PROCEEDINGS

International Workshop on the Scientific approach to the Acheiropoietos Images

4 - 6 May 2010
ENEA Research Centre of Frascati

Paolo Di Lazzaro
Chair / Editor

Organized by

ENEA

Italian National Agency for New Technologies, Energy and Sustainable Economic Development

Proceedings
of the
IWSAI 2010

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FOREWORD

Dear Reader,

You have in your hands the Proceedings volume of the International Workshop on the Scientific approach to the Acheiropoietos Images (IWSAI 2010) that was held at the ENEA Research Centre of Frascati, Italy, May 4 through May 6, 2010. The IWSAI was aimed at promoting a scientific discussion on chemical, physical, biological, forensic and historical aspects of the Turin Shroud, the Tilma of our Lady of Guadalupe and the Veil of Manoppello, in order to gain a deeper insight into these controversial images. They are controversial, indeed, mainly because, according to tradition, they are *acheiropoietos* images, that is, "*not made by hands*" and Science is still not able to fully explain their origin.

When looking first at the outstanding Scientific Program of the Workshop, then at the content of this volume, we conclude a primary goal was achieved. There were forty-three presentations by thirty-five speakers from Austria, Canada, Denmark, England, France, Israel, Italy, Mexico, Poland, Spain and USA. Forty papers were submitted for publication and thirty-five (87%) were accepted for publication in this volume after a rigorous peer-review process. Thanks are due to the Members of the International Scientific Committee who selected the summaries submitted for presentation, and to a group of twenty-seven Referees from six Countries that gave up their time and skill to review all the submitted papers, thus ensuring the high scientific level of the Workshop and of the Proceedings. This hard work made it possible to select papers able to shed light into a number of unclear aspects of the Veil of Manoppello, the Tilma of Guadalupe and the Shroud of Turin. The papers published in this Proceedings volume offer a multidisciplinary approach to the *acheiropoietos* images: in fact they face almost all the relevant topics, from the formation of the images to the Shroud dating; from image processing to textile properties; from archaeology and history to iconography; from philosophy to forensic medicine.

At the end of the IWSAI, we have improved our knowledge on these images, and new ideas, contacts and new collaborations have arisen. This is a very important result, as I am convinced that corroboration and (multidisciplinary) collaboration are necessary elements for progressive scientific acceptability and understanding of these images.

The IWSAI has been a peculiar (if not unique) event, from many points of view. It was the first time that the Turin Shroud, the Tilma of Guadalupe, and the Veil of Manoppello were discussed together, in an unprecedented attempt at cross-fertilization of the up-to-date knowledge of them. It was the first time that a top-level Research Centre was the venue of a congress concerned with *acheiropoietos* images. It was the first time that a genuine fiber of the Shroud was observed and analyzed through the microscope, in person, directly in front of the audience of the Workshop. And it is the first time as well that a Proceedings volume devoted to *acheiropoietos* images contains only peer-reviewed papers.

Let me give few numbers about IWSAI 2010: fifty participants, twelve authorized journalists and cinematographers from Italy, U.S.A. and Mexico, and many international echoes in the media (see a partial summary of interviews and broadcasts at www.acheiropoietos.info). Numbers convey concise information but cannot describe everything: I remind the hard work done to finalize in only five months the proposal to organize an international Workshop at ENEA Frascati on a so short notice; the pivotal support by Diana Fulbright and Giulio Fanti on arranging high-level invited-papers sessions, and over 2,100 e-mail messages sent to and received from scholars of *acheiropoietos* images all around the world. And finally, we experienced the deep emotion to see that all we had planned with passion in the previous months came into being, plainly and successfully.

The guided tour to the Exarchic Monastery of Santa Maria in Grottaferrata (also known as the Greek Abbey of Saint Nilus) and the visit to the Shroud exhibition after the Workshop added further memories of IWSAI.

During the visit to the Greek Abbey, we had special permission to see the treasures of the Library of the Monastery (with manuscripts of the tenth century) and to visit the Loggia of Vignola, with beautiful frescos, which are usually closed to public.

The coach trip to Turin and back to Frascati provided an occasion to continue the informal and lively discussions about the Workshop presentations. The concert in beautiful Savigliano, with the voices of Giovanna de Liso and her choir, moved us deeply. And finally, the group visit to the Shroud exhibition, allowing our attention to dwell in front of the mystery, was an unforgettable spiritual experience.

The IWSAI was made possible by the help of many. Here I would like to express my gratitude especially to the Director of the ENEA Frascati Centre, Gaetano Maurizio Monti, to the Local Organizing Committee and the International Scientific Committee, as well as to all the participants of the Workshop, the Authors of the papers and the Referees. Thanks to their efforts and their ability to work together as a team, we can enjoy the reading of this volume.

Finally, there are my wife Laura, and my family, who made it all worthwhile.

Have a good read!

Paolo Di Lazzaro

30th October, 2010

LETTER TO FRASCATI IWSAI

Dear Friends, Colleagues, Honored Guests and Speakers,

it is with true regret that I am sending only this short message and cannot be with you in Frascati in person, but other obligations made my attendance impossible.

I would like to first thank the organizers, most notably Paolo Di Lazzaro, for their dedicated efforts to put together such an excellent workshop on rather short notice so that it could coincide with the Exhibition of the Shroud in Torino. I would also like to thank and congratulate all of the speakers who submitted their work and are participating in this important event. Your dedication to the Shroud and its further research is truly important and conferences like this one are critical to keeping that work alive and moving forward.

Although some of us may have intellectual disagreements with each other from time to time (it is the Shroud, after all), it is important to continue to cooperate and share our work and data with the Shroud research community and the public. In my own lectures I often point out that the success of the STURP team came from the fact that they were a multidisciplinary group of scientists and researchers, WORKING TOGETHER as a team to answer a single question: how was the image formed? Now, 32 years later, their work has withstood the test of time and still remains the basis for much of the scientific data about the Shroud in the scientific literature.

Although we all approach the Shroud from our own, individual perspectives, we must remind ourselves from time to time that we all have a singular goal: to learn as much about this important relic as possible and insure that our work is perpetuated so that future generations will benefit from our extensive efforts. And it is conferences like this one that make that a true possibility.

Let me take this opportunity to thank you all for your dedication, attendance and participation. And most importantly, for your friendship!

May God bless you all for your efforts.

Warmest regards,

Barrie Schwortz

4th May, 2010

Singular Images at the "Sincrotone"*

*In Frascati there are a few Acheiropoietos images
and for them people exchange many intricate messages,
concerning physics, chemistry, statistics, medicine,
history, philosophy, iconography, and forensic discipline.*

*Where culture and wine have been for a long time shared,
lots of experts from almost three continents gathered,
from Austria, Denmark, France, Spain, England,
Italy, Mexico, Canada, USA, Israel, and Poland.*

*Presentations and discussions have been very intense
but nobody shouted loudly or told stories nonsense,
and at the very end of the last and long session
the audience applauded fully satisfied with passion.*

*The ancient Shroud had the lion share as expected
and every news made everybody very much excited,
especially when the novelties were significant
and explained the image imprinting in an instant.*

*Energy was emitted by the wrapped body like a bomb
and there was a burst of light in the fully dark tomb,
that left a blurred yellowish mark weak but still visible
and started a fascinating story which is still incredible.*

*Also neutrons were emitted as a further complication
and they may have changed the carbon nuclear datation,
which a robust statistical analysis is logically criticizing
and a new sensoristic approach is soon challenging.*

*But we were all surprised by the new information
that in a different way happened the resurrection,
which very likely took place with the body standing
well before the moment of the fierce radiation lighting.*

*Also a small cross has been recently found
in a well hidden corner of a holy ground,
which can provide some useful information
on the Shroud long and debated peregrination.*

*Even the fame of the Sudarium of Oviedo is deserved
certainly not for any image which cannot be observed,
but for some stains of blood since long time venerated
on a small and ancient towel of linen poorly fabricated.*

*Instead the Tilma of Guadalupe is not well known
because it came from a young nation still unknown,
but the Virgin is beautiful and mysteriously painted
so much so that the Aztecs people wholly converted.*

*Also the Veil of Manoppello is rather mysterious
and in comparison with the Shroud much less famous,
but the face image is so well and finely imprinted
that only in the heaven could have been painted.*

*At the end the doubts are as many as in the beginning
but our mood is in a much better shape for their sharing,
and the visit in the Turin baroque cathedral of the Shroud
gave us more than hope for an afterlife bright and proud.*

Giuseppe Baldacchini
22 September 2010

**The workshop IWSAI-2010 has been held at the Frascati Research Center of ENEA which insists on a geographic locality called "Sincrotone" to honor the first high energy accelerator built in Italy in the late fifties. The accelerator was a Synchrotron, in Italian Sincrotrone, but the name was misquoted by an unknown clerk, and became "Sincrotone" in the official maps.*

TURIN SHROUD IMAGE FORMATION

Sub-micrometer coloration depth of linens by vacuum ultraviolet radiation

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Abstract
We present experimental results of excimer laser irradiation (wavelengths 193 nanometers and 308 nanometers) of raw linen fabrics, seeking for a coloration similar to that of the body image embedded onto the Shroud of Turin. We achieved a very superficial Shroud-like coloration of linen yarns in a narrow range of irradiation parameters. We also obtained latent coloration that appears after artificial aging of linen following laser irradiations that at first did not generate any visible effect. Most importantly, we have recognized distinct physical and photo-chemical processes that are responsible of both coloration and latent coloration. These processes may have played an important role in the generation of the body image on the Shroud of Turin.

Keywords: Excimer Laser, Latent image, Coloration depth, Shroud of Turin, Photo-chemistry

1. INTRODUCTION

The faint yellowed body image embedded into the linen cloth of the Turin Shroud has peculiar chemical and physical characteristics [1] that at the moment cannot be replicated all together in laboratory [2 - 20]. Exhaustive in-depth analysis of the properties of the body image on the Shroud was performed under the auspices of the Shroud of TUrin Research Project, Inc., (STURP) [4 - 11]. STURP researchers found no evidence for pigments (paint, dye or stains) or artist's media on the Shroud. They concluded that the two faint body images are not painted, printed nor produced by heating the cloth. Moreover, the image color resides on the topmost fibers in the cloth weave, and recent results [18] show the depth of coloration is very thin, down to 200 nm (1 nm = 10^{-9} m), i.e. the thickness of the primary cell wall (pcw) of the single linen fiber. Up to date, attempts to reproduce an image with the same characteristics have been unsuccessful. Some researchers obtained images having a similar macroscopic aspect [6, 17, 19, 20] but none of them matches all the microscopic features of the Shroud image. In this respect, the origin of the body image is still unknown. In this paper, we summarize the main results of the experiments of linen coloration performed at the ENEA Research Centre of Frascati in the years 2005 - 2010, seeking for physical and chemical processes apt to generate a coloration similar to that of the Shroud image.

2. THE MAIN IDEA

Several independent works [13 – 17] have shown that a burst of electromagnetic energy may account for the main Shroud image characteristics, e.g., color superficiality, distance coded information, image in non-contact linen areas, absence of pigments. An attempt to reproduce the face of the Shroud irradiating a linen with a CO_2 laser (infrared emission wavelength λ = 10.6 µm, where 1 µm = 10^{-6} m) gave a similar macroscopic result, presently exposed at the Shroud Museum in Turin. However, the microscope analysis revealed a too much thick coloration depth and many linen yarns burned [20], which are substantial differences with respect to the Shroud image characteristics [1]. One of the main causes of the unwished burned yarns observed in [20] was the too long wavelength radiation emitted by the CO_2 laser. In fact, long-wavelength (infrared) radiation excites vibrational energy-levels of the target material that relax in far-infrared energy, instantaneously heating the irradiated linen. On the contrary, it is well known that the energy carried by short wavelength radiation breaks the chemical bonds of the irradiated matter, almost without secondary heating effects. As a consequence, in 2005 we have considered the ultraviolet (UV) radiation as one of the best candidate to obtain two of the main characteristics of the Shroud image: a thin coloration depth and a low-temperature image-formation process [1, 9, 11]. We have first irradiated linen cloths with two XeCl excimer lasers (UV emission wavelength λ = 308 nm, i.e. 34 times shorter than the CO_2 wavelength) emitting different pulse durations [21, 22]. The encouraging but improvable results, summarized in the section 3, pushed us to repeat irradiations using a shorter wavelength radiation in the vacuum UV (VUV), namely the λ = 193 nm emitted by an ArF excimer laser [23, 24] as discussed in the section 4.

3. EXPERIMENTAL RESULTS WITH UV LASER RADIATION

When irradiating linen cloths with a sequence of laser pulses (corresponding to an hypothetical burst of energy correlated to the Shroud image) emitted by a 5J/pulse, 120 ns XeCl laser (λ = 308 nm), we were not able to obtain any coloration. In fact, at large intensity values linens were burned, and at lower intensity values linens were not colored at all. Let us remind the intensity is the laser energy per unit time per unit surface incident on the linen fixed on a frame. The intensity on linen is varied by moving the linen along the optical axis of the 1-m focal length lens.

Then, we repeated the irradiations with a different XeCl laser emitting a 30-ns pulse duration (4 times shorter than before) and 0,4 J/pulse scanning a range of intensity values centered around the same intensity values tested with the previous longer pulse duration laser. In this way, we have obtained the permanent coloration of linens that can be achieved in a narrow range of pulse duration, intensity and time sequence of laser shots. Experimental setup and results are detailed in [21]. However, the hue of color (light brown) was darker than the yellow-sepia of the Shroud image, and the thickness of coloration of linen yarns was still larger than the topmost ($\approx$ 0.2 μm thick) fiber coloration of the Shroud body image [18].

To obtain a thinner color penetration depth, we used an ArF laser emitting a wavelength much shorter than XeCl lasers. In this way we obtained a reduction of the coloration depth and a better overlap with the features of the Shroud image.

4. EXPERIMENTAL RESULTS WITH VUV LASER RADIATION

The ArF excimer laser emits pulses at λ = 193 nm, in the VUV spectral region, with 0.08 J/pulse in a 12 ns pulse duration and 1 Hz repetition rate. As in the previous experiments, we investigated a wide range of different combinations of laser intensity and number of shots. Table 1 reports a summary of naked-eye observation of irradiated linens vs. the number N of consecutive shots, the spatially averaged single-shot intensity I and the total spatially averaged intensity I_T respectively defined as

$$I = (1/A)\times\iint_\sigma I(x,y)dxdy \, , \qquad (1)$$

and

$$I_T = (N/A)\times\iint_\sigma I(x,y)dxdy \, , \qquad (2)$$

where A = area of the laser spot and I(x,y) = local intensity value at the point with coordinates x, y within the irradiated spot σ. Table 1 clearly shows that the effects of laser irradiation on linens are proportional to the total intensity I_T and not to the intensity I. A yellow coloration like that shown in figure 1 is achieved when the combination of single-shot intensity (see eq. (1)) and number of shots produces a total intensity (see eq. (2)) in the range $I_T \approx (2 - 4)\times10^9$ W/cm^2. When $I_T > 4.6\times10^9$ W/cm^2 linen is ablated, and when $I_T > 6\times10^9$ W/cm^2 it is vaporized and holed.

An interesting property of the irradiated linen is that the hue of color continuously changes from light yellow to yellow-sepia by increasing I_T.

TABLE 1. Summary of the main results observed on linen as a function of the ArF laser irradiation parameters.

I (MW/cm^2/shot)	**N**	**I_T** (MW/cm^2)	**Macroscopic results on linen**
35	30	1050	unchanged
14	100	1400	small surface change observed at grazing incidence light
36	50	1800	light yellow coloration
10.5	200	2100	yellow coloration
11.2	200	2240	yellow coloration
6.6	402	2645	yellow-sepia coloration
6	600	3600	yellow-sepia coloration
13.3	500	6650	ablated

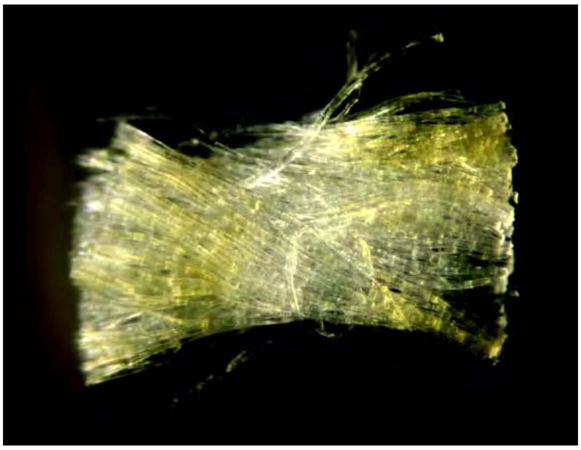

Figure 1. Microphotograph of a linen yarn irradiated with a total laser intensity $I_T = 2.2\times10^9$ W/cm^2.

In other words, we can easily adjust the RGB value and chromatic coordinates [25] just changing the total laser intensity, i.e. the number of laser pulses.

