

IV : DISCUSSION AND CONCLUSION

From this exhaustive research of cotton fibers in Raes # 7 (R7) thread through the microscope, it is possible to conclude that:

1. It is impossible to see the cotton on the whole tight thread "as received", even with polarized light microscopy: it is necessary to separate many fibers.
2. Cotton found in R7 is very different from modern cotton. According to the experts, it shows the characteristics of cotton of the "Old World" including the very low number of reversals (probably *Gossypium herbaceum*, according to G.Raes). High resolution microscopy (at least about 400x) is necessary to differentiate with a high degree of certainty this old cotton from some particular types of flax fibers: identification is not always easy. Only 3 or 4 modern cotton fibers (contamination) were found in R7.
3. Cotton is found in R7 as a very long bundle (or bundles) of several fibers running all along the thread with some of them penetrating in the core, several individual fibers dispersed in the thread and, after handling, many short broken pieces everywhere.
4. Cotton fibers are not at all evenly distributed: taking in account only the more or less "complete" cotton fibers (i.e., fibers forming long bundles or sometimes "nodes" or individual relatively long fibers) there is about 15% of cotton in the outer part (from 0% to 28% depending on the location studied) and about 10% of cotton in the core of the thread. In addition many short pieces of broken cotton fibers are found everywhere.
5. R7 is definitely some kind of blended thread: cotton (10%-20%)/ linen (80-90%). There is more cotton in the outer part than in the core. Both kinds of fibers have been spun together to obtain the thread.

Is this result consistent with previous observations?

Before trying to answer this question, it is important to gather as many data as possible about R7 and other Raes threads from Rogers' collection.

Where does exactly R7 come from?

We know with certainty that 14 Raes threads were given to Rogers in 1979 by Gonella.

There is absolutely no doubt about the origin of the samples and we have a chain of evidence.

According to Raes himself, his sample consisted in 3 main pieces:

- Piece 1 (about 40mm x 13 mm) from the main Shroud.
- Piece 2 (about 40 mm x 10 mm) from the "side strip".
- And the two-ply yarn used to sew together the two pieces. This means that this heavy linen yarn was in fact made of 2 individual threads, each being wound round the other.

When Rogers received the samples, he took a photograph of the threads "as received". The threads were still in the polyethylene bag. There is no scale bar on the original photograph. However a few photographs with a scale bar of some individual threads are available, so that the approximate length of some threads can be measured and compared.

The figure below (Fig.14) shows the Raes threads "as received" on which I added an approximate scale bar.

It appears that the length measurements are self-consistent. In particular, this is the case for the length of Raes#7 (about 10-11 mm).

