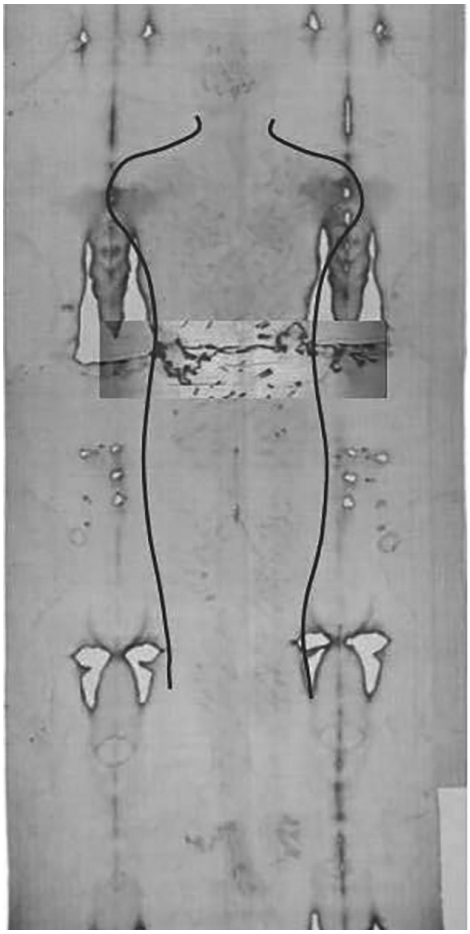

Figure 9
The dorsal half of the Shroud where the «blood belt» is remarked showing haw the stripe of blood stops at the boundary of the body on the side of the wound and exceeds the body boundary on the other side.

If this reconstruction is correct, the side of the Shroud with more fluorescence would be the one closest to the wall. This is another coincidence that would support the neutron hypothesis. Moreover, a neutron radiation would also affect the slab of the tomb, and a possible sudarium folded in a separate place

(Saint John gospel 20, 7). This sudarium can be considered that of Oviedo. If the Sudarium of Oviedo had been near the corpse but not together to it, the dose received would increase the C14 concentration in a lesser degree than in the Shroud and the radiocarbon dating of the Sudarium of Oviedo would result younger than the first century but older than the Shroud just as it happened (Barta, C. 2007). A single hypothesis would justify all these data.

In addition to the UV fluorescence, there are other possible nondestructive techniques being explored to identify new effects on linen irradiated with neutrons. The Raman background fluorescence points as a good index (Barta, Fernández-Álvarez, and Ruiz-Navas 2024).

4. Alternative dating methods

There are physicochemical alternative dating methods (Giulio Fanti, Malfi, and Crosilla 2015) Infrared and Raman spectroscopy (Giulio Fanti *et al*. 2013) X-ray diffraction (De Caro *et al.* 2022) and mechanical characteristics (Giulio Fanti and Malfi 2014) analyze the chemical, physicochemical, elongation and strength characteristics of linen fibers to determine the age by comparation against a calibration set of samples of known age. However, they have an error of hundreds of years, but it is still a limited error. The important fact is that their margin of error is compatible with the first century. And all of them, within their margin of error, are incompatible with carbon-14 dating.

The neutron irradiation would certainly alter the C14 dating, but a question can arise whether this neutron irradiation would alter the alternative methods. Would these alternative methods still be valid in the case of neutron irradiation? At least in the case of the Fourier Transform InfraRed spectroscopy (FTIR) dating the impact would be negligible and it is still valid (Barta *et al*. 2025). The physicochemical properties of irradiated linen only undergo noticeable changes for very high neutron fluences orders of magnitude higher than those estimated for the dated sample of the Shroud (Barta, Fernández-Álvarez, and Ruiz-Navas 2024).

Conclusions

The dating for carbon-14 of the Shroud of Turin presents a statistical inconsistency among the three laboratories that casts doubt on the validity of the measurement. Possible explanations for the error are the dating of a patch not representative of the true fabric or that the Shroud underwent a neutron radiation, which is indeed a singular and extraordinary event, but which could be related to some other unique and unrepeatable event.

Other alternative methods, having low precision, give results compatible with the life of Jesus Christ and incompatible with the dating by carbon-14. Thus, there are four methods that give an age compatible with the fact that the Shroud of Turin is that of Jesus Christ and one that denies it.

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Universidad Carlos III de Madrid. Physicist by UCM.
email: cbartagi@cofis.es

CÉSAR BARTA GIL

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