As an example, let us consider the third row of table 1. In this case we obtain a very light yellow coloration after 50 laser pulses. Each laser pulse changes a little the coloration achieved by the previous shot. Namely, each shot changes the contrast and RGB value of the linen coloration by a quantity 1/50 ≈ 2%, thus allowing a very accurate control of the chromatic coordinates. In fact, a change of 2% cannot be appreciated by naked eye observation, because in this case the coloration after 50 shots (i.e. the 100% color change) is close to the threshold for visual inspection. Similar arguments can be stretched to the second – to seventh rows of table 1.

Equations (1) and (2) show the intensity values in table 1 are "averaged" across the laser spot size. This means that due to the "bell-shaped" spatial intensity profile of the laser beam, the local intensity value I(x,y) may substantially differ from the average intensity I. As a consequence, coloration was not uniformly distributed across the laser spot at the yarn level. In some cases we observed all the possible effects on linen within the same laser spot. As an example, figure 2 shows linen yarns ablated in the middle of the laser spot (where the intensity is higher), while one yarn away, at an intermediate intensity level, there are yellowed yarns. At lower intensities, close to the spatial wings of the laser spot, linen yarns are unaltered. In this respect, the range of ArF laser parameters suitable to achieve a permanent coloration is much narrower than the equivalent range of XeCl laser parameters reported in [21].

Concerning the depth of coloration, microphotographs show the average color penetration depth in many different linen yarns irradiated with different I_T values ranges between 7 μm and 26 μm [24] that is, a factor 11 to 3 times smaller than the penetration depth achieved after irradiation at λ = 308 nm [21, 22]. This experimental evidence confirms that a shorter laser wavelength produces a thinner depth of coloration. Our linen yarns have an average diameter of 300 μm, so that the λ = 193 nm ArF laser pulses penetrate 2% to 9% of the yarn diameter, in average, depending on the specific irradiation condition.

Most importantly, among the available micro-photographs of colored yarns/fibers (we analyzed only few thousands fibers over half million irradiated fibers) we found at least one irradiated fiber showing a colorless medulla, see figure 3, and in this case the coloration may reside in the primary cell wall of the same linen fibers, which has an approximated thickness of 0,2 μm, a property that closely resembles the very thin coloration depth of the image fibers of the Shroud [18].

Figure 2. The linen area irradiated by ArF laser pulses shows different characteristics corresponding to the local laser intensity value I(x,y). 1) colored area; 2) ablated area; 3) area irradiated below threshold for coloration. From Ref. [24].

Figure 3. Microscope image of a single linen fiber colored with ArF laser. The mechanical damage in the middle shows a colorless inner medulla. Contrast-enhanced detail of figure 8 in Ref. [24]. Small shreds of the yellowed pcw are visible.

5. LATENT COLORATION

A suitable aging technique can color the irradiated area of yarns even when no visible results are obtained by laser irradiation, as described in the following.

We cut half of the laser spots on linen irradiated at $I_T = 1.4 \times 10^9$ W/cm^2, i.e. below threshold for coloration (see table 1). One of the two parts was heated 10 seconds by an iron at the temperature of 190 ± 10 °C, and a visible coloration of the heated part of the fabric appeared in the area corresponding to the laser spots, as shown in figure 4.

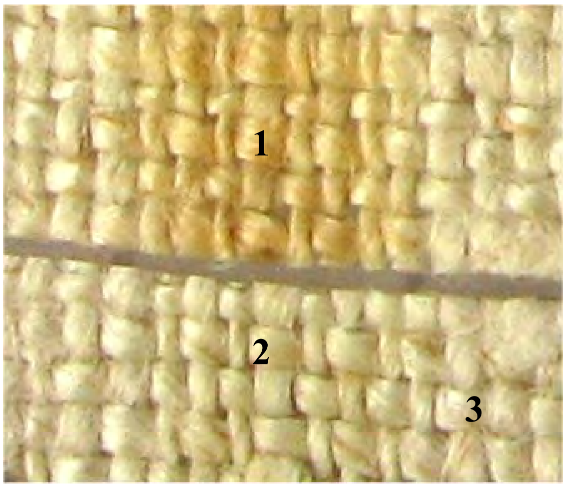

Figure 4. Linen fabric cut after laser irradiation below-threshold for coloration. 1) Irradiated region after heating. 2) Irradiated region not heated. 3) Non irradiated region. From Ref. [24].

Figure 4 shows that the heating process, which simulates aging, colored only the linen area irradiated just below threshold.

Moreover, when heating the laser spot on linen corresponding to the first row of table 1, latent coloration does not appear. This means we are below the threshold for latent coloration. As a consequence, we can fix the range of the total intensity suitable to obtain latent coloration as $I_T \approx (1.1 - 1.7) \times 10^9$ W/cm^2 corresponding to a range of total fluence (total radiation energy per unit surface) $F_T \approx (13 - 20)$ J/cm^2.

By the way, when heating a colored spot (i.e. a linen irradiated above-threshold for coloration) the yellow color becomes more visible as it shows a higher contrast with respect to surrounding not irradiated areas.

In section 7 we will discuss the physical and chemical processes possibly involved in the coloration and latent coloration results described above.

6. ULTRAVIOLET FLUORESCENCE

One of the peculiar properties of the Shroud image is the lack of fluorescence of the image fibers under UV illumination [1, 6, 11].

Figure 5a shows the UV-induced fluorescence of the linen after laser irradiation. Note the region irradiated by the ArF laser in the middle is much less fluorescent under UV illumination, like in the case of the Shroud image yarns. Figure 5a suggests that the VUV laser photons modify the electronic structure of linen in a way that allows the quenching of the fluorescence of the background linen.

As happened in the coloration process, the quenching of fluorescence of the irradiated fibers under UV illumination appears only in a very narrow range of irradiation parameters. As an example, figure 5b shows that a too much intense laser irradiation produces the strong reduction of fluorescence only in a spatial ring, corresponding to the “right” range of intensity across the laser spot, which has a “bell-shaped” intensity profile. Inside this ring the intensity is too large and outside the ring is too weak to allow the quenching of fluorescence.

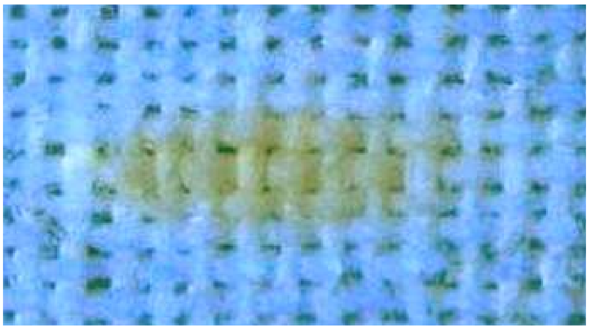

Figure 5a. Ultraviolet induced blue fluorescence of linen after irradiation with ArF laser in the working point of the third row of table 1. The irradiated area is recognized by the strong reduction of fluorescence. From Ref. [24].

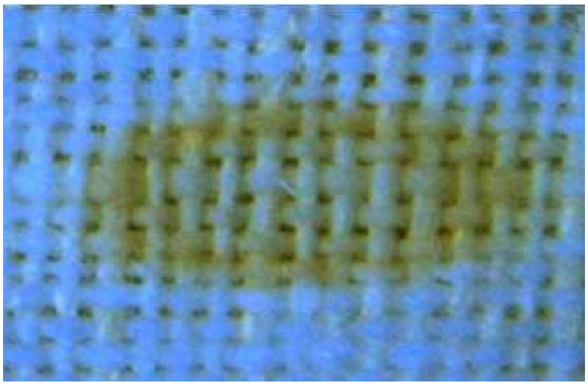

Figure 5b. Ultraviolet induced blue fluorescence of linen after irradiation with ArF laser in the working point of the seventh row of table 1. In this case, the fluorescence quenching is not uniform across the laser irradiated region.

Note that the laser spot of figure 5b gave an apparently uniform yellow-sepia coloration when observed at sunlight (cf. seventh row of table 1). This means the UV induced fluorescence gives a more accurate and selective response than the naked eye. In fact it allows to recognize linen regions irradiated by a intensity too large to obtain the quenching of fluorescence, but still giving a yellow-sepia coloration.

7. ANALYSIS AND DISCUSSION

The experimental results detailed in the previous sections are quite exciting, as it seems we found a way to obtain a hue of color and a very thin penetration depth inside the linen fibers that resemble those of the image embedded onto the Turin Shroud. The results are perfectly reproducible, provided that sufficient attention is paid to the narrow irradiation conditions suitable for obtaining Shroud-like linen coloration.

Obviously, nobody can claim the body image of the Shroud was made by a burst of VUV flashes emitted by an excimer laser. Rather, the excimer laser can be considered a powerful tool to investigate the physical and chemical processes experienced by the Shroud to finally give such a peculiar coloration. To gain a deeper insight into these processes, let us give a closer look at the chemical and physical properties of linens.

7.1 Chemical processes.

Flax fibers spun to produce linen yarns from which Shroud was woven are made by an inner part of nearly pure cellulose and by an external thin layer, the primary cell wall, basically made by hemicellulose [26, 27].

The very superficial coloration of the Shroud image was formed by an unknown process that caused oxidation, dehydration and conjugation of the polysaccharide structure of the flax fibers, to yield a conjugated carbonyl group as the chromophore, i.e. a kind of premature aging process of the linen [9, 10, 28].

Figure 6 shows different chemical steps possibly involved in the linen coloration of the Shroud.

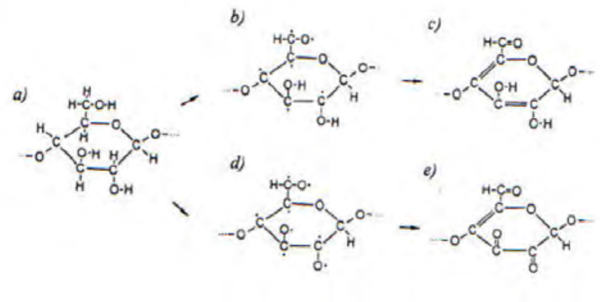

Figure 6. Main sugar kernel of both cellulose and hemicellulose (a) and steps (b) → (c), and (d) → (e) transforming it into a cromophore made by conjugated carbonyl groups after experiencing dehydrative oxidative processes. The alternate double bonds C=C and C=O in c) and e) ultimately lead to the coloration of the image fibers of the Turin Shroud. From Ref. [28].

The different coloration depths obtained with XeCl and ArF lasers (see sections 3 and 4) may be due to the different wavelength. In fact, the shorter λ allows a smaller penetration depth and then a greater energy absorbed for unit volume. However, in [23, 24] we have experimentally shown that there is only a 11% difference in linen absorption between 193 nm and 308 nm. As a consequence, an additional and more specific mechanism is necessary to explain the different depth of coloration as well as the different color, namely a yellow-sepia after 193 nm irradiation and a light-brown after 308 nm irradiation.

This additional mechanism could be triggered by the absorption peak below 260 nm of the ketonic carbonyls that promote yellowing of the less stable hemicellulose in the primary wall cell [26, 28, 29]. In other words, the VUV 193-nm photons are absorbed by ketonic carbonyls and bring photolytic degradation of hemicellulose, causing molecular bonds dissociations that promote Shroud-like chromophoric changes as shown in figure 6, finally leading to the yellowish coloration.

Note that the UV 308-nm photons do not match the absorption band of ketonic carbonyls. Rather they can be absorbed by aldehyde groups [29]. As a consequence, 308-nm radiation cannot start the above described multi-step process that lead to the yellowing of cellulose and hemicellulose. In fact, our UV 308-nm photons produced a light brown coloration of linens.

Concerning latent images formation described in section 5, they can be explained by the oxidation of cellulose (and thus production of conjugated unsaturated structures) induced by heat. In fact, the coloring process triggered by an initial exposure of UV light is accelerated and strengthen by heat, as detailed in [30].

7.2 Physical processes.

A key question is whether the intensity or the energy density (fluence) of laser pulses is the key parameter for the coloration of linens. We have shown in section 3 that two XeCl laser pulses having the same fluence and different pulse durations give much different coloration results, thus suggesting the intensity is the key parameter. However, Table 1 shows that subsequent laser pulses sum their effect, suggesting on the one hand that the total intensity I_T is the relevant parameter, and on the other hand that once fixed the pulse duration, the total number of photons for unit surface (i.e., the total fluence) is the key parameter. This apparent dichotomy testifies we are facing an intricate photochemical process, where the intensity and the fluence play a dominant role in turn, depending on the range of pulse duration, number of photons, number of consecutive shots and repetition rate of the laser pulses.

Let us now discuss why we obtained the Shroud-like coloration of the primary wall cell of linen fibers (see figure 3) only locally. As mentioned in section 4, the intensity profile of excimer laser beams is not flat-top. In particular, the excimer laser intensity profile shows high-spatial frequency fluctuations, that can be revealed and measured by a high-resolution CCD camera as shown in figure 7.

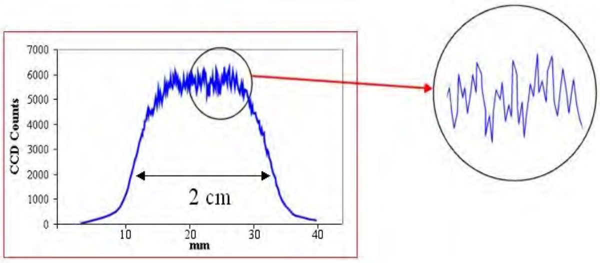

Figure 7. Two-dimensional intensity shape of the laser beam measured by a CCD camera Andor model DV-430UV, having a single pixel resolution 11 μm = 0.0011 cm. The inset shows a zoom of the high-frequency intensity fluctuations.

Figure 7 shows the intensity fluctuations have a period randomly fluctuating in the sub-mm scale, with intensity gradients as high as 350 $MW/cm^2/cm$. A so huge spatial gradient of the intensity explains why we can achieve the "right" intensity value for a sub-micrometer coloration only in a very small spatial region.

Let us devote a final comment about the main difference that still exists between our linen coloration and the Shroud image. Photomicrographs and samples show that the fading of the Shroud image is a result of concentrations of yellow to light brown fibers [1]. Moreover, the color of the image-areas have a discontinuous distribution along the thread of the Shroud, and striations are evident [31]. Obtaining the same characteristics with a laser is difficult, although possible. We would need a laser beam having a very peculiar spatial shape of the intensity, similar to a profile saw-toothed with variable period. The state of the art technology of diffractive optics can modulate the intensity shape of laser beams at easy, producing a shape able to reproduce striations and discontinuous distribution of colored fibers across the linen textile. However, in our opinion this effort would be meaningless and beyond our aim. Our goal cannot be the perfect reproduction of the whole Shroud image by a VUV excimer laser. Our goal is obtaining a deeper insight on the physical and chemical processes experienced by the Shroud to generate the image imprinted in it.

8. CONCLUSION

In this paper we have summarized five years of experiments apt to show that nanosecond-duration VUV laser beams are able to color the outermost portion of the linen threads (color penetration depth down to 7 μm). We also obtained at least one fiber colored across the sub-micrometer depth on the primary cell wall of linen fibers, see figure 3, comparable with the thinnest coloration depth observed in the Turin Shroud fibers image [18].

The permanent coloration is a threshold effect and it can be only achieved in a very narrow range of photons parameters: $I \times N = I_T \approx (2 - 3.6)\times 10^9$ W/cm^2. Above this range linen is ablated, while below this range irradiations bring latent images that appear only after artificial aging. When $I_T \leq 1.1\times 10^9$ W/cm^2 linen is not colored at all. Even when I_T is above threshold for coloration, not all the irradiated fibers are colored (see figure 2) due to spatial intensity fluctuations across the laser beam (see figure 7).

Compared with previous results [21, 22] it appears that the shorter the radiation wavelength, the thinner the color penetration depth and the narrower the range of laser parameters suitable to obtain a linen coloration.

The hue of color depends on the laser λ and on the number of shots. Linens irradiated at λ = 308 nm are light-brown, while at λ = 193 nm photons induce a yellow coloration (see figures 1 and 2) similar to the color of the Shroud image. In both cases the image contrast increases with the number of laser shots, also allowing a fine and accurate control of the RGB value and of the chromatic coordinates by varying the laser I_T see table 1 and figures 1, 2.

The different colors are due to different chemical reaction chains triggered by the 308-nm and by the 193-nm radiation. The 193-nm radiation, thanks to the absorption peak of ketonic carbonyls, induces a photolytic degradation of linen cellulose that promotes the formation of cromophores (see figure 6) having conjugated double bonds C=C and C=O leading to the yellow coloration of the linen fibers [9, 11, 28, 29].

The local spatial gradient of the radiation intensity may play a role in the color penetration depth, see figure 7.

Following laser irradiation that at first does not generate a clear image, latent images appear after artificial aging of the linen, see figure 4, or one year later by natural aging [21 - 24, 30].

The lack of UV-induced fluorescence observed in the irradiated spot is an additional characteristic of our coloration that resembles the Shroud image, see figure 5a. The UV-induced fluorescence has also shown the capability to selectively recognize the quality of coloration, cf. Figures 5a and 5b.