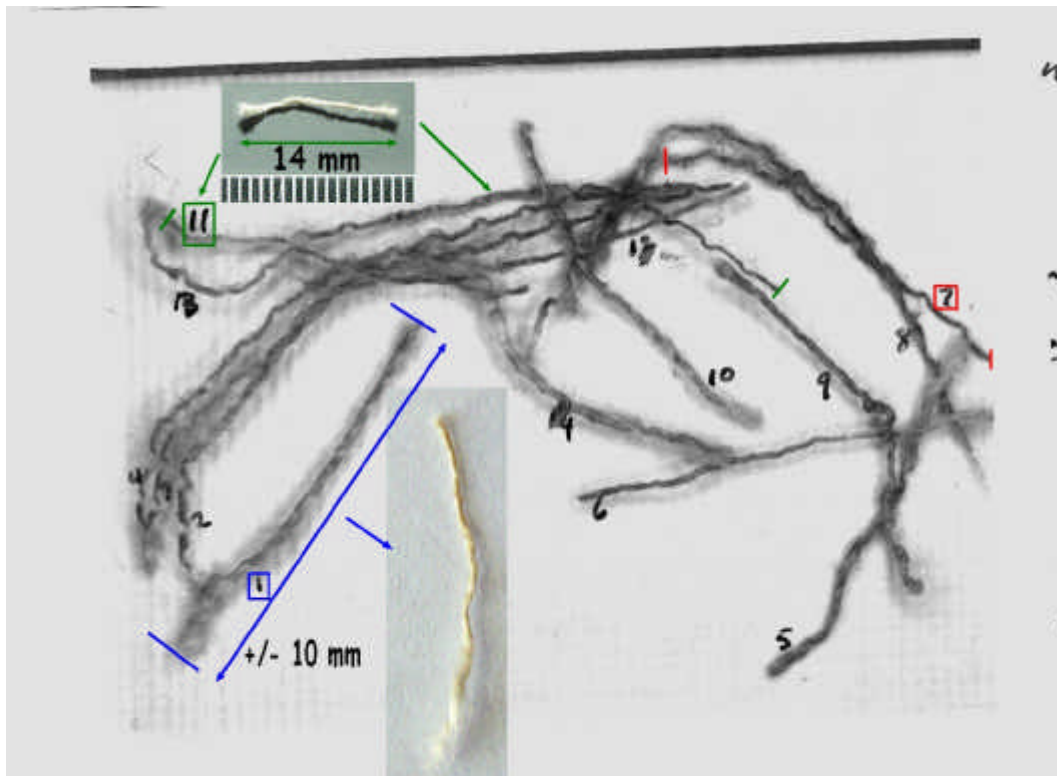


Fig.14: Raes threads "as received" by Rogers. I added 2 photographs of Raes#11 and Raes#1. The length of Raes#1 (about 10 mm) comes from LANL studies and that of Raes#11 (about 14 mm) from Rogers' collection.

(Original photographs: Raymond Rogers, courtesy Barrie Schwartz)

From the above photograph, we can see that some threads are straight (for example Raes #1) while some others show "distinct, periodic bends. They correspond to the 1:3 spacing of the weave, and they were compressed into the yarn segments. They are almost certainly weft yarns. The straight segments are almost certainly warp yarns (...) which were held under tension during weaving" (from Rogers, SSG message # 574).

According to Rogers (same SSG message) segments #7, #8 and #11 seem to be weft, while #1, #6 and #10 seem to be warp. Raes #7 is about 10 mm in length, Raes#11 about 14 mm in length while the length of Raes #8 can not be measured. The two other probable weft threads that can be seen (the numbers are not distinguishable) have roughly the same apparent length than R#11. Thus, it seems that none of the weft segments in Roger's collection is longer than about 15 mm.

Piece 1 of Raes sample was 13 mm in width. If the weft yarns actually come from Raes Piece 1, their maximum length should be in theory 13 mm. However, it is clear that "the crimps have changed and relaxed" (Rogers, SSG message #1234). In other words, weft threads "as received" by Rogers can be a few millimeter longer than the same threads when they were in the fabric. The lengths of Raes#7 and the other weft threads are certainly consistent with their assumed origin in Raes Piece 1.

Moreover, it is also possible to count the number of bends on the "as received" Rogers' photograph. For Raes#7, it is possible to count 7 or 8 bends. The photograph of Raes sample (backside= weft side) shows roughly the same number of "bends" (see Fig.15).

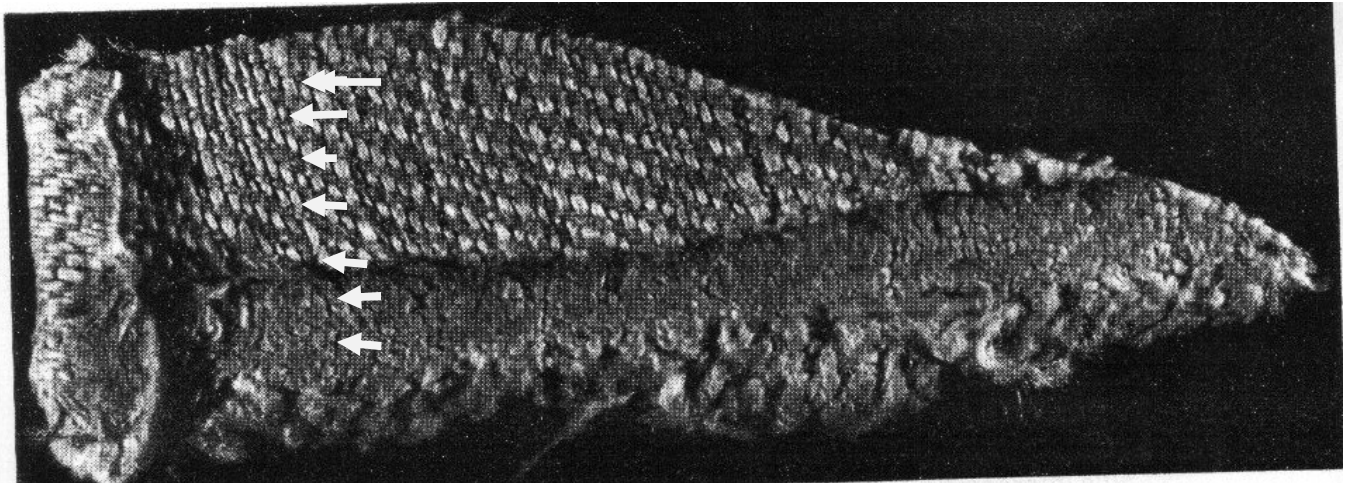


Fig.15: Raes sample back side (weft side), on which weft threads are clearly seen. The number of bends (6-8) does correspond to the number of bends shown on Rogers' photograph for weft threads.

