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Discrepancies in the radiocarbon dating area of the Turin shroud

ABSTRACT

Recent research reported new evidence suggesting the radiocarbon dating of the Turin Shroud was invalid due to the intrusion of newer material in the sampling area. This evidence included the detection of anomalous surface contaminates in specimens from the sampling area. This paper reports new data from an unpublished study conducted by the Shroud of Turin Research Project (STURP) team in 1978 that supports the above-referenced research findings. Additionally, this paper reports evidence supporting the identification of replacement material in the Carbon-14 (C-14) sampling region along with previously-unreported radiographic findings, corroborative textile evidence from the adjacent "Raes" sample, blinded-expert analysis of the Zurich laboratory C-14 sub-sample, independent microscopic confirmation of surface contaminates in Holland cloth/C-14 region, and historical restoration information. Based on these new data, the authors conclude that the radiocarbon sampling area was manipulated during or after the 16th Century and that further testing on the Shroud is warranted.

INTRODUCTION

In 1988, Carbon-14 findings from three Accelerator Mass Spectrometer (AMS) Labs independently dated a sample removed from the Turin Shroud, a linen cloth believed by many to be the burial cloth of Jesus of Nazareth and unarguably the most widely-studied linen cloth in history. The dates reported ranged between 1260 - 1390 A.D.; thus, leading to the conclusion that the cloth originated in the Middle Ages (1). Since the dating, many hypotheses have been proffered attempting to explain the C-14 results (2), which appear contradictory to a plethora of data pointing to a more ancient origin (3-6). An acceptable hypothesis of why the Shroud dated between AD 1260-1390 must satisfactorily explain the precise, statistically-determined angular skewing of the dates corresponding with the individual laboratories, with reference to the location of the sub samples received (7) (Figure 1). The hypotheses of generalized ionizing radiation, thermal effects, environmental carbon monoxide enrichment and bio plastic coating are incapable of meeting this latter requirement, as is the premise that the cloth itself, is, *in toto*, medieval (2).

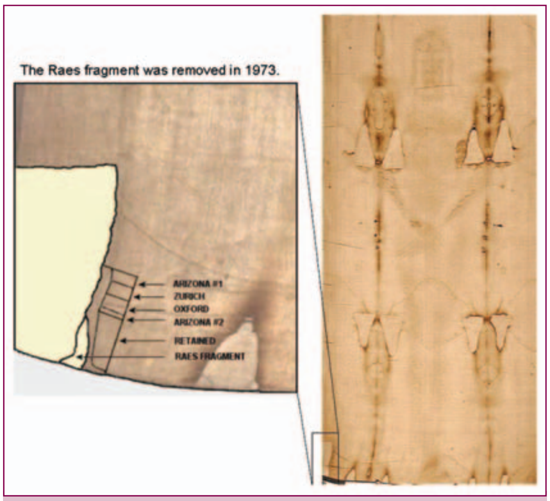

Figure 1. Approximate locations of questionable area used for C-14 dating in reference to full frontal portion of the Shroud. © 1978 Barrie Schwortz.

In 2005, the late Raymond N. Rogers authored a paper in *Thermochimica Acta* that reported the results of experimental tests evaluating the hypothesis that the radiocarbon dating of the Turin Shroud was invalid due to the intrusion of newer material in the sampling area (8). Based on data obtained from his analyses of samples from the area, Rogers concluded that the combined evidence from chemical kinetics, analytical chemistry, cotton content, and pyrolysis/ms proved that the material from the radiocarbon area of the Shroud is significantly different from that of the main cloth. Rogers identified an organic dye made from Madder root, calcium, and Gum Arabic along with an aluminium mordant. This current paper provides additional documentation from a previously-unpublished 1978 Shroud of Turin Research Project (STURP) study that clearly delineates surface chemical differences between the radiocarbon sampling area and other parts of the Shroud, excluding the charred areas. In addition, new data will be examined in light of existing radiographic findings, textile evidence from the adjacent Raes sample (sample extracted in 1973 for scientific examination by textile expert Gilbert Raes of the Ghent Institute),

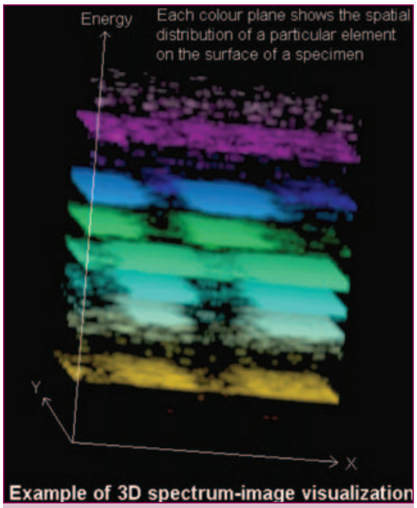

Figure 2. This spectral rendering employs the Karhunen-Loeve process to distinguish among various chemical elements on the surface of a given speciman. This same process was used by STURP to generate the Quad-Mosaic images. © 1996 University of Kent.