By using a petrographic microscope we have observed some UV- and VUV-induced defects in the crystalline structure of irradiated linen fibers, showing analogies to those observed in image fibers of the Shroud. This is not discussed in this paper, see [21 - 24] for details.

In summary, our results demonstrate that short and intense bursts of directional VUV radiation can provide a linen coloration having many peculiar features of the Turin Shroud image, including the hue of color, the coloration of the outermost fibers of the linen threads and the lack of fluorescence.

However, the total VUV radiation power required to color a linen surface corresponding to a human body, of the order of

$$I_T \times \text{body surface} = 2\times10^9 \text{ W/cm}^2 \times 17\times10^3 \text{ cm}^2 = 3.4\times10^{13} \text{ W}$$

makes impracticable the reproduction of the whole Shroud image by using a single laser, as this power cannot be delivered by any VUV source built to date. Rather, we have shown that a VUV laser is a powerful tool to gain a deeper insight into the physical and chemical processes that generated the body image embedded onto the Shroud, regardless of the radiation or energy source that generated this image.

The enigma of the origin of the body image of the Turin Shroud is still “a challenge to our intelligence” [32].

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PHOTO CREDITS

Figures 1 and 5b: Giulio Fanti.

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Shroud-like experimental image formation during seismic activity

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Abstract

Seismic oxidative phenomena on vegetal structures and ferromagnetic rocks, occurring only along parallel surfaces to the ground, led me to verify experimentally if, naturally, in conjunction with earthquakes, it is possible to form images with a 3D character, similar to Turin Shroud image, of objects placed between the two edges of linen cloths folded in two and soaked with different solutions. Some similarities with the Shroud image were obtained only on ferromagnetic rocks, during seismic radon emission, with electrostatic discharges and geomagnetic variations, in agreement with Lattarulo's theoretical hypothesis.

Keywords: Turin Shroud, images formation, seismic precursors, earthquakes

1. INTRODUCTION

Living in a slightly seismic area (west Piedmont), I studied the seismic precursors with methodical measurements of physical and chemical parameters for over twelve years, for earthquake risk prevention. When I observed that microwaves and oxidative phenomena on ferromagnetic rocks (gneiss), occurred only along surfaces parallel to the ground and not on lateral surfaces, I considered the analogy with the Turin Shroud, because on the Turin Shroud there are no lateral images. So I thought to **verify experimentally the hypothesis by G. B. Judica Cordiglia and Fanti of electrostatic field, and especially Lattarulo's theoretical hypothesis of seismic-electric processes being the cause of the Turin Shroud Image. Verifying the latter hypothesis was the main goal of my work**, because of the obviously difficult experimental verification of natural thunderbolt electric discharges that may generate Shroud-like images.

The cloth had been placed mainly in an underground place, partly excavated in ferromagnetic rocks, in a place with radon emission, in structures (churches) with radioactive stones, and in underground places, not very far from iron and copper mines.

The monitoring of an increasing number of parameters allowed me to gradually reduce the margin of error on the temporal and spatial prediction of the earthquakes. In fact, the earthquake warning signs can now be well specified, thanks to the comparison "a posteriori" of the data observed before, during and after the earthquakes, some of which happened more times, with the same epicenter and the same magnitude.

The error margin on the temporal forecast is now about 10-15 hours, while the error on the distance of the observation place from the probable epicenter is still around a hundred kilometres, for an only *local forecast* .

Separation of the variables, reducing the error margin in the forecast of the earthquakes and verifying their realization are fundamental to distinguish, while studying image formation, what is due to earthquakes and what is not.

2. EXPERIMENTAL

2a) Experimental Methodology of Seismic Parameters Monitoring

In order to find the causes of image formation that I obtained experimentally, it is necessary to consider a synergic action of several factors, mainly unknown or not easily distinguishable from other variables. So, I progressively increased the number of the instruments, in order to quantify more data. Unfortunately, the experimental errors, due to the limited sensitivity of the instruments and to the modalities of non continuous data prospecting, put a limit to the precision of the forecast and to the measurement of all the parameters, while instruments continuously working in conjunction with a computer, would give more reliable elements.

Nevertheless, in every experimental stage, I tried to separate the measurable variables, working simultaneously on more cloth, changing only one parameter at a time. The instruments are:

3 Geigers counter of alpha, beta and gamma particles
1 induction magnetometer (0 - 100 μT)

1 induction magnetometer (0 - 50 mG)
1 ELF detector (0 - 10 mW/cm^2)
1 RF detector (mw/cm^2)
1 EHF detector (0 - 0.1 mw/cm^2)
1 electric field detector (0 - 1000 V/m)
1 thermometer (sensitivity of ± 1/100 Celsius degree)
1 igrotester
many radon dosimeters
2 Wood lamps
4 compasses.

As regards monitoring methodology, having neither a declinometer, nor a theodolite to estimate the angle of the magnetic declination, I placed four compasses in the underground place, a few meters away from each other. The place is partly excavated in ferromagnetic rocks, so every compass gives me a different position of the local north, N1, N2, N3 and N4. Every deviation towards east of the respective needles defines a positive δ angle of declination, in comparison with the starting position of the local north (at the beginning of the long observation period). Every variation towards west defines a negative δ angle.

After exchanging the compasses among themselves, to verify the instrumental sensitivity, I adopted some expedients to reduce the errors due to parallax. The study of the final position, after several oscillations, compared with the initial position of the needle, gives approximately the place where there was a variation of the magnetic permeability, due to the intense magnetic pressures to which the rocks are exposed. The spatial forecast, however, is not always given by the geometrical resultant of the local north of the compasses. Sometimes, in fact, all the compasses have the same dip and the magnetic anomaly is very close, comparing it with previous earthquakes. Moreover, I put iron material quite close to one of the four compasses, in turn, to evaluate the answer of the others. I study magnetic variations also for distance over 50 Km from Torre Pellice, so I can evaluate a new geometrical resultant.

About the temporal forecast, instead, I noticed it is very important to pick up the right moment of the **sudden commencement**, that is the sudden beginning of a magnetic storm: the sudden variation compared with the previous static condition, in fact, is followed by a "small-storm" for a term of about two hours when the magnetic storm shows generally worldwidely, with a complex sequence of phenomena affecting the magnetosphere, almost always caused by sun glares. This is, however, estimable "a posteriori". Instead, when it is a seismic warning sign, even if with a sudden beginning, it is followed for some days by a variation of the absolute value of δ and by a variation of the intensity of the geomagnetic field (the maximum variation of the magnetic induction were not over 4 μT). The needles of the compasses have, in fact, a dampened oscillating motion around a new local north. After 10-15 hours from the moment in which they settle on this axis there is generally the first shock. But I value magnetic variations in microteslas, not in nanoteslas.

Comparing "a posteriori" several earthquakes that occurred in the same area, even with identical magnitude, I noticed several times a direct proportionality between the absolute value of the declination angle δ, noted at the moment of the sudden commencement, and the magnitude of the coming earthquake. Nevertheless, the complexity of all the parameters, the necessity to specify the anthropic factors, valuing, for example, the induced magnetic and electromagnetic parameters, lead to a strict discretion.

Except for some periods, the monitoring frequency of the physical parameters during the last twelve years was daily. It was repeated several times a day when I observed either an angle different from 0, or an increased radioactivity. The maximum variation of electic field was of 100 V/m

2b) Experimental Methodology About Cloth

I used linen cloth both in a "fishbone" way, like the Shroud, both with warp and weft disposed in an orthogonal way. These clothes since 1860 were washed only with Marseilles soap.

The clothes were soaked with water or oily solutions of aloe, myrrh and tolù balsam, together or in mixtures in different percentages. Sometimes I added sodium chloride or bovine or my blood.

Inside the cloth, folded in two and laid on different surfaces, objects of different nature (vegetal, animal, mineral, synthetic) were inserted for a period of time between 3 and 48 hours. In each experiment the different objects were placed together in every cloth to find out if the possible image formation could depend on the electric conductivity of the objects.

In every experiment I separated the possible variables:
- open air, close environment in the underground place, the 1st floor and 2nd floor.
- support in gneiss, in marble, wood, polystyrene, PVC, soil, iron and copper.
- the cloth had been placed mainly between **two parallel gneiss layers (200×50×3 cm each one**), with different distance between the two layers. The superior layer was sustained by other smaller gneiss layers or by insulating material. They had been placed near a fissure where, before earthquakes, radon comes out variably, carried by warm gas, especially sulphureous gas.

2c)-Experimental Results

About an hypothetic radioactive influence, I tried to separate the variables formed by the alpha particles of the radon, β and γ particles, enclosing the layers in a wooden coffer; when I have tried this, I have not obtained images with 3D (Three Dimensional) character.

Three to eight hours before the the first local earthquake shock, I have always noticed **a ground temperature increase**, with an average increase of about 4-5 C°, near places where there is gas emission (radon and sulphides). So, three hours before the earthquake shock of 25 December 2008, (at 03.38 a. m., with magnitudo 2.9 and depth of 12 km, epicenter Angrogna), I noted a snow melting on the Vandalino montain (Torre Pellice), with a sudden increase flow of the mountain stream, near my house. I was naturally in alert, but I have experimented after the seismic first shock, no seismic storm, so, **without magnetic variation (measured in µT) and electric variation (measured in V/m), I have had no images.** In fact, just some hours (3-8 hours) before the first seismic shock, I have never recorded magnetic variation in µT and electric variation in V/m.

The objects were removed only when the cloth was dry. During seismic activity, some images formed already after seven or sometime three hours from the moment in which they had been placed, **if the humidity rate of the environment was not over 35-40%**. But this is possible before the first seismic shock or before any other shock of the following seismic storm, with higher magnitudo. In order to compare the objects and the eventual images, I took a picture of the objects just placed on the inferior face of the cloth and then at the end of the experiment. This let me sometimes note **some double image**, due to a probable earthquake, with objects shifting (Figures 1, 3).

I observed also that many images were **ghost images**, because of the creases of the cloth and the humps made by the objects; ghost images are realized only with myrrh and/or aloe solutions, without earthquakes, probably due to a slow cloth fibres oxidation at the sun.

Some hours before earthquakes, (10-40 hours) in dark and closed places, also with water solutions, ghost images are generated probably by electrostatic discharges, due to telluric currents and magnetic inductions, but they are feebler (see Figure 2).

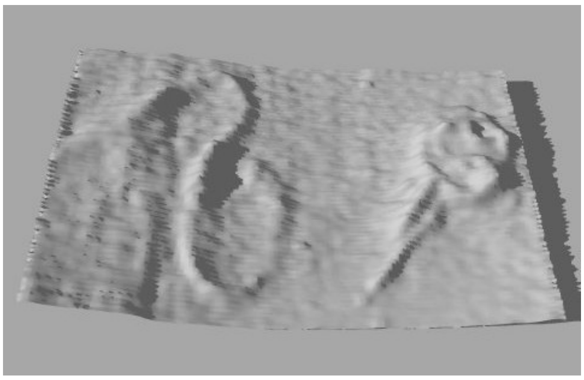


Figure 1 Double images of the key and 3D character for the snake and the key (earthquake of October-27-2000, Incisa Scapaccino, magnitudo VII Mercalli). Aloe imbibition.

After every experiment some clothes have been exposed to the sun, others have been placed in a microwave and then repeatedly washed, others heated up. **The images obtained during earthquakes persisted even if washed**.

During periods when no earthquakes occurred, I carried out similar experiments, with the values of magnetic induction and natural radioactivity reduced.

Figure 2 Ghost image on superior outside face (earthquake of October-04-2000, in Asti, IV Mercalli). Myrrh imbibition.

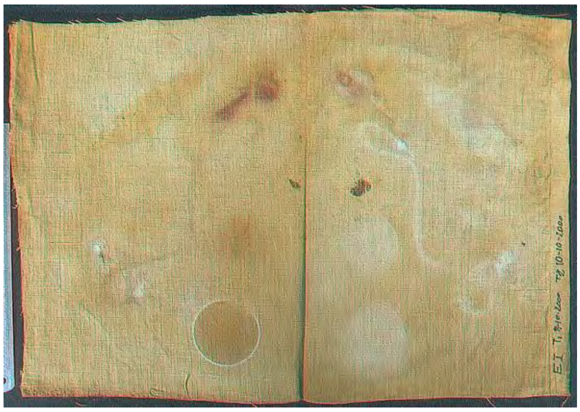


Figure 3 Earthquake of October-09-2000, Torre Pellice, magnitudo 3.2. Aloe imbibition.

In the following I summarise the results of over five hundred experiments:

1) the best dilutions, in order to form images, for **aloe and myrrh,** together or not, must not exceed **20g/l,** in water or oil, while the Tolù balsam is not efficient.

2) the **photosensitivity of linen cloth** treated with water or oily solutions of aloe and/or myrrh is confirmed, but the images of objects placed on **cloth exposed to the sun** are originated by **"shield effect"**. However these images are unstable, and fade with time. I have so obtained only support surface images and cloth creases images. After just three years some confused images, not 3D, are visible only with a Wood lamp.

3) the images (3D or not 3D character) come out naturally, with or without earthquakes, only if the clothes are soaked.

4) with or without earthquakes, any soaking with aloe or myrrh produces on the cloth a greater intensity of basal colouring where aloe and myrrh quantity is larger due to gravity: on the inferior face if the cloth lies horizontally,

folded in two, towards the bottom if vertically, so it is possible to observe different luminance values.

5) **in the presence of earthquakes, a soaking with even only water is sufficient to form images** (I have obteined the best images with similarities to the Turin Shroud characteristics).

6) in absence of earthquakes the images are confused or in the best case enlarged in relation to the orthogonal projection of the objects onto the planes of the cloth and have no 3D character.

7) only during earthquakes or 2-3 days before, images come out which are not enlarged, with respect to the projection of the objects onto the planes of the cloth. This could be compatible with **3D character**: in fact the image of the snake (figure 1) has 3D character (as noticed by Prof. Balossino of Turin University and Prof. Giulio Fanti of Padova University). The richness of details and the clearness of the images of the objects reproduced are inversely proportional to the distance from the epicenter, directly proportional to the magnitude of the earthquake and to the radioactivity of the place: (from an average natural radioactivity of 0.13μSv/h I have registred tips of 0.98 μSv/h and one time of 3.74 μSv/h). It is very interesting to note how the best images with 3D character are possible only if the cloth is placed between two gneiss layers, near radon emission and iron material**,** that amplifies magnetic variations (I suppose). Radioactive places, but without gneiss layers and iron material, are not sufficient to generate 3D character images.

8) the blood trace of a reptile, that left a 3D image, looks dark brown on the cloth middle; away from body, it looks clear on the body and inside, so inside the mouth and the caudal extremity it appears clear (figure 3), while my own blood, with an identical experiment, on another cloth, looks ancient pink (figure 4). About my blood, it is possible to note an effect consistent with an electrostatic discharge.

Figure 4 Human blood looks more ancient pink, after ten years (earthquake of October-09-2000, Torre Pellice, magnitudo 3.2). Aloe imbibition.

9) snake blood is not fluorescent at the UV light, on cloth middle, it is fluorescent on snake body (Fig. 5), so human blood is fluorescent at the UV radiation (Fig. 6). Snake inside mouth and the caudal extremity are fluorescent at the UV radiation on the two surfaces (see Fig. 5).

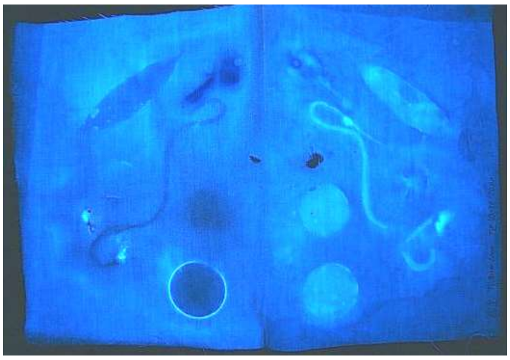


Figure 5: (earthquake of October-09-2000, Torre Pellice, magnitudo 3.2). Aloe imbibition. Cloth under UV light

Figure 6 Human blood looks fluorescent under UV light (earthquake of October-09-2000, Torre Pellice, magnitudo 3.2). Aloe imbibition.

10) two linen fibrils of the image of the snake of figure 7, analysed with a microscope (60×) under cross-polarised light by Prof. Fanti from Padua University, show **pleocroism** with probable spatial periodicity correspondent to the cloth weft.

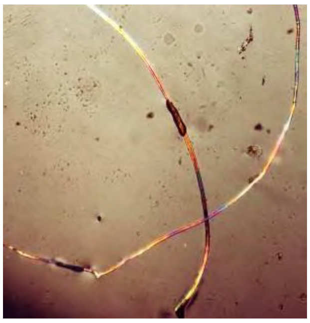


Figure 7 Pleocroism on 2 fibrils of the snake's image

11) the objects made of baked clay, brass, pewter, bronze, copper and wax left no images, so did the objects placed on a PVC surface.

12) on the same cloth the images are different according to the chemical nature of the object and we can have different colours.