Also, R7 can not be a sewing thread. We have seen that Raes reported having found a sewing thread which was a two-ply yarn. If R7 (and the other "weft threads") were part of the sewing thread, it could not show the 1:3 spacing of the weave but some kind of spirally shape.

Clearly, R7 (and the other weft threads in Rogers' collection) are genuine weft threads coming from Raes' sample Piece 1.

How do we know that the Shroud of Turin is pure (or almost pure) linen?

First, it must be recalled that Gilbert Raes found no cotton in Piece (or Part) 2 of his sample contrary to Piece 1. Piece 2 was the smallest part of his sample and was in the so-called "side-strip" of the Shroud. Different studies have shown that the side-strip pertains to (or at least is continuous with) the original Shroud.¹²

Second, many sentences from Rogers are very clear. For instance: "*I did not attempt to make quantitative cotton comparison between Raes and radiocarbon threads and Shroud tapes, because there was too little cotton of any kind on Shroud samples. (...) The cloth appeared to be pure linen*" (in Ref.3, p.66). Another example: for Shroud sample 3AF as well as sample 1 HB, we find exactly the same sentence: "*Absolutely no cotton could be found in this sample*" (in Ref.6, p.29).

At least, another researcher "*had the privilege of examining three of STURP's tapes which came from the main body of the Shroud cloth. Those tapes are 6AF, 3BF, and 3EF. Nowhere on those three tapes did I find any cotton! All of the fibers are linen!*" (Paul Maloney, SSG message #6214).

¹² See for example: « Concerning the side strip on the Shroud of Turin » by Alan Adler in *The Orphaned Manuscript*. Effata Editrice, 2002. Page 87. Adler concluded: "*Therefore we concluded that the side strip is actually continuous with the rest of the Shroud*".

Many surface STURP samples (some of them containing hundreds of fibers) do not show cotton at all and some others show only "*occasional surface trace-which is usually fluorescent*" (Rogers' SSG message #4302) and "*according to Raes' criteria, it was all modern. The Shroud appeared to be pure linen*" (Rogers' SSG message # 2056).

Finally, Professor Giulio Fanti kindly furnished to me the result of a [study](#) performed on the end of a thread coming from the 1988/C-14 area named F15001. He found about 2% of cotton fibers among about 188 fibers (see Appendix). However, it must be noticed that this thread came from the edge of the cloth in proximity of the "Riserva sample", at the border of the C14 sampling area.

We can therefore conclude that the Shroud is pure or almost pure linen. It must be recalled that the STURP sticky-tapes covered a surface of about 5 cm², which means that they contained many fibers coming from different adjacent threads.

Given the number of cotton fibers found in the outer part of R7, there is no doubt that if a tape had been applied on this thread, many cotton fibers would have been seen.

There is a very clear difference regarding cotton between R7 and the rest of the Shroud which is pure linen (except very few modern contaminations which are easily recognized as we have seen).

Is Raes #7 representative of the Raes area regarding cotton?

The answer is certainly: yes.

Gilbert Raes found "traces of cotton" in both weft and warp threads of his sample (Piece 1).

Raymond Rogers was the only one who had both Raes threads and fibers from many different locations of the main Shroud (on sticky tapes).

Regarding cotton in Raes threads, he wrote: "*Cotton fibers are easy to find mixed intimately with the linen fibers of Part 1 Raes threads*" (in Ref.3, p.66). More specifically, it is possible to find references to cotton in Raes threads for Raes # 14 and Raes # 5 (in Ref.3 and Ref.6).

John Brown also wrote: "*the cotton fibers found by previous investigators are evident during examination of [Raes] thread R14 in a stereomicroscope at 100x magnification*". (In Ref.8).

Also LANL found that Raes #1, Raes #7 and Raes #14 FTIR-spectra are similar, showing the characteristics of cotton.

What about the radiocarbon dated samples?

First, the photographs show that at least some threads coming from the Raes area extend into the radiocarbon area which is almost adjacent to the Raes area.