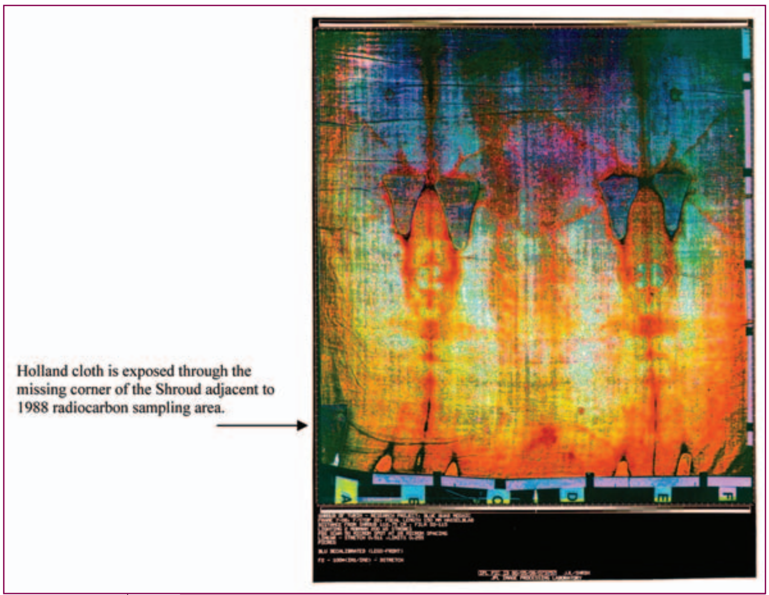

Figure 3. Lower-ventral image of Quad-Mosaic.
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blinded-expert analysis of the Zurich (one of the three laboratories that dated the Shroud in 1988) C-14 sub-sample, independent microscopic confirmation of surface contaminates in the Holland backing cloth/C-14 region, and historical-restoration information documenting known techniques resulting in both front and backside "invisible" repairs.

One of the numerous scientific tests conducted in 1978 by STURP included "Spectrally-resolved Quad-Mosaic Photography" (9). This study, utilizing state-of-the-art NASA technology of the time, was designed to generate colour discriminability products capable of conducting a chemical distribution analysis of the surface of the linen cloth. According to the STURP researchers in charge of this study, "The generation of colour products was considered the most important image processing task. From a colour enhanced, relative colour display, the colour (indicative of chemical composition) of different features of the image can be compared" (10). Several steps were involved in producing the Quad-Mosaic images. One step "consisted of substracting from each image, before the Principal Component calculation step, the local background calculated by a large Media filter" (10). It should be noted that some unidentified damage was reported to have resulted from this particular step; however, the researchers reported the consistency of the colours was somewhat better as a result (10).

The technique employed principal component analysis, also known as Karhunen-Loeve transform (10). Researchers at the University of Kent explain that, "Multispectral imaging entails acquiring several images of the same scene using different spectral bands. For instance, a digital colour camera detects three separate images for the red, green and blue components of light. Collecting several spectral bands generally provides more information than would be obtained from a single monochrome image. This idea has been applied in the field of remote sensing for over 20 years". (11) see Figure 2. The STURP authors noted that "if the chemicals were spectrally differentiated, the multispectral classification process could provide a map of chemical composition throughout the Shroud image" (12). In keeping with this objective, this paper includes a critical evaluation and related discussion of the previously-unpublished original four Quad-Mosaic images to identify areas of chemical correspondence pertinent to the radiocarbon sampling area.

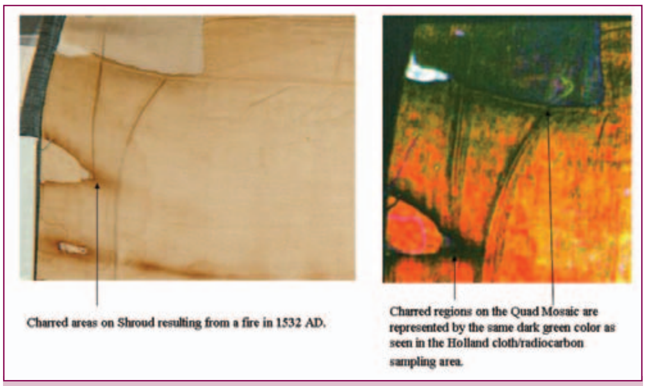

Figure 4. Close-up comparison of lower ventral corner of the Shroud showing C-14 sampling area.
© 1978 Barrie Schwortz (left), © 1978 Avis, Lynn, Lorre et al. (right).