13) **when the gneiss superior layer is not insulated**

from the inferior one, the images are dark on the superior face of the cloth, white on the inferior face, in negative, maybe because of the shield effect; this occurs if the imbibition is with aloe and/or myrrh (Figures 3 and 5).

14) images realized during earthquakes appear with **double superficiality** at thread-level, but it is necessary to control it at fibril-level.

2d) Some Considerations about a Relation between Image Formation of my Experiment and Earthquakes

We must consider how all physical and chemical seismic parameters share in sinergism for images formation, but in several experiments, only a place with radon emission, iron material, gneiss support for linen cloth and underground rock cavity was able to form images with 3D character and other similarities with Turin Shroud Image.

In the same experiment in a closed place, with constant distance *"d"* beetween the parallel gneiss layers (200×50×3 cm each one), radioactivity over 0.35µS/h, we obtain images with **3D character if the height of the objects in the linen cloth does not exceed the 35% of distance *d*.**

The following tables summarize the results:

TABLE 1. Without earthquakes on linen and cotton cloths with or whitout radioactivity

Imbibition	Sun exposition	Shade	Darkness
Dry or Water imbibition	support surface images and cloth creases images No 3D (Shield-effect and cloth photosensibility)	No images	No images

TABLE 2. Without earthquakes on linen and cotton cloths with or whitout radioactivity

Imbibition	Sun exposition	Shade	Darkness
Myrrh, Aloe, Aloe and Myrrh together		No images	No images

I obtained images with **3D character**, with the percentage reported in table 3, as a function of the **distance of epicenter** and with a **radioactive parameter** R ≥ 0,35 µS/h, during earthquakes or two or tree days before seismic shock:

TABLE 3. Images 3D character percentages, on linen and cotton clothes, only with water/aloe/myrrh imbibition, with electric conductor objects, with cloth only on gneiss support and radioactivity intensity R ≥ 0,35 µS/h

Magnitudo	ED≤20 km.	20≤ED≤50 Km	50≤ED ≤100km
M ≤3	100%	93%	75%
3≤M≤4	100%	100%	80%
4≤M≤5	//	//	100%

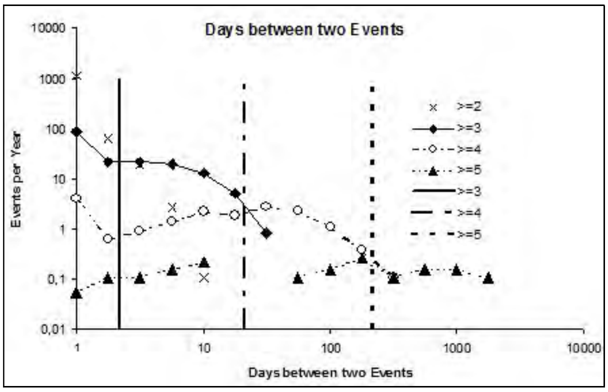
ED = Epicenter Distance
R = Radioactivity Intensity
M = Earthquake Magnitudo

About the relation between the 3D character images and earthquakes, we have to consider how the seismic warning signs in slightly seismic areas are better perceived than in other seismic areas.

We must value the number of Italian seismic events, their magnitudo and distance from the place of the experiments (Torre Pellice). So, I considered the analysis of the phisicist **Ulf Winkler** which concerns the period of time from January 01-1984 to December 31-2002.

In total, 22481 events with a magnitude of 2 or more occurred in Italy between 01-01-1984 and 12-31-2002, hence in 19 years. Events with a magnitude of 3 or more occurred 3206 times. Magnitude 4 was exceeded 333 times, and finally magnitude 5 occurred 33 times. The highest magnitude reached during the years under consideration was 5.9, reached on 5July-1984, in Abruzzo. Divided by 19 (the number of years) this yields 1184, 169, 18 and 1.7 events per year with a magnitude of at least 2, 3, 4 and 5 respectively, see table 4.
This equation holds for all magnitudes between 2.3 and at least 4.5.

TABLE 4: Ulf Winkler's table



The horizontal axis of Table 4 shows the day interval between two earthquakes in Italy with a magnitude of at least 2, 3, 4 and 5 respectively. The vertical axis shows the average interval which results from the average number of events per year (2, 20 and 217 days for events with magnitude of at least, 3, 4 and 5 respectively).

Events with at least magnitude 2 should occur at a rate of 3 a day (table 4). Torre Pellice lies rather far away from the seismically most active areas of Italy. The two major active zones are about 500 and 900-1050 km away. Still, every year about 10 events with a magnitude of 2 or above take place within 50 km from Torre Pellice.

However, in order to register 10 events per year with a magnitude of 3 or above, events within up to 300 km from Torre Pellice have to be considered.

To register 10 events of magnitude 4 or above, the range has to be extended to 800 km (note that only events occurring within Italian territory are considered here).

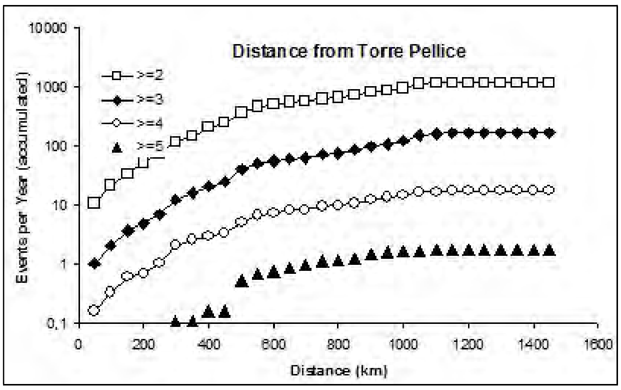
Events of magnitude 5 or above are on average only expected once or twice a year in whole Italy.

It is important for electric seismic discharges to evaluate the distance from the epicenter, so it is prudent to consider **only local earthquakes, not over a distance greater than 150 Km.**

Really, in spite of high values of radioactivity and of magnetic induction variation before earthquakes of magnitudo 4-5, far over 300 km, without a temperature ground increase and other local warning signs, I have not obteined images.

The table 5 shows the number of seismic events per year in Italy from 1984 to 2002 within a certain radius from Torre Pellice.

TABLE 5: Ulf Winkler: table from his manuscript sent to me.



So, about image formation during earthquakes, it is important to consider the synergy of numerous parameters.

I don't know why the two paraller gneiss layers are so indispensable to originate images. I can suppose that two paraller gneiss layers behave like a "maser" and that the iron material enhances magnetic variations.

I have often registered **infra-sound with 4-5 Hz of frequency for local earthquakes,** it is also necessary to know how **seismic infra-sounds** can influence image formation.

Two days before the first seismic shock of 10 September 2000, Torre Pellice Magnitudo 3.2, at 09.13 am, I have observed in a small area of Torre Pellice a sudden sun light decrease, due neither to astronomic phenomena, nor to sudden weather variations. The sun light was almost green, like before a sun eclipse. I registered an emission of infra-sounds, with 5 Hz of frequency.

2e) Reflexion About Similarities and Differences With the Turin Shroud Image

We can resume the following points.

Similarities with the Shroud:

1) the image looks, at first sight (this needs to be checked) an **oxidation of the fibrils** due to a probable electrostatic discharge, because I noticed variations of magnetic and electric field (Figures 2, 3, 8);

2) when the **imbibition is only with water** there is **no image fluorescence** (Figures 8a);

-at a first sight the images seem to have a **3D character** (Figure 1, 3, 8, 8a);

3) **when the imbibition is only with water, luminance values are constant**; in fact**,** we have some similarities with the Turin Shroud if we use a similar linen cloth, with water imbibition, but not with aloe and myrrh, that give different luminance values**.**

It is important to know how the 3D character images obtained appear at **infrared light**, with different frequencies, to compare if also these experimental images show a visible emission in the 8-14 micrometers infrared range, like the Turin Shoud. We know that on the Turin Shroud there is no Body Image in **a range of infrared light between 3 and 5 micrometers**. I must verify this for my experimental images.

In figures 8, the cotton cloth was soaked only with water, the gneiss superior layer was not insulated from the inferior one, the cotton cloth was put in an underground place two days before the earthquake of the 10 September 2000, Torre Pellice, magnitudo 3.2 and depth 12 Km. It is possible to notice a clear halo, around the key, on the inferior and interior surface.

The key image on the superior and interior surface shows a slight 3D character, with a feeble inclination, due to the cloth raising by the leaf near the key.

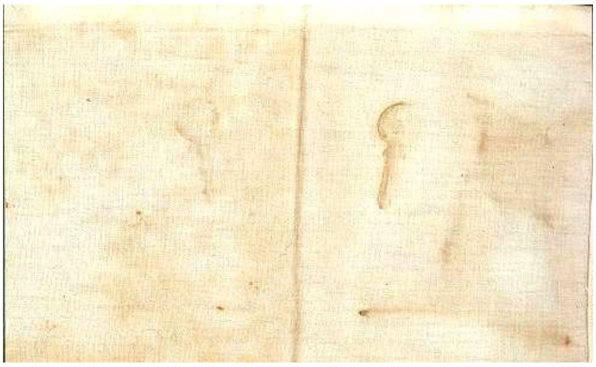


Figure 8 Internal surface (two days before the earthquake of 10-09-2000, Torre Pellice, of magnitudo 3.2 and depth 12 Km), water imbibition

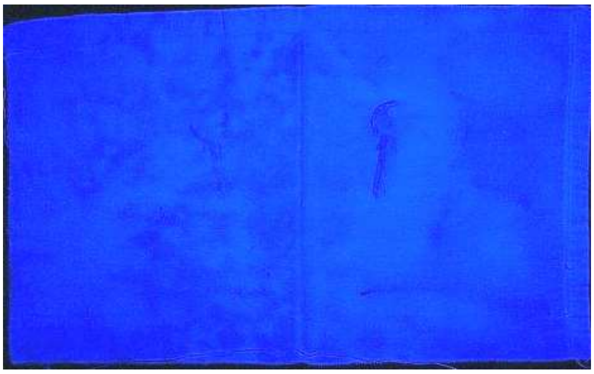


Figure 8a Internal surface, experiment of Fig. 8, UV light; key's image is not fluorescence.

- When the earthquakes have a magnitudo ≤ 2.5 and they are local (ED ≤ 50 km), we have an image only on the interior surface with more frequency;

Differences from the Shroud:

1) the **mechanic resistance** of the fibrils with grey images, (figure 1) as mentioned in the testing of Prof. Fanti, is not much lower than the ones without images, the other images were not analysed;

2) **with aloe and/or myrrh soaking there are different luminance values**;

3) when gneiss superior layer is not insulated from the inferior one, **the images are dark on the superior face** of the cloth, **white on the inferior face**, like negative images, maybe because of the shield effect; this occurs if the soaking is made **with aloe and/or myrrh**;

4) sometimes on the same cloth some objects give images only on the interior surface, other objects give images also on the exterior surface;

5) with a microscope (60×) under UV light, we can notice that the **darker area is in relation with the fibrils crossing**, while on the Shroud Image the area more oxidated is superficial. (see Figure 9);

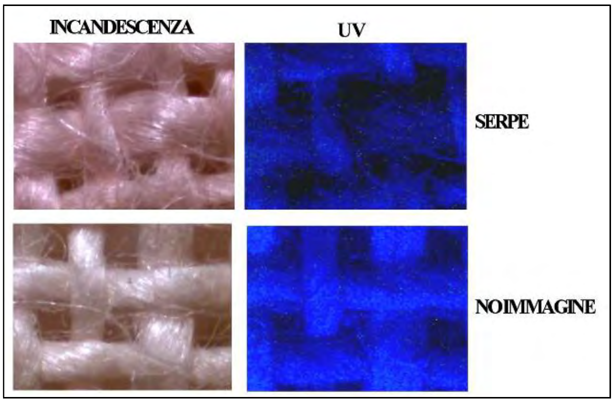


Figure 9 Oxidation kind of fibrills of figure 1.

In order to perform, using strict criteria, an evaluation of the features of the obtained images, weather or not similar to the Shroud, it would be convenient to perform some further quantitative and qualitative analysis, like for instance the evaluation of the colour intensity with a reflectance spectrometer, of the mechanical resistance with every kind of image, infrared and UV light answer, in order to clarify if the image formation is really due to electrostatic discharge.

CONCLUSION

Some images similar to the Shroud image were obtained only on ferromagnetic rocks, during seismic radon emission, with electrostatic discharges and geomagnetic variations, near iron material, with infra-sound emission. The lack of even one of these parameters does not allow to obtain images.

I am the first researcher that has naturally obtained, during seismic activity, images with 3D character and some similarities with the Turin Shroud. My work is in agreement with Lattarulo's theoretical hypothesis [11] and partially to Cordiglia's [10] and Fanti's [8, 9] hypotheses. About Fanti's hypothesis of "corona discharge" there is a different quantity level about electric discharges, not over 100 V/m for my experiments, but I have luckly observed earthquakes with magnitudo M ≤ 5 R.

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Scientific comparison between the Turin Shroud and the first handmade whole copy

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Abstract
Luigi Garlaschelli recently provided an interesting "Shroud-like" image. He used a variant of the well-known Nickell's rubbing technique on a sheet lying on the body of a volunteer and a bas relief for the face. For the first time a beautiful whole front and back image made by chemical discoloration of the cellulose was obtained.
After having explained the experiments, we examine the characteristics of the image at macroscopic level as well as at fabric, threads and fibers level to compare them with those of the Turin Shroud image. We conclude that most of the critical characteristics of the Turin Shroud image are very different from those of Garlaschelli's image. As a consequence, it is unlikely a forger may have produced the body image on the Turin Shroud by this technique. We conclude the image is still not reproducible.

Keywords: Turin Shroud image, life-size reproduction, Garlaschelli, rubbing.

1. INTRODUCTION

The double image on the Turin Shroud (TS) is very peculiar and its main characteristics are described in Refs. [1, 2, 3]. In the past, numerous attempts had been carried out in order to reproduce them but none were able to reproduce all these characteristics.

Some months ago, Luigi Garlaschelli (LG) provided a copy of a whole (front and back) TS-like image which was made by means that were available to a medieval forger. This image is undoubtedly one of the best never obtained until now. Moreover, according to LG, his full-size replica has all the properties of the TS image, i.e., it is pseudo-negative, fuzzy, with half-tones, resides on the topmost fibers of the cloth, has some 3D properties and does not fluoresce.

More recently, LG published his experiments and results in a scientific journal [4].

Following a previous work [5], the aim of the present paper is to present LG experiments and results, to provide a detailed comparison with the TS image and its properties and discuss the LG image formation hypothesis on the basis of our observations.

2. GARLASCHELLI'S EXPERIMENTS

2-1) Garlaschelli's hypothesis.

After a comprehensive discussion of the main features of the TS image as well as the many attempts to reproduce it, LG assumes the following for his own image formation hypothesis.

Today, the image is mainly formed by dehydrated cellulose with no or few proteins (from some binder, if any) and only traces of sub-micron iron oxide particulates (from the pigment) [6].

The chemical alteration of the cellulose of the linen might therefore come from long-time interaction with some component of the pigments (or the binder).

With time, the pigment (and the possible binder) might have worn off, leaving only the chemical alteration of the cellulose coming from the still unknown component ("sensitizer") associated to the now lost pigment.

Regarding the practical mean by which a medieval forger could have made the TS image, LG found that the only possibility was very likely to use a direct contact transfer mechanism very similar to the well-known Nickell's technique: the artist might have molded a linen sheet over a bas-relief and/or a real human body and used a dauber to apply the pigment to the surface of the linen [7]. It is the only way to obtain a realistic human form without distortion. Moreover, the bas-relief rubbing technique automatically produces a pseudo-negative image with some 3D properties.

2-2) Master plan of Garlaschelli's experiments.

According to [4], after some preliminary works, LG used the following settings for his experiments:
He used a cloth matching as closely as possible the TS (herringbone 3:1 linen with the same dimensions and thickness than those of the TS).
In the first step, the cloth was slightly tended over a

naked male volunteer lying on a table and was clamped at its four corners. The pigment was gently rubbed only over the more prominent features and the image was completed free-hand on the flat cloth after removing it from the volunteer's body.

The same procedure was used for the back (dorsal) image.

For the face, a suitable bas-relief was used in the same way instead of the real face of the volunteer in order to avoid obvious large distortions.

Finally, the "blood" stains and rivulets as well as the scourge marks and "scratches" were made with a small brush with a diluted suspension of red ochre, cinnabar and alizarin in water. Scorched spots and water stains were imitated for the sake of visual imitation.

2-3) First experiment: "red ochre only/dry powder".

In this first step, LG used a red ochre pigment in his "real body/bas-relief head" approach described above, but only for the front image. (see Figs.1 and 2).

Figure 1. "Red ochre only" LG experiment (positive).