Second, Rogers clearly stated that he found also many cotton fibers in his radiocarbon threads. Although the chain of "custody" is not as well documented as for the Raes threads, there is no serious reason to doubt the origin of the Rogers' radiocarbon threads. However, it is likely that these threads came in fact from the so-called "Riserva". When the strip was cut in 1988, it was divided in 2 parts: one part for the laboratories (this part was then divided in 4 subsamples) and the other part (the "Riserva") that was kept in Turin.

I had access to the private notes of Rogers about the radiocarbon threads he got. One can read for example: "*Radiocarbon warp (dated 2/3/04): several cotton fibers are visible*" or "*Two cotton fibers visible (.), there is cotton in the radiocarbon warp (...), there is **plenty** [emphasis mine] of cotton in the warp*".

There is little doubt that the properties of the Raes threads regarding cotton can be extended to the radiocarbon dated area.

In 1988, the textile experts looked at this area with binocular microscopes and later the laboratories performed some observations with the microscope on their samples. Interestingly, cotton fibers emerging from one of the Oxford samples were found and sent to "*P. H. South (Precision Process (Textiles) Ltd, Derby) for examining and identifying the cotton found on the shroud sample*" (from *Nature* report). A laboratory in Derbyshire determined that the rogue fibers were cotton of "*a fine, dark yellow strand.*" According to Peter South of the lab, "*It may have been used for repairs at some time in the past...*"¹³.

We have seen that it is necessary to separate the fibers to see the many cotton fibers found in the Raes threads. To our knowledge, this was never performed by the laboratories involved in the radiocarbon dating. They certainly simply looked at the surface of their samples (and perhaps of some individual threads) with their microscope.

Are our findings consistent with previous studies?

Gilbert Raes (cf. Ref.2, p.5) found "traces of cotton" in Piece 1 of his sample. R7 is very likely one of the threads of Piece 1. "Traces of cotton" is ambiguous. Clearly cotton is a minor component of R7 and can be seen as "traces". It is also possible that some other threads he studied did contain less cotton.

Raes pointed out that all the cotton fibers he saw were of the *Gossypium herbaceum* variety, on the basis of the number of reversals. This variety has less than 10 reversals per cm, while the other types, *G. barbadense* and *G. hirsutum*, have 18-20 and 20-30 reversals per cm respectively. With regard to modern cotton which is not of herbaceum variety (this type is almost never used), the cotton found in R7 has very few reversals and is from the "Old World", according to the experts who looked at the photographs: it is very likely from the herbaceum variety.

According to Raes "*it is evident that if traces of cotton are found in the linen, it is necessarily at the time of **spinning** that the mixture came about and not at the time of weaving*". He also wrote: "*it has sometimes been remarked that these [the cotton fibers he found] were superficial fibers having come upon the Shroud at time of the numerous expositions. If this were the case, it is scarcely probable that all the cotton fibers would be of the *Gossypium herbaceum* variety*". He added in a footnote: "*Until the advent of the Industrial Era, spinning and weaving were carried out in the same room, where piles of raw cotton would be heaped in one corner, piles of flax in another. Cotton fibers float about everywhere and stick to anything they touched. Spinners often twisted fibers by rolling them against the thigh, where, on the spinners' long skirts, cotton lint had wafted. Cotton fibers, then, would quite legitimately be incorporated **inside** [emphasis from Raes] the flax.*"

¹³ Rogue Fibres found in the Shroud, *Textile Horizons*, 1988 December, pg. 13.

Except perhaps the amount of cotton, all that I found is consistent with Raes' claims: *Gossypium herbaceum* **inside** the linen thread.

However, given the amount of cotton I found, there is another possible hypothesis: the mixture could have been the result of a willful act. The spinner could have spun together flax fibers with some cotton fibers as it was sometimes carried on in the Middle-Ages (and this is still the case today). This would be consistent with Rogers' finding of a unique dye on Raes/radiocarbon fibers because cotton is known to retain the colors much more easily than linen.

It was often thought that the type *Herbaceum* of cotton pointed to the Mediterranean Basin for the geographical origin of the Shroud. This is not true. In fact, cotton was imported in Europe during the 13th century and local cultivation began one century later. The type of cotton used in the Medieval Europe was mainly *Herbaceum*¹⁴. Interestingly, it is written in the source: "*Cotton was a relatively inexpensive fiber, and was incorporated into many weaves with other fibers to reduce the cost of the finished cloth. It was mixed with every conceivable fiber, flax, wool, silk, camel hair, and also with itself*". Of course here the problem was not the cost but this sentence shows that the making of cotton/flax threads was very usual in the Middle-Ages. We now know that the Shroud is made of pure linen and that the cotton is only found in the Raes/radiocarbon area. This area could have been made during the Middle-Ages in Europe.