RESULTS

Evaluation of the image from the ventral-lower corner depicts the radiocarbon sample area next to the Holland cloth, which is observable due to the missing 14 cm x 9 cm (5.5" x 3.5") corner piece. According to textile historian Mechthild Flury-Lemberg, who observed the area during her work to restore the Shroud in 2002, both of the Shroud's missing corner pieces were already missing prior to the addition of that backing cloth in 1534 AD, which had been added during repairs made due to fire damages in 1532 AD (13). Both the exposed Holland cloth and the adjacent radiocarbon sample area are a uniform dark-green colour. The ventral-corner section consists of a unique, uniform solid dark-green region in a rectangular pattern with distinct borders. The dark green encompasses the side seam and extends approximately an inch (3 cm) into the main Shroud cloth region. Similar solid geometric patterns with defined borders in this hue are not observable elsewhere on the cloth (see Figure 3).

Also observable in this Quad-Mosaic image are several areas showing charred cloth that resulted from the fire of 1532 AD. These areas, and the other charred areas throughout the cloth, range from medium to very dark green. Non-charred areas also contain some scattered dark green colour in random patterns and with indistinct borders (see Figure 4).

Images of the larger dorsal missing corner piece section, also exposing some of the Holland cloth, have a completely different chemical-colour signature consisting of a myriad of lighter-toned colours. Noteworthy is the fact that the colour variation within the dorsal section Holland cloth does not extend into the adjoining side seam or the main cloth section, as it does on the ventral side (see Figure 5).

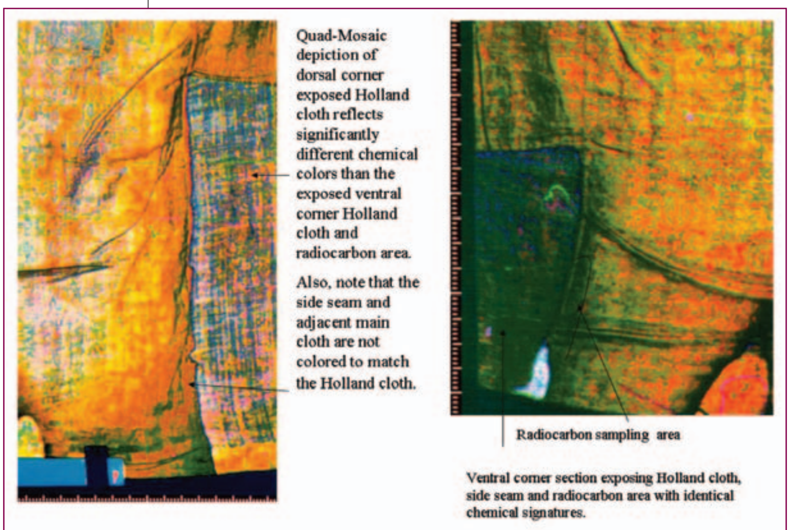

Figure 5. Left – Quad-Mosaic close-up of dorsal-side missing corner region; Right – Quad-Mosaic close-up of ventral-side missing corner region. © 1978 Avis, Lynn, Lorre et al.

In terms of evaluating the reliability and validity of the Quad Mosaic to reveal true surface chemical discrepancies via the colour patterns on the Shroud versus reflecting simple illumination variations, evidence for this can be found in the images of the known patches attached to the Shroud (see Figure 6). The clear difference among the patches with differing historical provenance and, thus, different preparation techniques, supports the assertion that the Quad-Mosaic images provide valid indicators of surface-exposed chemical variation throughout the Shroud.

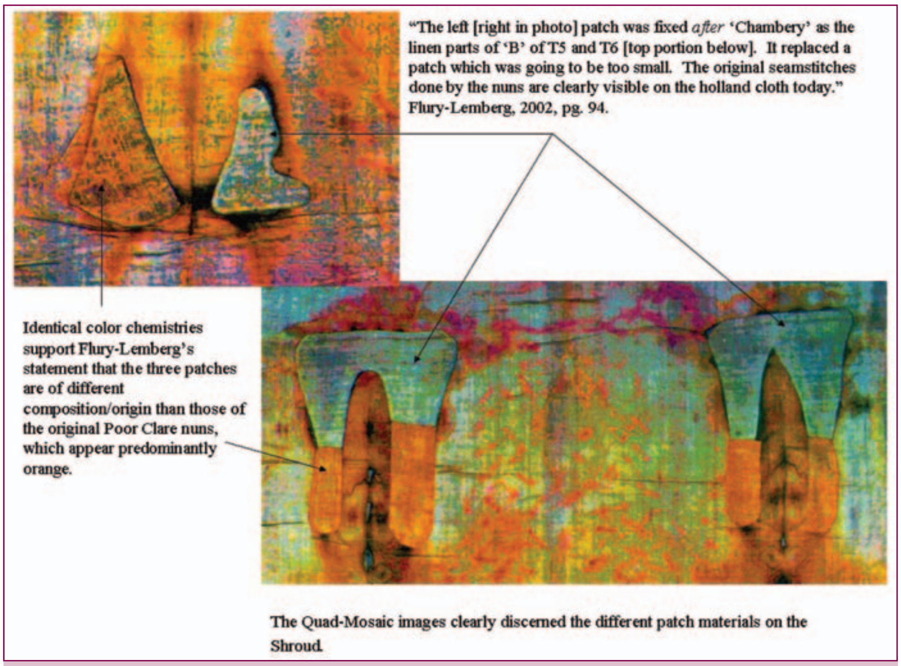

Figure 6. Quad-Mosaic images showing ventral-side patches.
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DISCUSSION