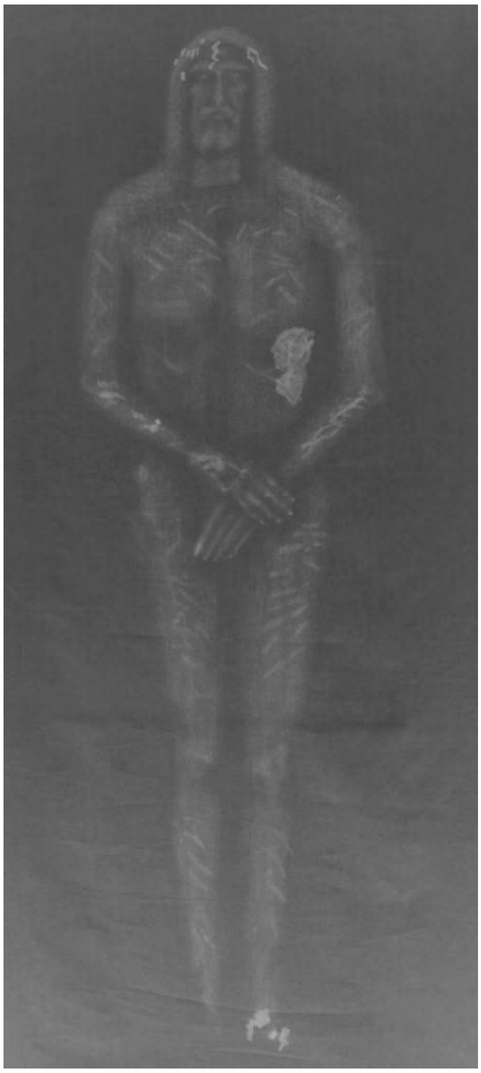

Figure 2. "Red ochre only" LG experiment (negative).

LG wrote [8]: "*Of course, the results do not look like the actual Shroud of Turin: rather, they look the way the Shroud must have looked shortly after it was made. The image is much more visible, the pigment is still there and there are no water stains and burn marks*".

LG found that the only way to obtain a "fuzzy image" more or less similar to the TS image was to use a dry powder rather than a liquid:
"*it is nearly impossible, when "painting"with slurry, to obtain the soft tones and the shading effect which are generated almost automatically when rubbing with a dry powder. Also, it is very difficult to spread a thin, even layer of slurry over large areas like the chest*".

Following LG complete hypothesis, the TS man was actually "painted" using this way (the only mean to obtain a rather fuzzy image like that of the TS).

Because, according to LG, natural red ochre is necessarily contaminated by traces of acidic materials (like humic acids, organic impurities, various salts…), this foreign "reacting" material might be responsible for the degradation of cellulose. Meanwhile the pigment itself fell down with time.

In order to test this hypothesis, LG had to find some kind of solid non-neutral "sensitizer" which, once rubbed onto the cloth and artificially aged, could slightly discolor the cellulose. After testing dozen of salts and solid acids, either mixed with a pigment or even pure, "*none of them*" left any trace on the linen after heating and final washing.

LG recognizes that it is "*a major drawback in this kind of reproduction attempt*".

Because the presence of water "*seems to be*" necessary for the chemical sensitizer to come in contact with the fibers, LG performed then another experiment described below.

2-4) Second experiment: "acidic pigment/slurry".

LG prepared a highly diluted (about 1%) solution of H_2SO_4 in water mixed with a neutral blue pigment (cobalt blue).

The color of the pigment was chosen so that after washing it was possible to be sure that all the pigment had been eliminated and that the color came only from the discoloration of the linen by the acid.

Rubbing was performed as described above and the linen was heated in air (3 hours at 215°C) for artificial ageing and then washed.

Bloodstains, scourge marks were added as previously described and a pen-sized butane blowtorch was used to mimic the burn marks.

The results are shown in the Figures 3 to 7 (all LG figures are slightly contrast enhanced).

According with LG, the resulting image is superficial (there is no image on the back of the cloth), does not fluoresce under UV at 366 nm. (while the background is slightly fluorescent) and

"*the negative image also shows the required shading and half-tone effect*". Some 3D properties are also embedded in the image and at 50x magnification, "the *image was made up of several discolored spots on the top fibers*".

In his conclusion, LG wrote:

"*The experiments presented here can doubtless be improved. No accelerated aging technique will ever be completely equivalent to the natural process (...). In particular, a better way should be devised to put slurry on the cloth, or a solid "sensitizer" should be found*".

Consequently, the following discussion will compare LG results with the critical properties of the TS image, also taking into account the possibility of an improvement of the technique.

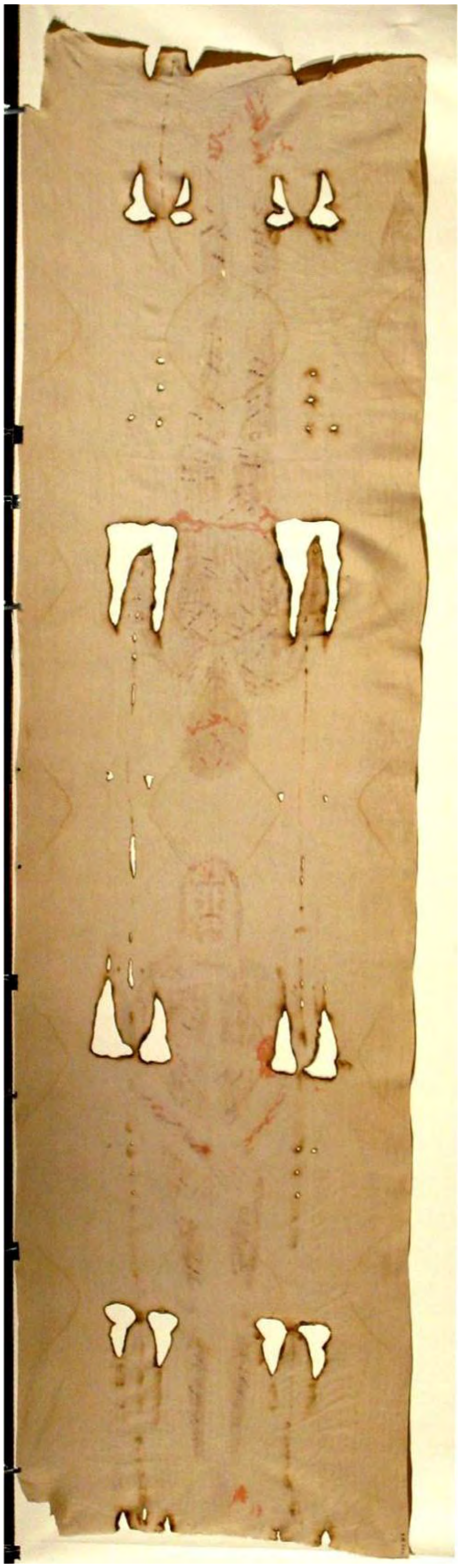

Figure 3. LG complete pseudo-shroud.

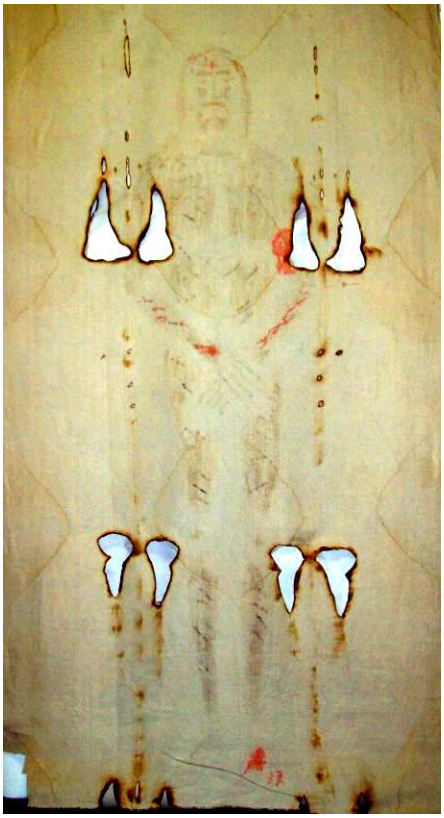

Figure 4. LG image. Front (positive).

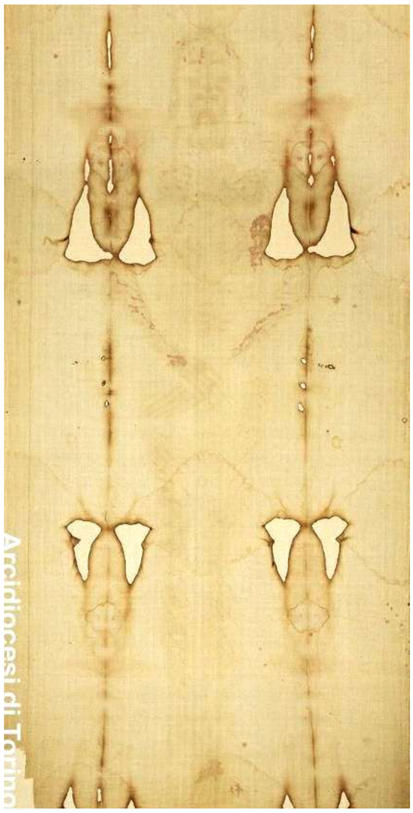

Figure 6. Turin Shroud. Front (positive).

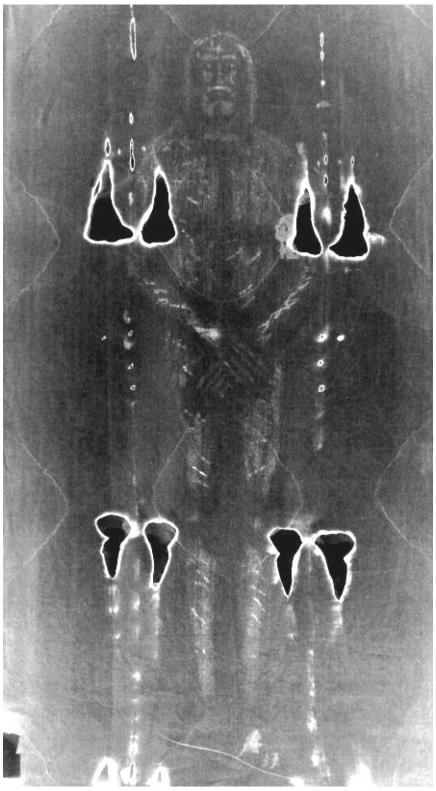

Figure 5. LG image. Front (negative).

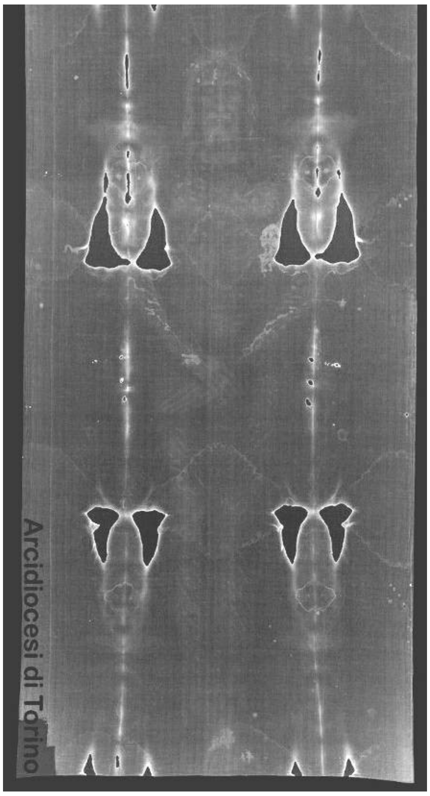

Figure 7. Turin Shroud. Front (negative).

3. DISCUSSION

3-1) LG first experiment (ochre only/dry powder).

The first experiment (ochre dry powder only) has a major advantage over the second one: according to LG himself, it is the only practical way to obtain a fuzzy image (Fig.8) even if the fuzziness of the TS image is difficult to be reached [9] especially for smaller human parts like the fingers. The detailed observation of this first LG image shows that it has no sharp contour but a gradation quite similar, even if different, to that of the TS.

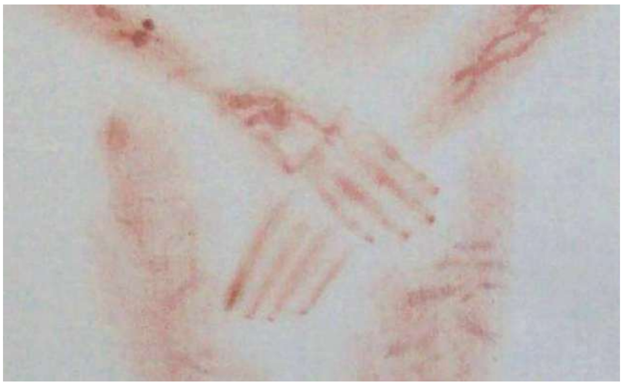

Figure 8. Detail (slightly contrast enhanced) of LG first experiment.

However it is very unlikely that a medieval forger could use any kind of dry powder. Without some kind of binder, most of the powder would have fallen down quickly [10]. As the TS was rolled and folded many time, we would also observe some colored spots out of the image area, and some less colored areas in the image. None of these features are seen on the TS.

At thread level, the powder on the topmost fibers would have been lost almost immediately, while the powder in the interstices could remain in place for a long time allowing the development of the color only or mainly in the interstices according to the alleged mechanism. This is not observed on the TS.

At fiber level (microscopy), the color could only appear as tiny spots (of the order of one micrometer) where the "sensitizer" associated to the pigment particulates could have been in close contact with the fiber. To the contrary, the color on the TS is made of a very thin *continuous* layer, uniformly distributed all around the fibers. LG did not provide any microscopy view but similar experiments [11] made in the same way (dry powder pigments) are available, allowing a reliable comparison (Fig. 9).

Most importantly is the fact that LG could not obtain any image, after heating the cloth, with many salts or solid acids. According to LG himself, the reason is that the presence of "*water seems to be necessary (...)*".

Figure 9. Comparison of the color distribution at fiber level. Top: colored fiber of the TS (STURP sample 1-EB), G. Fanti. Bottom: dry pigment distribution on a linen fiber, [11].

Since the salts and acids tested by LG are known to discolor the cellulose only as liquid solutions, we conclude that the same chemicals in the form of solid powder could not have been used to produce the TS image. It is very unlikely that any, even unknown, 'sensitizer" in powder could produce a TS-like image.

3-2) LG second experiment (acidic pigment solution).

LG image has no fuzzy contours and is not continuous.

According to LG, "*the image is not as fuzzy as the one generated previously by rubbing with a dry powder, but it is still acceptable*".

Figure 10 shows to the contrary that the image is not continuous and has no fuzzy contour at all. Clearly, painting with a semi-fluid paste ("Slurry"), even with hand-free finishing, does not allow producing an image with fuzzy contours. The image/non image spatial variation (image resolution) in LG experiment is less than 1 mm while it is 4.9 mm for the TS [12]. In addition LG image is composed of more or less colored spots ranging from 0.1 to 1 mm in size (Fig.14) while the TS image is continuous. One might think that a better result could be achieved using another pigment-to-solution ratio but LG made many attempts and this one apparently gives the best result. It is also worth noting that most of the slurries previously prepared with many salts or acids at various concentrations did not work because "*in every case, when a discoloration was obtained, it was visible also on the backside of the cloth and (…) tented to spread homogeneously over the threads*".

In other words, an artist would have found *by chance* the mixture: why, for example, would it be important for him to avoid an image on the backside?

From our point of view, the result cannot be considered as "acceptable" and the reason is the technique itself.

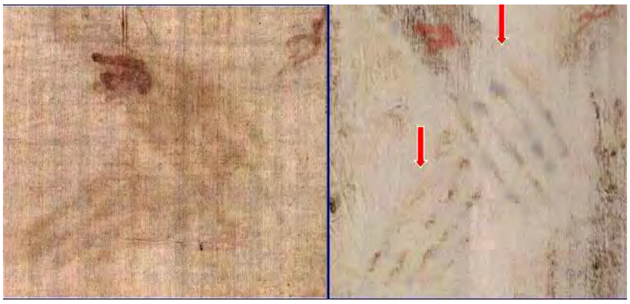

Figure 10. Close-up of the LG image (right) showing that it has no fuzzy border and is not continuous contrary to the TS image (left).

LG image is a "contact image". The TS image is not.

By "contact image", we mean "contact-only image", i.e., an image for which the color formed only in areas where the sheet was in contact with the 3D model (body, bas-relief…). Even if LG finished the image free-hand, his technique can be defined as producing a "contact image". To the contrary, the TS image is not a "contact-only" image and the differences are shown below (see Fig.11).

First, the LG image shows large colorless areas where no contact occurred, while the TS shows the image color also in the corresponding non-contact areas. This is particularly true for the inner part of the legs (compare Fig.4 to 6 above) and for the face (see Fig.11).

Figure 11. Many non-contact areas are colored on the TS image (right) and not on LG image (left).

In theory, it would be possible for an artist to try to paint the non contact areas free-hand but apparently LG did not try (or failed), probably because it is not easy to paint such a fading.