Rogers: It is obvious that the present work is in full agreement with previous observations of Rogers.

Finally, the team of Los Alamos National Laboratory (LANL)¹⁵ also analyzed with FTIR the surface of Raes # 1, 7 and 14. They found that the spectra of all these threads were similar to the spectra of modern cotton and "*very different*" from the spectra of modern linen. Although I found that most of the fibers of Raes # 7 are linen fibers, there is no doubt that this study confirms that there are many cotton fibers in Raes # 7, 1 and 14. The difference can probably be explained. First, only a few fibers were analyzed at each position along the threads by the method. Second, the resulting spectrum of a mixture of flax and cotton fibers is not well known, depending of their respective contribution to the overall spectrum. I found many cotton in the outer part of R7 and almost on its entire length. Taking in account the limitations of the FTIR microspectroscopy method performed on a blended thread, there is no doubt that LANL results are not incompatible with the present study. In this case, R1 (a warp thread) and R14 are similar to R7 (a weft thread): the 3 pieces of threads are blended cotton/linen threads. There is little doubt that these 3 threads can be considered as representative of the entire Raes sample (Piece 1) and very likely representative of the entire Raes/radiocarbon area because Rogers found also many cotton fibers of the same kind in both warp and weft threads of the radiocarbon ("Riserva"?) dated area.

One of the most interesting and amazing discovery of LANL is the definite confirmation that R1 is a splice, confirming Rogers' statement. "*After conducting analysis at high vacuum with the ToF-SIMS, the "spliced thread" broke into three distinct pieces*" (from LANL abstract). No such splice is found on

¹⁴ See the excellent web site : <http://des.kyhm.com/cotton>

¹⁵ All these data are from the presentation of LANL results given at the Columbus conference in August 2008.

the main Shroud. The 2 ends of the spliced thread were bound together by some kind of resin (see Fig.16 below).