Research has demonstrated that the charring of cellulose materials significantly increases carbon content (~20-30 percent) as compared to corresponding non-charred material (14). The carbon content of charred cellulose and cotton ranges from approximately 43 to 71 percent of total weight (14). As such, it is possible that the Quad Mosaic's chemical-colour signature reflecting the medium to very dark green on the charred portions of the linen Shroud may represent carbon. Rogers observed copious amounts of Gum Arabic on yarns obtained from the radiocarbon sample area. Gum Arabic is composed of pentose-sugar units. Rogers further identified the organic dye made from Madder root along with calcium. Although unconfirmed, the calcium may have been calcite. Calcium Carbonate (chalk/calcite) was used in medieval dyeing and may have been incorporated with the red Madder, which was typically used with a white base (15). Each of these substances, identified by Rogers from the radiocarbon sampling area, is comprised primarily of carbon.

The Quad Mosaic reflects significant differences between the two exposed (ventral and dorsal) Holland cloth sections in the excised-corner regions.

The dark-green signature is missing from the Holland cloth on the dorsal region of the cloth. Conversely, the exposed ventral-region Holland cloth, side seam, and adjacent radiocarbon sampling area consist of a deliberate, uniform and well-delineated dark-green chemical signature.

The spectral discrepancies noted between the two exposed regions of the Holland cloth (dorsal versus ventral) is likely explained by the observation that these are two separate pieces of cloth added to the Shroud at different times and under different circumstances. First recognition that the Holland cloth was not a single, uniform piece of material came following radiographic examinations by the STURP team in 1978. Mottern, London and Morris found that, "the Holland cloth is not one piece but instead three pieces hand sewn together" (16), Flury-Lemberg further noted that "the lining (Holland cloth) had been made wider by the addition in the length of a 30 cm wide strip in order to match the width of the Shroud. This added strip consists of two pieces" (17). Flury-Lemberg also found the two pieces were stitched together forming a transverse seam (17). The smaller of the two pieces from the added strip was under the ventral missing corner/C-14 region.

Also in the ventral missing corner section, which we hypothesize to consist of restorative surface dyes and what was likely an undocumented "invisible" medieval repair, is the section from which the 1973 Raes sample was extracted for analysis. In this sample, Raes found that the side seam had been attached to the adjacent main Shroud by a 2-ply-linen sewing thread (18). By removing the sewing thread, Raes was able to separate his sample into two distinct pieces, which he identified as "Piece 1" and "Piece 2." Each piece exhibits different characteristics, such as cotton content, lignan content at the growth nodes, and thread size, suggesting two different origins of the yarns (Figure 7).

Further, the significance of the sewing thread Raes identified is that its character and quality along the length of the side seam were observable via radiographic examination. "The radiographic images substantiate the 4-5 mm width of the 'seam.' In addition, two rows of stitches, one along each edge of the

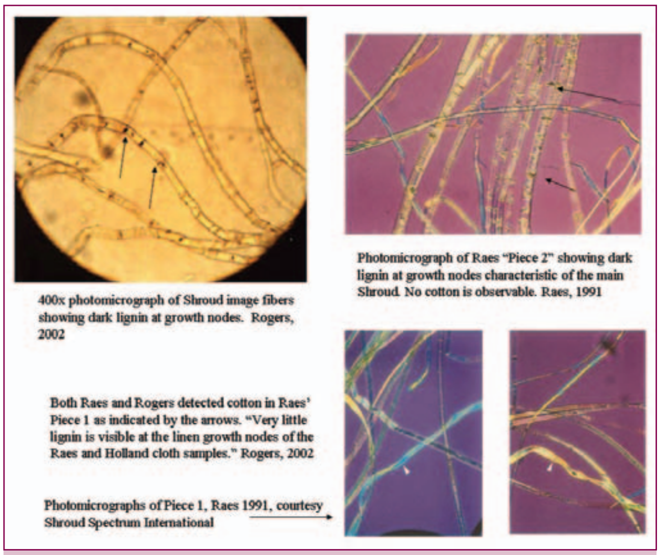

Figure 7. Top, Left – photomicrograph of Shroud image fibres; Top, Right and Bottom – photomicrographs of fibres from the Raes sample extracted in 1973.