Another related problem occurring with any frottage technique is the control of the saturation. As LG wrote: "*If he (the artist) wanted to represent a body print on a cloth, the protruding parts were obviously supposed to leave darker traces, and the receding ones lighter or no traces*". If the artist adds to many colored material on protruding parts and/or not enough on receding parts, the percentage of pixels with extreme luminance values (ELV) ("black pixels" with luminance <5 and "white pixels" with luminance >250, gray-scale) will be high. This work has been done on two images of "shroud-like" faces: J.Nickell's who used a frottage technique similar to LG's and V. Pesce Delfino's who used a heated metal bas-relief. While the TS face has ELV of 23%, Nickell's image has ELV of 60% and Delfino's image of 41% (uncertainty of ± 5% in all three cases) [9].

The differences between TS and LG images are even more obvious at higher magnification (Figures 12, 13 and 14). TS image is continuous without any spot while LG image is made of non-continuous sharp spots with large differences in luminance values.

Figure 12. Face of LG second experiment.

Figure 13. Close-up of the TS face (contrast enhanced).

Figure14. LG face: close-up of the same area as in Fig.13.

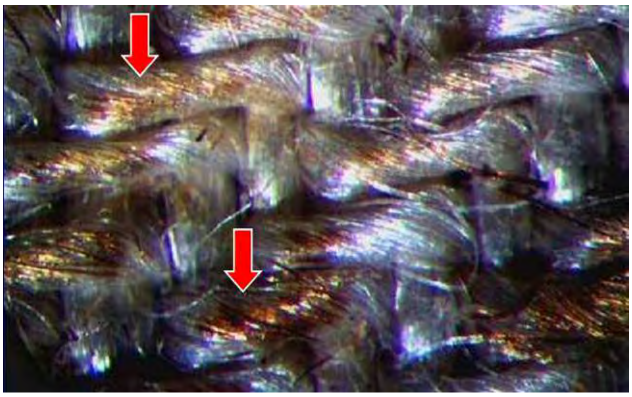

Figure 15. LG image showing the characteristics of the color at thread level (arrows indicate areas with very different hues).

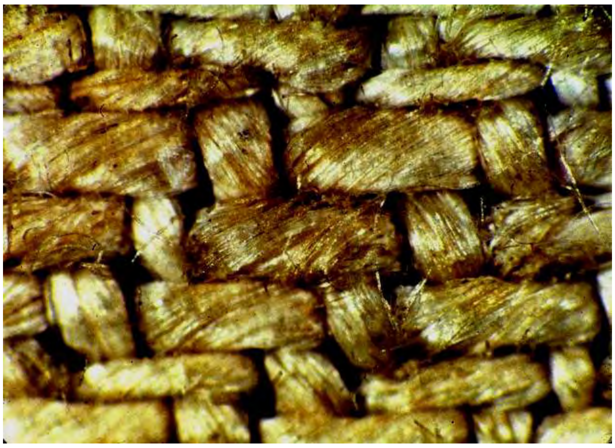

Figure 16. TS image (M. Evans) - Foot area. Contrast enhanced.

TS and LG image color distributions are very different at thread and fiber levels. The differences are obvious:

- Distribution: in LG image, the color is *only* on the most protruding parts of the surface of the threads forming more or less discrete spots. On the TS, the color often covers the main part of the surface of the exposed thread (no spot) and shows a clear tendency to follow the direction of the fiber, sometime continuing on the adjacent thread (striation).

- Half-tone. This term is often used to summarize the fact that the hue of the TS image color is about the same everywhere and that shading is only explained by the different number of colored fibers per area unit. As seen in Fig.15, the hue and the saturation of the color are very different from a given thread to another. LG image has *no* half-tones.

Figure 17. Rust contact imprint on the TS.

Figure 17 shows traces of rust found on the TS in 1978 by STURP resulting from a previous contact with a thumbtack. The pattern is very similar to that of the LG image and very different from the TS image color distribution.

At higher magnification, the difference is even more obvious, see Figures 18 and 19.

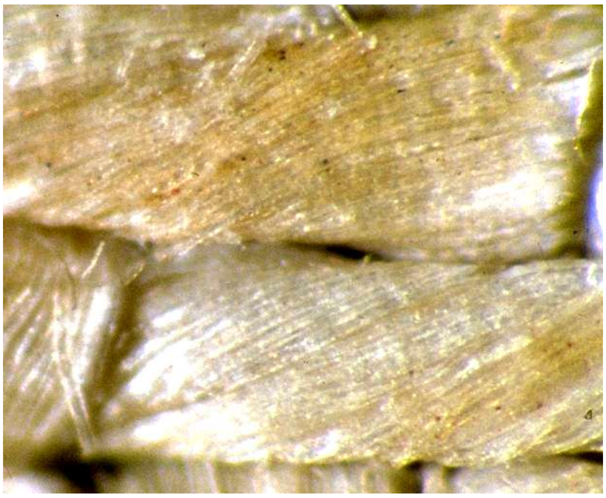

Figure 18. Typical TS image color distribution (high magnification).

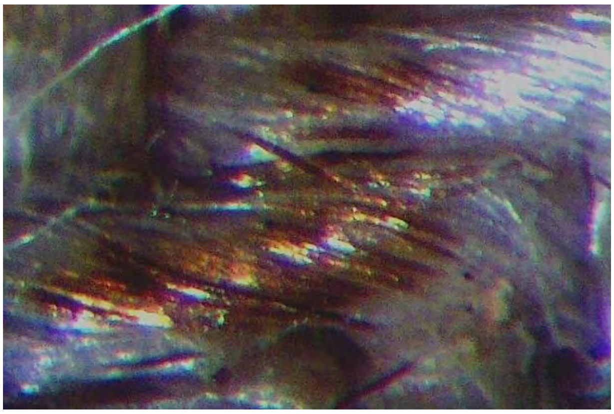

Figure 19. Typical LG image color distribution (high magnification).

At fiber level, experiments similar to this LG second hypothesis show that the color is not uniformly distributed or is only on one side of the fiber's surface (see Fig.20). Instead, on the TS it is both uniform and all circumferentially around the colored fibers [13].

3D properties.

Keith Propp used a software emulating the famous VP-8 to compare the 3D properties of the TS and LG images (see Figures 21 and 22). It must be noticed that both images were analyzed side by side with exactly the same settings. In addition, Keith Propp did not use the best TS image available.

LG image shows some 3D properties, which is not surprising. However, the differences are obvious: LG 3D image is mainly made of flat "plateau" (contact) and "valleys" (no contact) with abrupt "vertical cliffs" between them. Instead, the TS 3D image has fine variations of the "altitude". Of course, this fact results from the technique used by LG and its limits.

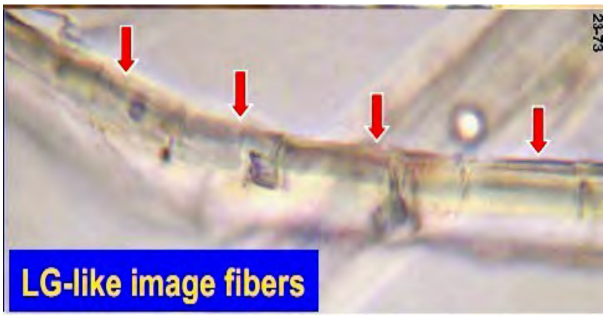

Figure 20. The color is only found on one side of the surface (arrows) in experiments similar to LG second hypothesis.

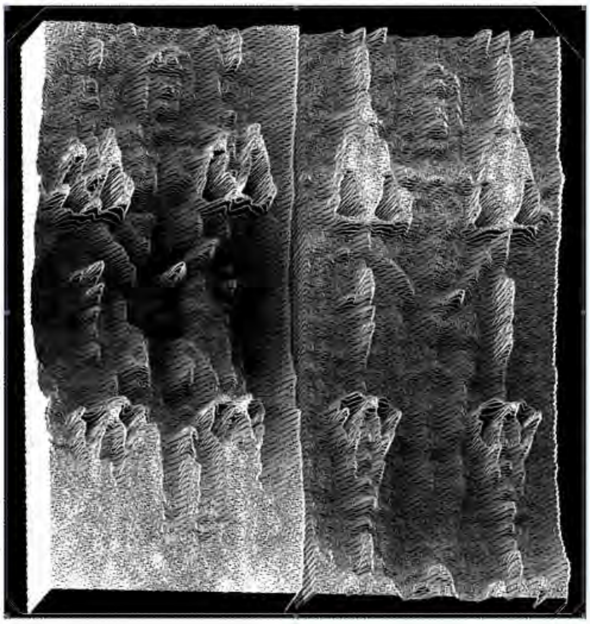

Figure 21. 3-D comparison of the whole front image (left: LG, right: TS), © K.Propp.

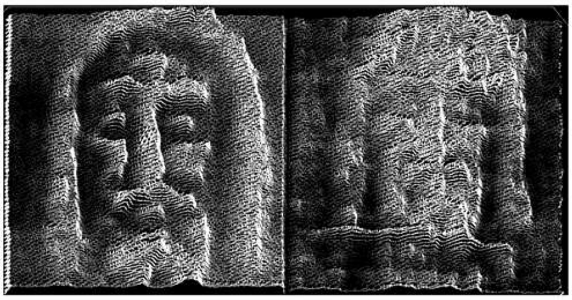

Figure 22. 3-D comparison of the faces (left: LG, right: TS). © K.Propp.

Particularly, the 3D properties of the TS image emphasize its continuity, its extraordinary fine variations of the "altitude" and the immediate perception of a real body. None of these properties are found in LG 3D images.

4. CONCLUSION

LG experiments are based on a well-known "frottage" technique. The main difference with previous similar works reside in the fact that the whole (front and back) TS image is reproduced.

His first experiment with dry powder provides an image with fuzzy borders more or less similar to those of the TS. We have shown however that for several reasons, dry powder could not have been used by a medieval forger and that the distribution of the color at fiber level is very different from that of the TS.

Most important, LG himself has shown that no image at all could be obtained, after artificial ageing, by any kind of sensitizing substance in solid state, while it is known that the same acidic substances as liquids easily discolor the cellulose. This alone seems sufficient to eliminate this "dry powder" hypothesis.

The second experiment (rubbing with acidic pigments in the form of "slurry"), after many attempts, provides an image which has some of the properties of the TS image: it comes from the chemical discoloration of the cellulose, is pseudo-negative, superficial (no image on the back side), has some 3D properties and does not fluoresce when illuminated by ultraviolet light [4].

A careful examination of the LG images shows that many other *fundamental* properties of the TS image are not verified:

The LG image has no fuzzy borders, is not continuous (discrete dark spots), has no image in non-contact areas even if LG finished its image free-hand on the flat sheet and consequently its bad 3D properties are far from the extraordinary precise and realistic 3D front and back body images of the TS.

It is *in theory* possible, for a medieval genius using some kind of frottage technique to make an image having the above properties but, *in practice*, it is very unlikely since all of the many attempts (including LG's) failed up to now.

Most importantly, we have demonstrated that at thread and fiber levels, all the properties of LG image are very different from the strongly amazing and *critical* properties of the TS image color distribution.

At least at the thread and fiber levels, it seems difficult to imagine any improvement of the technique able to produce a color distribution similar to that of the TS image.

Finally, the question of the blood, not considered by LG, remains one of the strongest arguments against his hypothesis as well as any theory involving a human production for the TS image.

Incidentally, from LG himself (personal email to the first author), there is, as expected, no fluorescent halo around his "blood stains" made of pigments, contrary to the serum haloes on the TS.

We know that there is no image under the blood stains [14]. The critical question still remains: how and why a forger would have "painted" the blood this way, i.e. before the image?

We therefore conclude that the TS image was certainly not produced by the technique proposed by LG or, very likely, by any kind of similar rubbing technique, because the technique itself seems unable to produce an image having the most critical TS image characteristics. The TS image still remains not reproducible and not explainable.

ACKNOWLEDGMENTS

The first author is very grateful to Luigi Garlaschelli, who kindly discussed via emails and furnished the microphotography shown in Fig.15. The second author thanks Luigi Garlaschelli for the CD of images given and because he kindly allowed the author to make photographs directly from his experiments, showed for the first time during the XI National Meeting of CICAP Abano (PD, Italy), October 2009. The authors also thank Keith Propp for his authorization of using his beautiful 3D images of Figures 21 and 22.

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IMAGE PROCESSING

Sight and brain: an introduction to the visually misleading images

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Abstract
The visual perception of the reality is a complex process involving eyes and brain. The result of this process is an individual response to the external stimulus which, in some cases, can differ person-to-person and, most important, can give a false representation of the reality. In this paper we discuss some aspects of the visual perception, focusing our attention to shapes and colors recognition. We also present a brief introduction to the physiology of the vision and a discussion about the potentially misleading use of the modern techniques for elaborating images. The link between the visual perception and the acheiropoietos images is commented.

Keywords: visual perception, optical illusions, image processing, pareidolia

1. INTRODUCTION

The visual perception is a very complex process which mainly involves the eye and the brain. The former behaves as an electronic device that collects the data while the latter elaborates the information.

The result of this process is what we call "perception" and it is a subjective sensation, which can be different person-to-person.

Sometimes, the aspect of many images can be modified by our brain, depending on many reasons linked to the internal mechanisms of our mind. The state of mind, the past experience, the particular context in which the object is inserted act as a filter that transforms the objective image in a personal sensation.

In this paper, starting from a brief introduction on the basics of the human vision, we demonstrate how much is easy to be deceived by our senses thus achieving a wrong or, at least, a debatable conclusion.

2. THE HUMAN VISION

The eye is the main organ of sight. It takes light from an external subject and sends electrical pulse to the brain [1].

The human eye is an excellent detector, and in spite of the impressive development of the electronic technology, it is still largely better than the most advanced CCD cameras available today [2].

The active region of the eye is the retina, a membrane that lies on its back and where the crystalline lens let the light rays converge to form an image. Unlike electronic devices, where there are three detectors per pixel (one for each primary color), on the retina there are two distinct detectors, namely the cones and the rods.

The cones are sensitive to the colors and they are subdivided into three categories (red-, green- and blue-sensitive) similarly to the electronic pixel. On the contrary, the rods are sensitive only to the luminance and they are particularly active to low levels of light. So, the cones are responsible for the day-light vision (and they distinguish colors), while the rods are responsible for the vision in the darkness (and they distinguish shapes).

Figure 1 shows the section of a human eye and an electron microscope image of the retina, where cones and rods are well visible.

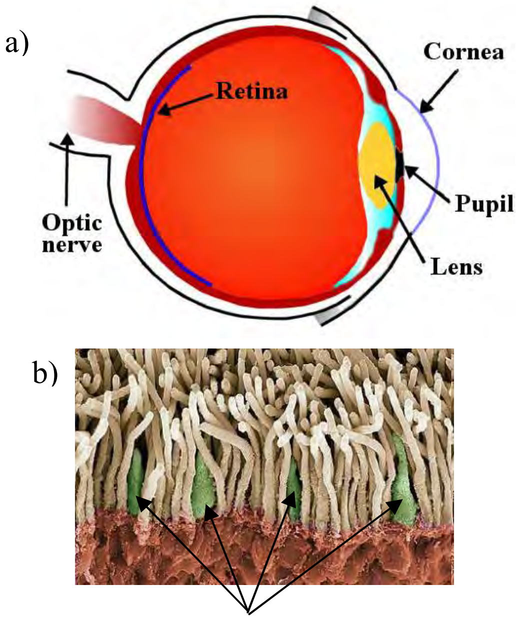

Figure 1. a) Schematic of the section of the human eye.
b) A scanning microscope photo of the retina, where the rods (thin and long) and the cones (thicker and shorter, marked by arrows) are visible.

The cones are concentrated in the central region and their number is about 5-6 millions, while the rods are distributed around the peripheral region and their number is greater than 100 millions.

A so large number of micro-detectors and the mechanical movement of the iris allow us to adapt our vision within a very broad range of light levels. The "*dynamic contrast*", that is the ability to distinguish different luminosity levels, is of the order of some millions to one. As a consequence, we are able to recognize the objects in a dark room illuminated by a single candle (an illumination level of about 0.001 lux) and we can perfectly see in a sunshine day (up to 100,000 lux).

On the contrary, when the light level is fixed, our ability decreases down to a few hundreds to one. In this case we speak of "*static contrast*" and in Section 4 we will discuss the consequences of the limited static contrast.

Despite the eye is an almost perfect detecting system, and the information sent to the brain are the result of a physical-chemical process, the data given by the eyes and elaborated by the brain do not always correspond to the object seen.

In particular, both the shape and the colors of an object are elaborated by the brain, filtered by the experience, and the integral outcome of this process, that is the perception, may give a misleading result.

3. THE PERCEPTION OF SHAPES AND COLORS

There are several sources of errors that can lead to a wrong perception of the shapes. Some of these errors are unexplainable, and they are probably due to a wrong mechanism of the image elaboration caused by the elements surrounding the subject. Figure 2 shows two examples of wrong perception of the reality.

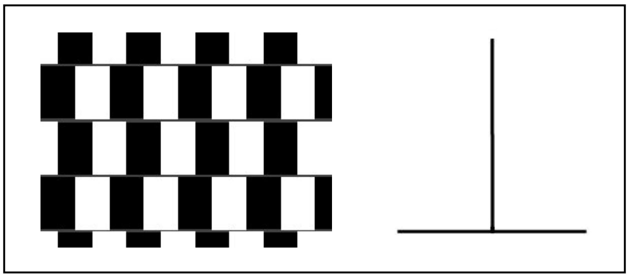

Figure 2. On the left a typical optical illusion: the horizontal lines are parallel, but we have the impression. that they are converging and diverging. On the right the horizontal and the vertical lines have the same length, but we perceive that the vertical line is much longer than the horizontal one.