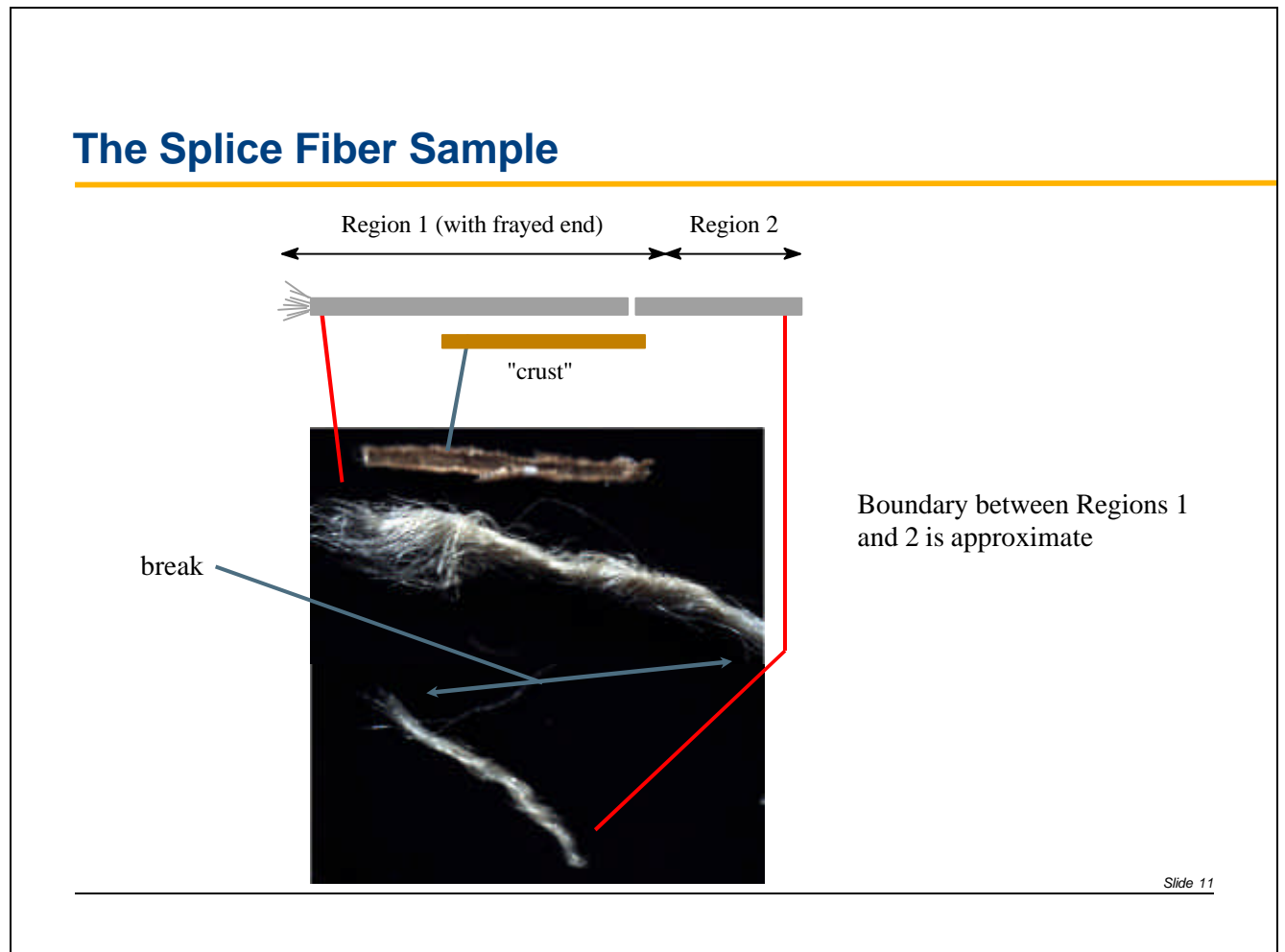


Fig.16: R1 is a splice. ©LANL 2008. From LANL presentation. Courtesy Robert Villareal.

This discovery is obviously of paramount interest for the following reasons: first, the splice is not at all obvious if we look at the photograph. Raes did not see it. Rogers (who was not a textile expert) did, looking carefully at the sample with his microscope. Second, the brown resin-like crust described as "a *micro-sized circular cocoon-shaped brown crust*" (from LANL abstract) could not be seen under the microscope. This is very surprising. Third, this shows that this part of the Shroud has been "managed" **thread by thread**, contrary to the main part of the Shroud.

Conclusion:

The fact that the Raes/Radiocarbon area is strongly anomalous regarding cotton was already known. The present study of Raes #7 thread not only confirms this but also provides more information about the type, the amount and the layout of the cotton fibers in the thread.

Under the very probable assumption that Raes #7 is representative of the Raes/Radiocarbon area, the threads of this corner are blended linen/cotton threads. The two kinds of fibers were spun together and this has been performed likely deliberately as it was often the case in the Middle-Ages. To the contrary, the main part of the Shroud is pure linen.

This alone would be sufficient to know that this area is not part of the original Shroud.

If we add the other findings: the dye (Rogers, Brown), the splice (Rogers, LANL) with the resin binder (LANL) and the amount of lignin/vanillin in the flax fibers of this area as compared with that found on the main Shroud (Rogers), there is an extraordinary set of self consistent data converging on the inevitable conclusion: the 1988 radiocarbon dating is invalid and nobody knows the true age of the Shroud.

ACKNOWLEDGEMENTS:

This paper is dedicated to the memory of Sue Benford.

I sent to her many emails before and after the Columbus conference in August 2008 and she always kindly answered to me. I also met her at the conference. I know that she was anxious to read the present paper which finally supports her hypothesis of a "medieval repair". Unfortunately, because I first wished to be sure of my results, this was not possible before her death.

I am very grateful to my friend Barrie Schwartz for his confidence in giving me R7 for further studies and sharing with me some of the Rogers' private papers, photographs and files.

I can't also forget Joe Marino and Robert Villareal (from LANL) who were present with Barrie Schwartz and Sue Benford when I received with strong emotion the sample. Thanks also to Robert Villareal for his authorization to use the slide showing the splice in Raes #1.

Because I am not an expert, I wanted to be sure of what I saw in R7.

I am very grateful to the following experts for their kind help: Dr. Lisbeth G. Thygesen (Ph.D., Senior Researcher, Forestry and Wood Products Danish Centre for Forest, Landscape and Planning, University of Copenhagen, Denmark) and her colleagues, for directly examining the sample and taking excellent microphotographs, Dr. Jana Jones (Dept of Ancient History, Div. of Humanities, Macquarie University, Sydney, Australia) who carefully looked at the microphotographs and also read the final version of this paper (except the conclusion).

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