'seam', are observable" (19). Flury-Lemberg makes an important observation about the side seam and adjacent stitches. "The sewing has been done from the reverse of the fabric and the stitches have been executed with great care and are barely noticeable on the face of the Shroud" (20). While top-side radiographs of the ventral corner show a continuous sewing thread next to the side seam in the C-14 region, beyond this region, the stitching becomes intermittent and barely visible in the main Shroud as confirmed by Flury-Lemberg (see Figure 8).

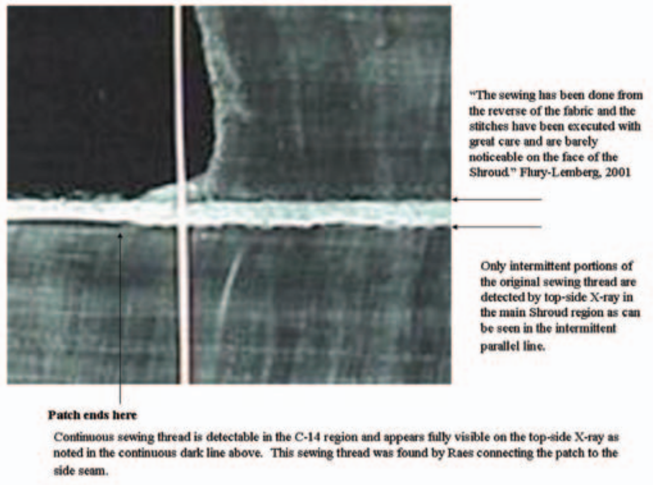

Figure 8. Radiograph of ventral missing corner region.
© 1978 Mottern, London, Morris.

The continuous, fully-observable sewing thread represents a significant change of technique, and suggests this section of thread, which incorporated the Raes sample and C-14 sample areas, was applied from the top versus reverse of the cloth. This further implies the two sections of sewing threads (C-14 region versus main Shroud) were applied at different times and by different artisans with the main Shroud stitching possibly from the same time period as Masada (21).

Other observations support the assertion that expert and undocumented manipulation took place in the C-14 sample region. Independent, blinded analyses of one of the sub-samples (Zurich) used for C-14 dating by textile experts also revealed significant discrepancies in the two sides (proposed patch versus original cloth) of the sample (2). In the analysis of the sub-sample, by Albany International Research Company, Louise Harner remarked that "the float is different on either side of the sample" (2). It forms a thick/thin, thick/thin pattern on the right side, whereas the left is much more consistent throughout (see Figure 9). Harner surmised that this was due to each side of the pattern being woven independently.

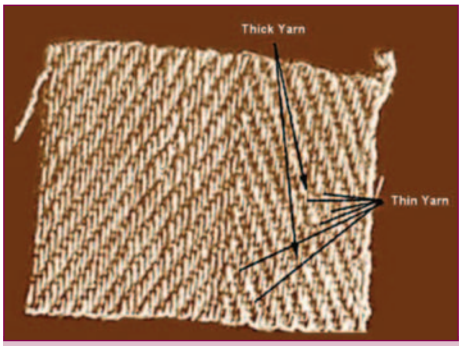

Figure 9. Front-side of the Zurich C-14 sub-sample used to date the Shroud in 1988. Blinded analysis revealed different weave pattern in proposed "patched" region suggesting the two sides were woven at different times.

As mentioned previously, Rogers reported finding significant amounts of surface contaminates on both the Raes and the C-14 yarns. In contrast, he reported that, "There was absolutely no coating with these characteristics on either the Holland cloth or the main part of the shroud" (22). However, independent microscopic analysis of one of the yarns extracted from the ventral-corner-exposed Holland cloth by microscopist Joseph Kohlbeck of Hercules Aerospace, revealed copious amounts of unidentified red particle contaminates (23) (see Figure 10).

This discrepancy may be explained by the different locations from where the Holland cloth samples were taken. Reports indicate that while most of the Holland yarns were extracted through burn holes in the main part of the Shroud (24), one yarn sample, which Kohlbeck examined, was taken from the exposed Holland cloth in the ventral corner (25) (see Figure 10). According to Kohlbeck (26), his sample from the ventral corner was not returned to Rogers for comparative analysis; thus, confirming the above scenario explaining the different results. This supports the Quad-Mosaic findings showing that the same surface chemistry extended from the ventral-exposed Holland cloth into the adjacent C-14 region material but varied considerably from other regions of the Holland cloth and main Shroud.

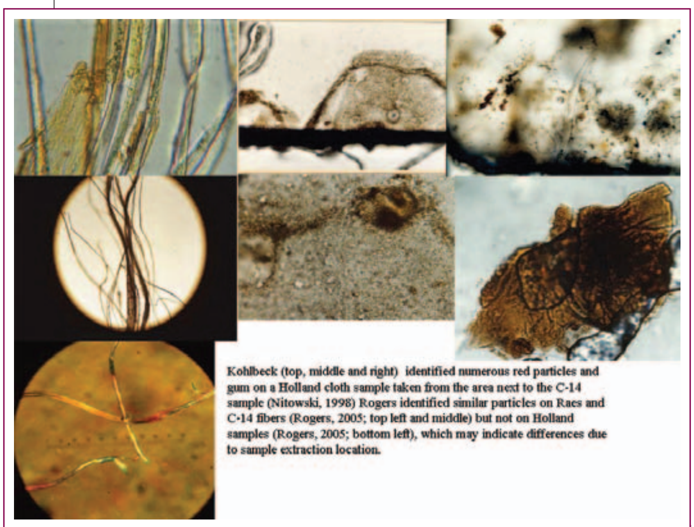

Figure 10. Representative photomicrographs of Holland cloth fibres independently examined by Rogers and Kohlbeck.