The experience is another element that influences the perception. A typical situation happens when we are in front of a paint with a strong perspective effect: we are able to describe the bi-dimensional scene as if it was in three dimensions because we are familiar with the concept of perspective. So, we understand that e.g., some people are short because they lie at a larger distance from the observer than the tall ones. But if children or aboriginals (who are unaware of the perspective rules) examine the same image they would reach a different conclusion: in their view, short people are just short people, not more distant persons [3].

Figure 3 shows an example of the strong impact of experience on to the "reconstruction" of a scene with some missing parts. What do you see in fig. 3?

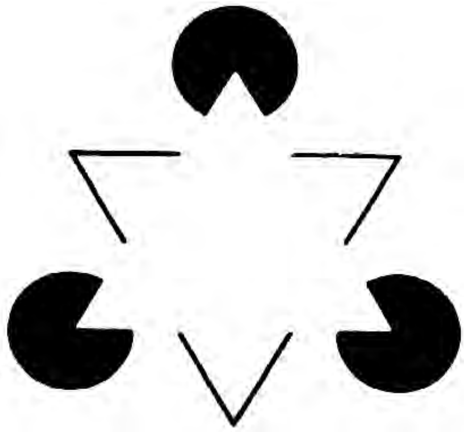

Figure 3. This drawing demonstrates the principles of the Gestalt theory. We see this picture as an ensemble of geometrical figures (circles and triangles), reconstructing the contours of some shapes, in particular of the (not existing) white triangle.

Probably your answer could be: "A white triangle above the black contour of another white triangle, and three black circles". It would be unlikely someone giving the correct description, that is a set of three circles with a missing portion and three couples of segments!

This happens because the presence of a boundary is not essential for the perception of the shape. So, our brain chooses the "best" interpretation of the data coming from the eyes, following one of the principles of the Gestalt theory [4]. According to this theory, the visual perception is not a simple sum of the elements seen by the subject, but it is the result of the relations among the detected objects.

Not only the shape may be perceived in a wrong (or subjective) way: also colors reveal an impressive limit of our eye-brain system. What we see as a definite color, in fact, is the consequence of the comparison between the observed object and its frame. Figure 4 shows two identical gray-level objects that appear different just because they are surrounded by different contexts.

So far we tried to demonstrate that we may have a wrong perception of the reality, but the error sources are independent of our will, and what is more important, the response of our eye-brain system to an image is almost the same for all the humans having similar experiences. When this happens we normally consider it is an optical illusion. In other cases, the interpretation of an image becomes more subjective and the next section describes how the modern computing techniques can introduce misleading elements.

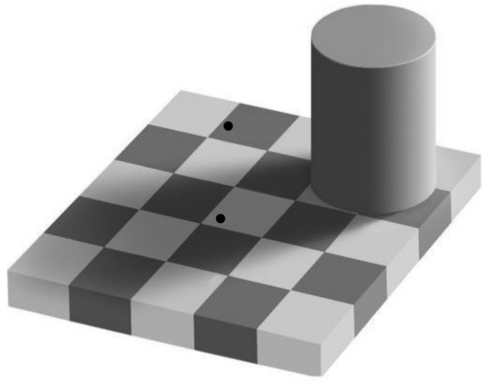

Figure 4. An incredible misleading interpretation concerning colors. It is hard to admit the two squares marked by the black dots have the same gray level. To convince us it is necessary to cover all the surrounding picture and to observe only the marked squares, using, e.g., a screen with two holes.

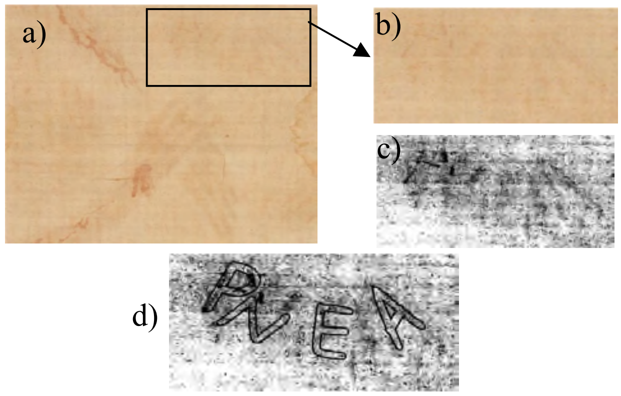

Figure 5. A trial to let appear a writing on the Shroud that does not exist. Although the photo does not seem to hide anything, by using a image processing software it is possible to make visible some letters.
a) Original photo of a particular of the Turin Shroud.
b) Detail of a)
c) What happens after applying some software filters.
d) The "interpretation" of the hidden written.

4. IMAGE PROCESSING TECHNIQUES AND ACHEIROPOIETOS IMAGES

As discussed in section 2, the human eye has a very high dynamic contrast, but a limited static contrast. This means that, at a fixed light level, we can distinguish differences in terms of brightness only in a range of about 1 to 100. An image seen on the computer monitor may hide many details that we can see only if we adjust the brightness/contrast level. In this case, it is hard to establish if the original image has or has not embedded the information that we can reveal only by manipulating it. Probably this is a philosophical doubt rather a scientific argument but, in the case of acheiropoietos images, the possibility to disclose some hidden signs may have crucial consequences.

Also the use of other software skills, as, for example, the boundary detection or the texture removal, may lead to a moot point.

The examples shown in figures 5a-5d may help to understand that it is relatively easy to achieve a result which is completely alien to the original image.

Figure 5a shows the photo of hands detail of the Turin Shroud framed with very high resolution by the STURP photographer B. Schwortz. At a first glance we cannot see any trace of particular importance, except for the hands image and the blood stains. Figure 5b is a zoomed region of fig. 5a where, again, only some darker details can be noticed. By adjusting the brightness/contrast setting and using some processing filters, some signs come out from the background. The last (and the potentially most dangerous) operation is the interpretation of these signs. Figure 5d represents the (personal) reconstruction of the hidden writing. Obviously, this writing has no meaning, but it demonstrates that the results of image processing techniques should be very carefully weighed up.

The "ability" to recognize particular writing or familiar shapes can be referred to a phenomenon called "pareidolia" [5]. A common example is represented by clouds shapes reminding animals, objects, or faces. Generally, we are able to distinguish between a genuine image and what is arising from an subjective sensation. But as in the case of some optical illusions, the state of mind may induce a sort of "I think, I see".

Figure 6 is a surprising example of this phenomenon [6]. The old photograph represents a family with a man, a woman and a child. But, at a first glance, the profile of a human face is well visible, similar to the Jesus profile depicted according to the classical iconography. In order to agree that this is a false interpretation, or better, it is a pareidolia effect, it is necessary to recognize that what we believe is a face profile, in reality is a child with a white hat sitting on the knees of the man.

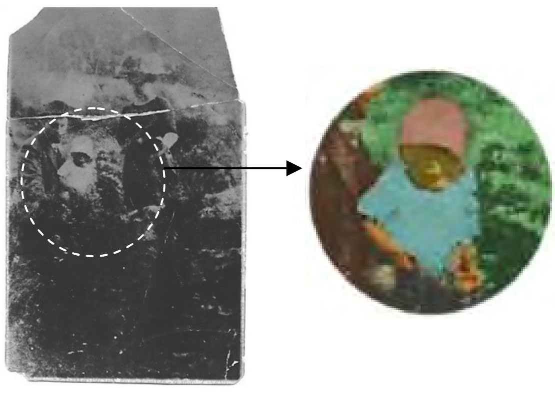

Figure 6. An example of pareidolia. On the left: the original photo, where the profile of Jesus seems to appear. On the right: the detail of the photo (artificially colored) where a child with a white hat can be recognized.

Of course, this is only a remarkable pareidolia example, but it may help to be aware that, although the information given by our eyes are objectively right, the elaboration made by our brain may lead to a wrong result. Our mind tends to see what it expects and/or wants to see.

Clearly, when the pareidolia phenomenon regards a cloud whose shape is similar to a horse, we are aware that it is only a figment of our imagination. But when we are looking to an image like that in fig. 6, probably we are not sure that it is just an interpretation mistake and not the result of a paranormal mystery [6].

The figures 2 to 6 discussed above are just few selected examples of optical illusions and pareidolia. Interested readers should know that Internet is an amazing reference to find optical illusions [7] and pareidolia images [8].

5. CONCLUSION

When observing an object, we trigger a complex process involving our eyes-brain system. The result of this process is what we call "perception". The perception is individual, and in some cases, it is highly subjective. Even when the answer to a stimulus is the same for almost all people, we cannot be sure that our perception is correct, like in the cases shown in figures 2, 3, 4 and 6.

Moreover, it is likely the perception process can be strongly influenced when external events, past experiences or personal beliefs are linked to the phenomenon we are observing. Our mind tries to make sense out of any "patterns" our eye can see, see fig. 5.

We should consider this "subjectivity risk" when using computer tools to elaborate images, because we may generally have the propensity to make visible something that we want to see but that is not embedded in the original image.

Concerning the scientific approach to the acheiropoietos images, only reproducible experiments are scientifically acceptable.

Interpretations of shapes, coins, faces, flowers or letters "seen" on acheiropoietos images by means of image processing tools should be considered a track useful to address further studies, but they cannot be considered as self-consistent proofs.

ACKNOWLEDGMENT

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PHOTO CREDIT

Figures 5a and 5b: Barrie Schwortz.

Construction of a quantitative image of Turin Shroud for details recognition

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Abstract
In 1978 measurement of x, y, z CIE color values were made for the first time on many small areas of the Turin Shroud; also quantitative photographs were made in 1978 on features but up to now no quantitative image of the whole Shroud is available. For this reason after the conversion of color space and the correction of single color channels, basing on a photograph of G. Durante realized in 2002, a quantitative photograph of the whole Shroud was obtained. The measurement of colors on this quantitative image, that has an uncertain of 4%, with a reference database, allow to recognize and distinguish various interesting TS features.

Keyword: quantitative image, characteristics recognition, color measurement, Turin Shroud.

1. INTRODUCTION

Even if many different studies on the TS (Turin Shroud) have been performed [1], up to now it was not available a quantitative photograph of the whole TS to which made reference in color measurements or in the analysis of small characteristics like the differentiation of different types of human blood.

In 1978, measurements of x, y, z CIE color values were made for the first time on small areas of the Turin Shroud [2]. Also quantitative photographs were made in 1978 by D. Devan & V. Miller [3] on parts of the TS. For this reason, starting from the photograph of G. Durante realized in 2002, a quantitative photograph of the whole Shroud was obtained after a proper calibration of the RGB values using colorimetric data of selected small areas of the TS. The used procedure was calibrated in order not to exceed an uncertainty of 4%.

2. METHOD

This study is primarily oriented to construct a quantitative image of the TS starting from a photo realized in 2002 by G. Durante using a Fuji Provia 100 ASA film, printed and successively digitalized by a scanner.

Color information of the digital photo, was converted [4, 5, 6] from sRGB color space into XYZ CIE color space to build the quantitative image. That transformation was operated because the data reported in Ref [2] were expressed in CIE XYZ color space coordinates. The obtained x, y, z chromatic coordinates were used for comparison with colorimetric data [2], acquired in 1978 on the TS by a colorimeter and CIE XYZ color space was also used for a database construction. Many measurement points were acquired on the TS, but only 18, were selected for calibration.

To perform the color measurement, histogram function of a common photographic software, see Figure 1, was used to have the 3-channel average of an image area.

After correction and calibration of the TS photograph a color measurement was performed in order to build a x,y,z CIE database of the main TS characteristics like cloth, blood, image, water spot and burnings.

A total of 1188 measurements in different spots of the TS image were performed and the color relationships x/z and x/y were reported in a plot, useful for measurement comparison of unknown or not clear characteristics.

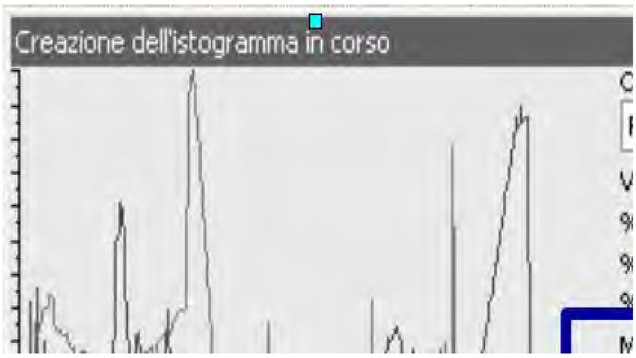

Figure 1. Histogram function of Jash Paint Shop Pro© software used to determine the average values of the region of interest.

3. CALIBRATION PROCESS

The image calibration phases are reported in the following steps:

1. Acquisition of RGB values from photographic image

(2002 G. Durante).
2. Conversion of color space from sRGB to XYZ CIE and to xyz and conversion of the illuminant D55 to A.
3. Comparison of digital measurements with colorimetric data [2] to determine the calibration function.
4. Correction of colorimetric xyz coordinates
5. Application of the correction to the TS photo of Step 1.

Correction operation can be summarized by the scheme shown in Figure 2.

The measurements were performed by using the same circular area of 13 mm in diameter, utilized in Ref. [2].

In reference to the TS photo of Step 1 which has pixel sizes of 0.19 mm/pixel, the diameter of circular digital area selector was of 68 pixel.

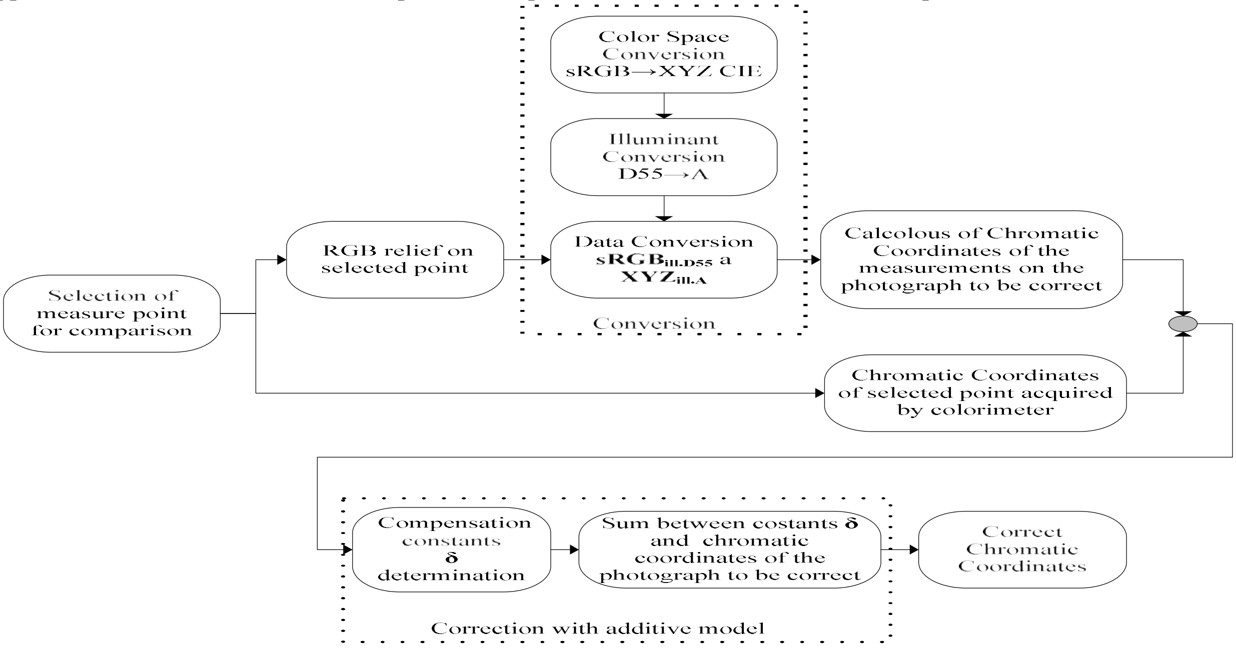

Figure 2. Flow chart of the calibration procedure to build a quantitative image of the TS.

With indication contained in Ref. [2], considering the problem relative to the definition of the reference areas, 18 points were selected on the basis of the smaller position uncertainty.