An archaeologist, the late Dr. Eugenia Nitowski, who obtained numerous Shroud fibres from Rogers, conjectured that the red particle contaminates discovered by Kohlbeck were the burial spices Aloe and Myrrh; however, this assumption was based solely on her comparison of the debris with reference photos of the suspected substances and not via chemical analyses. She reported: "The study could go no further (beyond photo comparison), because of the inability to perform testing which would either remove or destroy materials from the tapes" (23). Along with the lack of any chemical characterization of the debris, the fact that the singular yarn (1FH) with the impurities came from the ventral missing-corner-exposed-medieval Holland cloth (see location #1 in Figure 11) and not the main Shroud, argues strongly against Nitowski's assumption that the debris was from burial spices. Based on the Quad-Mosaic data and Rogers' findings it is far more plausible that the 1FH impurities were also red Madder and Gum Arabic as chemically-verified by Rogers in multiple adjacent samples.

The Quad-Mosaic images, radiographic findings, textile evidence from the adjacent Raes sample, blinded-expert analysis of the Zurich C-14 sub-sample, and independent microscopic confirmation of surface contaminates in the Holland cloth/C-14 region supports Rogers' assertion that a surface dye was added to the Shroud in the area of the 1988 radiocarbon sampling to disguise an undocumented repair. These data further confirm that this substance included the exposed Holland cloth on the ventral, but not dorsal, side of the cloth. Thus, the application of this substance occurred sometime after the Holland backing cloth was attached to the Shroud in AD 1534 and prior to the 1973 Raes sample extraction but was intentionally added to only one side of the cloth. These data further support the theory that the radiocarbon sampling area was manipulated during or after the 16th Century.

The Raes sample is highly-significant due to its thorough examination and adjacent location to the C-14 sample area. Given the stark differences between yarns found in the Raes' Pieces 1 and 2, combined with the existence of the sewing thread, which connected the two disparate materials, we hypothesize that Piece 2 was the original Shroud material/seam and Piece 1 was a cotton-containing patch made to resemble the original Shroud cloth (see Figure 12).

In this paper we have also discussed additional supporting evidence that, not only is the Raes and C-14 sampling region anomalous in comparison to the main Shroud cloth, but the piece of Holland cloth in the ventral corner is also significantly different from the rest of the Holland cloth. The most probable scenario is that the original smaller section of Holland cloth was extracted for relics. This section was most likely replaced with newer material that did not match the exposed dorsal section of Holland cloth. Also consistent with the data is the hypothesis that the person(s) responsible for taking this section of Holland cloth also extracted a small section of main Shroud cloth directly adjacent to the side seam and missing ventral corner, e.g., the C-14 sampling area (see Figure 13; additional details available in reference 2). To hide the extraction, the missing material would have been patched and surfaced dyed, along with the newer backing material, such that it would not have been detected.

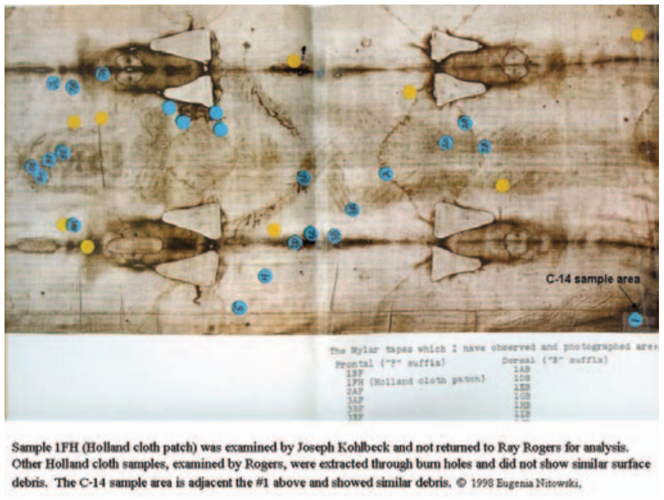

Figure 11. The area labelled "1" in the above photo shows the location of the "1FH Holland cloth patch" sample examined by Kohlbeck that contained red debris.

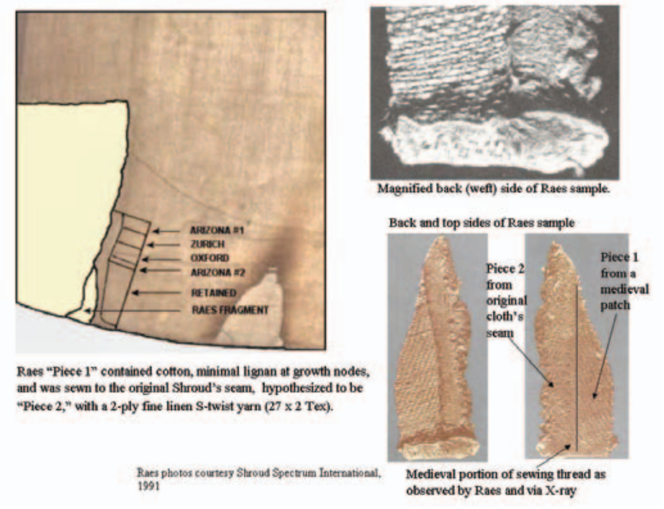

Figure 12. Close-up photos of both sides of the Raes sample indicating the hypothesized locations of sub samples identified by Raes as "Piece 1" and "Piece 2" as well as the sewing thread joining the two pieces.

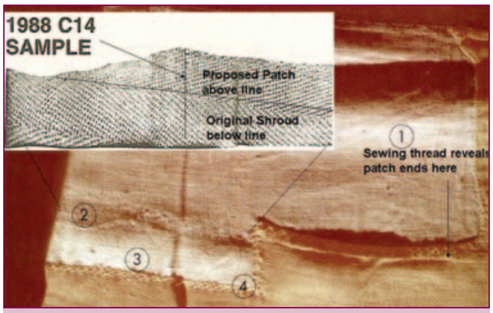

Figure 13. Ventral corner of the Shroud with 1= replaced Holland cloth, 2 = Raes sample area, 3 = C-14 sample area, 4 = connecting stitches of main cloth to removed area. The pullout area portrays proposed medieval patch region in reference to the overall sample.
© 1996 Gino Moretto.

Starch, which was identified in this area, was routinely used by medieval restorers to disguise invisible mending (27).

Historical evidence demonstrates that it was not only possible for medieval weavers and embroiderers to invisibly mend textiles such that they were not top-side detectable, but it is also recognized that they could choose whether or not to permit their handiwork from being detected on the back side as well. "Historically, reweaving was not carried out through a support fabric and was often executed so skilfully that it is not always recognizable as a later addition, although differences in the rate of dye fading have often revealed its presence […] Evidence of reweaving would now (16th Century) usually be left deliberately visible on the reverse of the tapestry by the presence of the warp ends and knots" (28). As this passage infers, skilful medieval weavers could choose whether or not to leave evidence of their work on the back side of a fabric.

Although a less-than-conventional restoration practice, it is known that in early part of the 16th Century the art of "reversing" was practiced such that tapestries could be viewed intact from either side of the cloth. "In August 1524 Wolsey's Wardrobe of the Beds […] were shorne and new dressed on the wrong side" (29). Reversing resulted in the lack of any telltale signs of a back-side repair.

It has been previously hypothesized (2) that if an undetected 16th Century repair impacted the C-14 sampling area the ratio of medieval to 1st Century material would have been approximately 60 percent to 40 percent based on expert observations (2); however, the area would have been a mixture of both age groups. According to modern-day weavers (withoutatrace.com) skilled in the medieval art of invisible mending, "Depending on the size and condition of the damaged area, and the fabric to be worked on, one of the following methods is applied: FRENCH WEAVE - also known as the Invisible Weave, this technique is done on select fabrics with small tears, holes and burns. Individual thread strands from hidden areas, such as a cuff or inseam, are actually woven together by hand. This creates new fabric as it closes the hole and the repair is virtually indistinguishable from the surrounding fabric [...] INWEAVING - For larger tears, and when the French weave is not practical. The weaver cuts a patch of hidden fabric and places it over the damaged area, matching the fabric's pattern. The frayed edges are then hand woven into the material. The edges of the repair are invisible to the eye" (30).

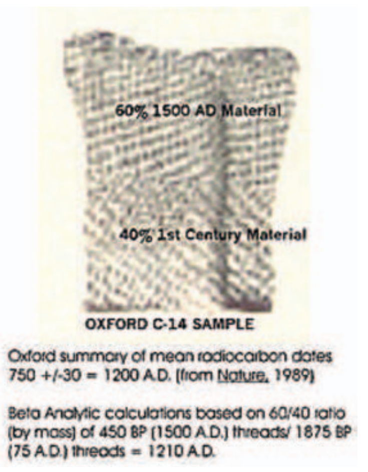

Figure 14. Hypothesized percentages of medieval vs. 1st century material in Oxford C-14 sub sample.

In the "In Weaving" technique described above, it is important to note that there is a requisite overlap and intermixing between the newer patch material and the existing textile via the integration of frayed edges into the damaged textile and vice versa. The unavoidable interweaving required of this invisible mending technique would, most assuredly, have created heterogeneity in the C-14 sample area.

The exact ratio of patch versus original threads is not determinable by photographic analysis alone; however, a well-supported estimate, based upon weave-pattern changes, has been posited (2) reflecting approximately 60 percent of the C-14 sample consisting of 16th Century threads while approximately 40 percent were 1st Century in origin. The radiocarbon date was calculated using the percentage of observed 16th Century (representative date used AD 1500) versus 1st Century (representative date used AD 75) weave types appearing in the Oxford sub sample. The radiocarbon calculations were derived using the following mathematical calculations and in consideration of the above hypothesis. The question asked was what percent cal AD 1500 + percent cal AD 75 radiocarbon would be required to derive an average age of cal AD 1210 (~Oxford results)? Using standard Measured Conventional Before Present equivalents, the formulas for calculation become $0.9003 = (x)(0.9558) + (1-x)(0.7851)$. Solving for X (where X ~ percent cal AD 1500 carbon present) $X = 0.6749 \sim 67$ percent.

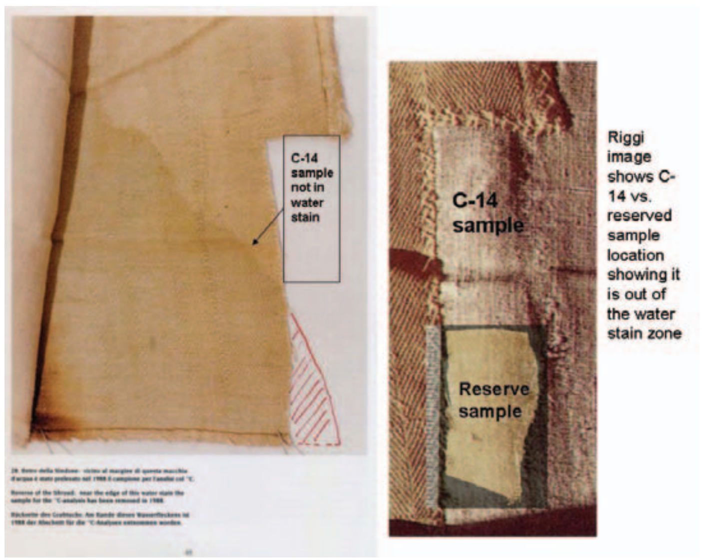

Figure 15. (Left) Close-up of water stain with drawing indicating predicted location into the C-14 region. (Right) C-14 sample extraction site showing reserved sample location.

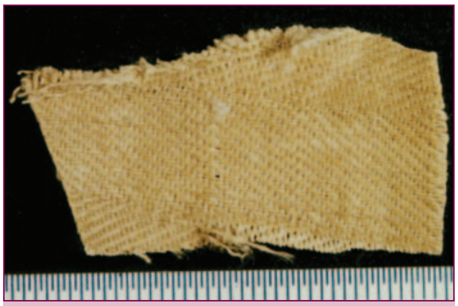

Figure 16. The reserve portion of the C-14 sample extraction does not reveal any observable water stain markings.
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Therefore, as proposed in our hypothesis, a sample containing ~ 67 percent cal AD 1500 radiocarbon and ~ 33 percent cal AD should yield a calibrated date of ~ cal AD 1210. NOTE: the percent variability between these percentages and the original claim of 60/40 is within an accepted margin of 10 percent (Figure 14).
In terms of the C-14 area in relationship to the water stain, which has been posited to be much older than the 1532 fire and also impacted the sample area (31), photo analysis demonstrates that this latter assertion is incorrect (Figure 15). This photograph, when placed next to an image showing the location of the reserve versus C-14 sample clearly demonstrates that the entire C-14 sample area was outside the water stain region. The crease can be used as a marker to compare the two photographs and location of the C-14 sample.
Further, it is also notable that the reserve sample (Figure 16) does not appear to have any water stain markings. According to the illustration of the water stain area, the stain should have gone directly through the mid-section of the reserve sample forming a distinct marking discoloration. Since the sample does not show any evidence of a water stain marking, this could very well be explained by the later addition of a patch in this area.

CONCLUSION

It is impossible to quantify the amount of surface carbon, other contaminates, and/or intruded newer material in the radiocarbon sampling area based upon the Quad Mosaic or other data presented in this paper. Similarly, it is impossible to determine if either the surface carbon, or the manipulation it represents, had any impact on the 1988 radiocarbon dating. However, in light of these new data along with a recently-posited theory that does not preclude a 1st century origin for the cloth (32), additional radiocarbon dating incorporating other areas of the cloth is recommended. Further, characterization of the remaining C-14, Raes samples and the Holland cloth to ascertain the presence of cotton, surface dyes and other restoration substances in accordance with these findings is warranted.

ACKNOWLEDGEMENTS

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