The RGB values acquired in these points were converted to XYZ CIE color system using the matrix operation of Eq. (1):

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_A = [T] * \begin{pmatrix} R \\ G \\ B \end{pmatrix}_{D55} \qquad (1)$$

Where:

$$[T] = \begin{bmatrix} Bradford \\ Matrix \\ D55 \to A \end{bmatrix} * \begin{bmatrix} Transform \\ sRGB \to XYZ \\ Matrix \end{bmatrix} \qquad (2)$$

and:

$$sRGB \to XYZ = \begin{pmatrix} 0.4125 & 0.3576 & 0.1804 \\ 0.2127 & 0.7152 & 0.0722 \\ 0.0193 & 0.1192 & 0.9503 \end{pmatrix} \qquad (3)$$

$$D55 \to A = \begin{pmatrix} 1.1803 & 0.0969 & -0.1386 \\ 0.1334 & 0.9183 & -0.0499 \\ -0.0217 & 0.0327 & 0.3732 \end{pmatrix} \qquad (4)$$

Applying Eqs. (3) and (4), the T matrix becomes:

$$T = \begin{pmatrix} 0.5049 & 0.4748 & 0.0882 \\ 0.2494 & 0.6985 & 0.0429 \\ 0.0052 & 0.0601 & 0.3531 \end{pmatrix} \qquad (5)$$

Using the previous relationship, after obtaining the XYZ value with A illuminant, it's possible to calculate the xyz chromatic coordinates using Eq. (6):

$$x = \frac{X}{X+Y+Z} \quad y = \frac{Y}{X+Y+Z} \quad z = \frac{Z}{X+Y+Z} \qquad (6)$$

Calibration made by comparison between data measured by colorimeter [2] and those calculated from RGB values of the photo of Step 1, allowed to determine three compensation constants δ_x, δ_y, δ_z for the to x, y, and z values. These values were calculated for each color channel basing on the mean value resulting from the 18 calibration points.

The differences between the mean values of the 18 calibration points reported in Ref. [2] with the data calculated above, gives the following compensation values:

$$\delta_x = 0,026 \quad \delta_y = 0,016 \quad \delta_z = -0,042$$

4. QUANTITATIVE IMAGE CONSTRUCTION

Using the analyzed color space transformation and the compensation constraints it's possible to build the quantitative photograph of the TS.

Every digital image is represented by a tridimensional matrix formed by a "sandwich" of 3 layer (R, G, B) of $m \times n$ matrix (where m is the number of horizontal pixels and n is the number of vertical pixels of the analyzed image), so by loading the digital photo in a mathematical software, it's possible to transform and to compensate each pixel for every color channel to get a quantitative image in XYZ CIE or sRGB color space. As an example, the results for the face of the TS Man are reported in Figure 3.

The resulting uncertainty at 95% confidence level of the quantitative image is ± 4%. This value was obtained by using the square root sum of the square power of the single relevant uncertainties.

It was considered. –a) the uncertainty of the G. Durante's photograph, mainly due to the non uniform illumination of TS (±2.5%); -b) the uncertainty connected to the transformation matrix (±0.5%); -c) the uncertainty of calibration correction (±2.0%); -d) the uncertainty of the reference value (±1.5%).

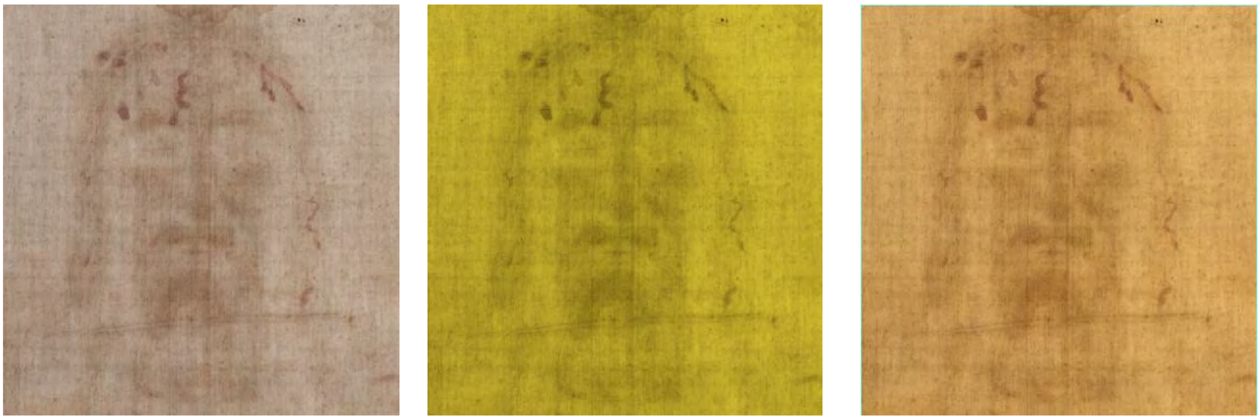

Figure 3. Example of correction of the TS face. From left to right: original photographic image, corrected image represented in XYZ CIE color space, quantitative image represented in RGB color space.

5. COLORIMETRIC DATABASE

After the procedure of color correction, a database of chromatic coordinates was built to define the color characteristics of cloth, body image, bloodstains, water and burns,. With this database it is possible to compare colorimetric data to classify unknown details present in the body image such as small spots, stains and segments.

Before to construct the database, a smaller measurement selector was determined to reach a better adaptability on small features. The spot was optimized in shape and dimensions, after the comparison of the stability to color measurements obtained on various TS reference areas; a circular spot selector with a diameter of 12 pixels (equivalent to 2.3 mm) was selected. For example, Figure 4 reports two different shapes of the color measurement areas, applied on the "reversed 3" bloodstain: the circular selector results the best fit.

To obtain the mean RGB values, the same procedure based on the average provided by the histogram function was used.

The data, relative to color measurements, were reported in the x/y and x/z chromatic coordinates ratios; then the values obtained can be plotted to show the chromatic characteristics of each feature and to classify it.. As an example the plot relative to the bloodstain measurements is reported in Figure 5. Two data clusters are evident: area A contains the values referred to scourge marks, and area B contains the values referred to draining blood marks. Obviously the same operation can be made for the other features examined in the database construction.

For the database use, consider for example the additional draining blood marks reported in Figure 6 that were not used for the database construction. The chromaticity data of these five points are reported in Table 1. By comparison of these data with the bloodstains database plotted in Figure 5, it can be seen (star points) that this characteristic falls in the area B confirming that these bloodstains coming from the image of the wrist are really draining blood marks.

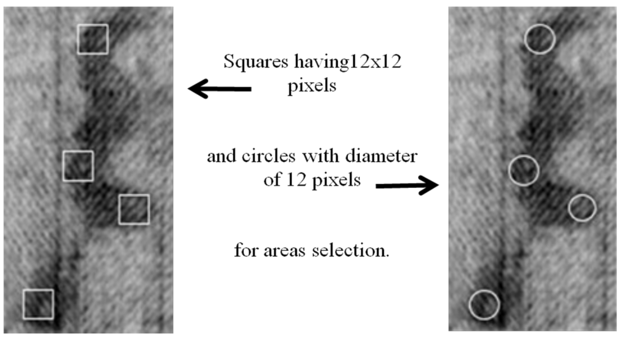

Figure 4. Different shapes of area selector in the color measurement of the "reversed 3" bloodstain.

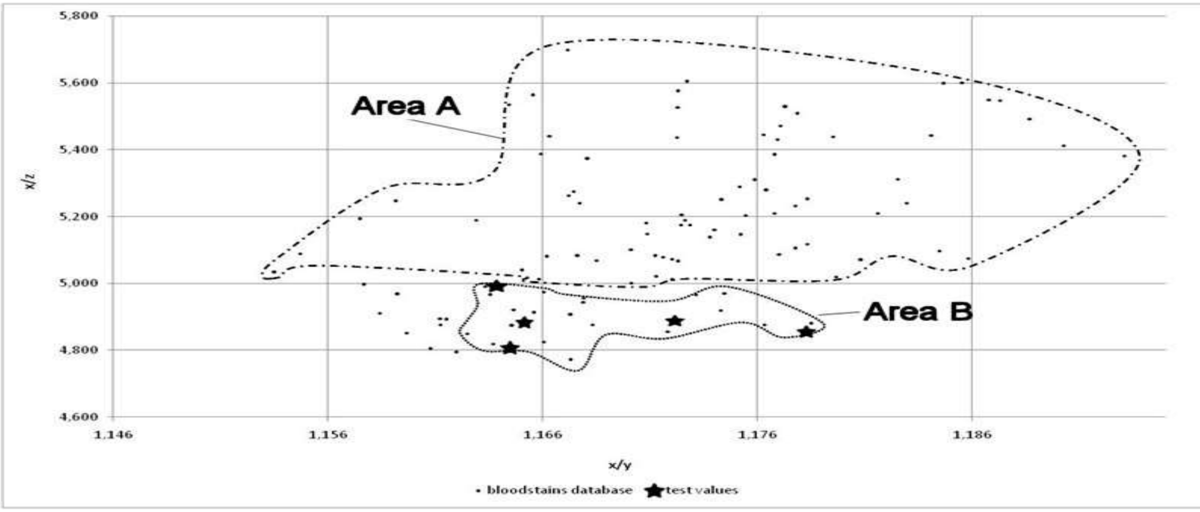

Figure 5. Plot of chromatic coordinates ratio (x/y and x/z) relative to bloodstains characteristics area. There are also indicated the test point in reference to figure 6 and table 1.

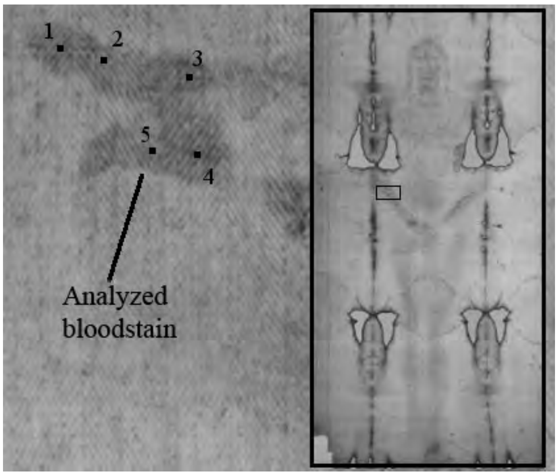

Figure 6. Measurement points on a draining blood mark used for test.

TABLE 1. Colorimetric data acquired in reference fig.6.

Ref.	x	y	z	x/y	x/z	y/z
1	0,485	0,416	0,099	1,165	4,890	4,197
2	0,486	0,415	0,099	1,172	4,891	4,172
2	0,486	0,418	0,097	1,164	4,996	4,293
4	0,487	0,413	0,100	1,178	4,857	4,122
5	0,484	0,416	0,101	1,164	4,801	4,124

With this method it is possible to classify unknown details by a simple chromaticity measurement on the quantitative body image of the TS and comparison with database values.

In the following figures and tables the color measurements relative to some characteristics area are reported:

- Figures 7 and 8, and Tables 2 and 3: body image;
- Figures 9 and 10 and Tables 4 and 5: bloodstains;
- Figure 11 and Table 6: cloth (front side);
- Figure 12 and Table 7: water stains of TS (front side).

For page limitation, other figures and tables are not reported but the authors are planning to put them in the first author's website.

6. CONCLUSION

This study allowed to correct a digital image of the TS with an uncertainty of ± 4 % basing on some photometric data. An additive model was used for correction of chromaticity coordinates, obtaining the first quantitative whole image of the TS.

The quantitative image allows to make color measurements of TS details such as body image, bloodstains, cloth, water stains and burns.

The recognition of details on the TS image has been successfully tested using areas of both bloodstains and body image areas not used during calibration; in the paper an example of bloodstains is presented.

With the resulting quantitative photograph of the TS it is possible now to measure and compare various details from a colorimetric point of view giving the possibility to perform new investigations, without the necessity to be physically in front the most important Relic of Christianity.

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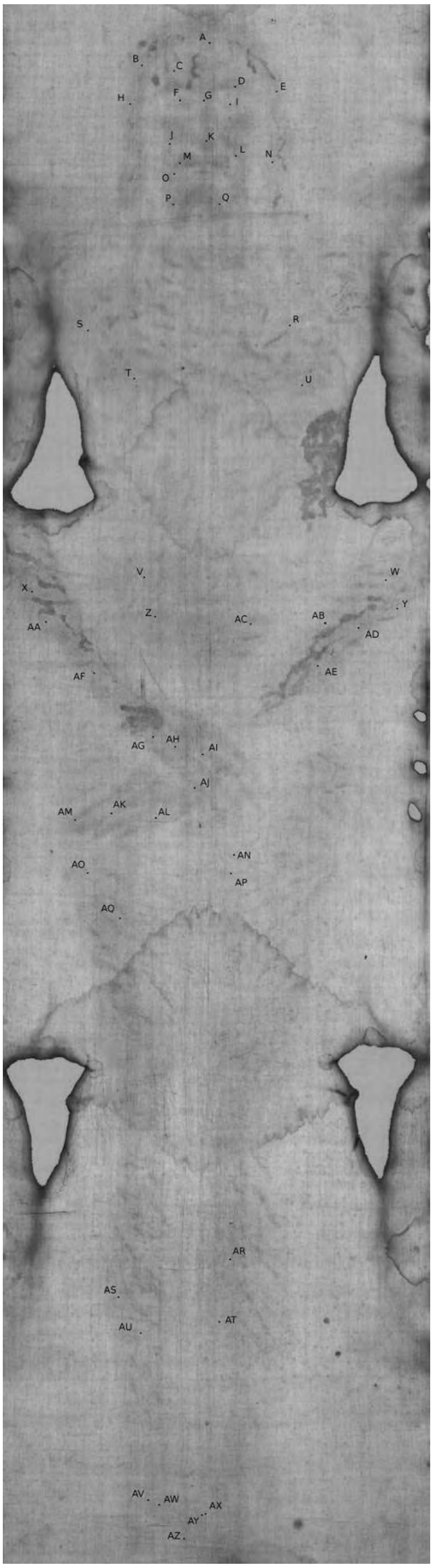

Figure 7. Image colorimetric data acquisition point in front side.

TABLE 2. Colorimetric data acquired in reference to fig.6.

Ref.	x	y	z	x/y	x/z	y/z
A	0,481	0,421	0,099	1,143	4,868	4,260
B	0,478	0,421	0,101	1,136	4,720	4,157
C	0,479	0,421	0,101	1,136	4,741	4,173
D	0,485	0,423	0,093	1,146	5,227	4,562
E	0,476	0,421	0,105	1,130	4,549	4,024
F	0,478	0,422	0,101	1,135	4,732	4,171
G	0,479	0,421	0,102	1,137	4,708	4,139
H	0,478	0,421	0,102	1,134	4,663	4,111
I	0,479	0,422	0,100	1,134	4,803	4,237
J	0,479	0,422	0,100	1,135	4,785	4,217
K	0,486	0,422	0,093	1,151	5,252	4,563
L	0,478	0,423	0,100	1,132	4,779	4,221
M	0,484	0,422	0,095	1,146	5,104	4,452
N	0,478	0,422	0,102	1,133	4,707	4,155
O	0,481	0,422	0,098	1,142	4,907	4,298
P	0,486	0,423	0,093	1,149	5,246	4,566
Q	0,485	0,422	0,094	1,149	5,183	4,512
R	0,477	0,422	0,102	1,132	4,687	4,139
S	0,478	0,422	0,101	1,134	4,754	4,193
T	0,476	0,421	0,104	1,130	4,580	4,052
U	0,478	0,422	0,101	1,132	4,726	4,174
V	0,477	0,423	0,101	1,127	4,703	4,172
W	0,477	0,421	0,104	1,134	4,604	4,061
X	0,478	0,421	0,102	1,137	4,675	4,111
Y	0,477	0,421	0,103	1,132	4,616	4,078
Z	0,481	0,422	0,098	1,141	4,925	4,316
AA	0,480	0,422	0,099	1,138	4,826	4,241
AB	0,477	0,421	0,103	1,131	4,644	4,105
AC	0,477	0,421	0,103	1,131	4,628	4,092
AD	0,477	0,422	0,103	1,130	4,641	4,106
AE	0,478	0,421	0,102	1,133	4,684	4,133
AF	0,478	0,422	0,101	1,135	4,742	4,179
AG	0,478	0,422	0,100	1,133	4,765	4,206
AH	0,481	0,422	0,098	1,141	4,888	4,284
AI	0,480	0,421	0,100	1,138	4,809	4,224
AJ	0,480	0,422	0,099	1,138	4,833	4,248
AK	0,478	0,422	0,101	1,135	4,742	4,179
AL	0,479	0,423	0,099	1,134	4,821	4,251
AM	0,480	0,421	0,100	1,139	4,779	4,195
AN	0,477	0,422	0,102	1,131	4,692	4,147
AO	0,478	0,421	0,102	1,134	4,666	4,114
AP	0,475	0,421	0,105	1,129	4,526	4,010
AQ	0,480	0,422	0,098	1,139	4,879	4,285
AR	0,479	0,422	0,100	1,133	4,785	4,222
AS	0,479	0,422	0,100	1,135	4,785	4,217
AT	0,478	0,422	0,101	1,134	4,743	4,185
AU	0,479	0,423	0,100	1,132	4,806	4,247
AV	0,476	0,421	0,105	1,131	4,550	4,023
AW	0,478	0,421	0,102	1,135	4,666	4,112
AX	0,477	0,421	0,103	1,134	4,623	4,077
AY	0,477	0,421	0,103	1,131	4,627	4,090
AZ	0,478	0,422	0,102	1,133	4,699	4,147

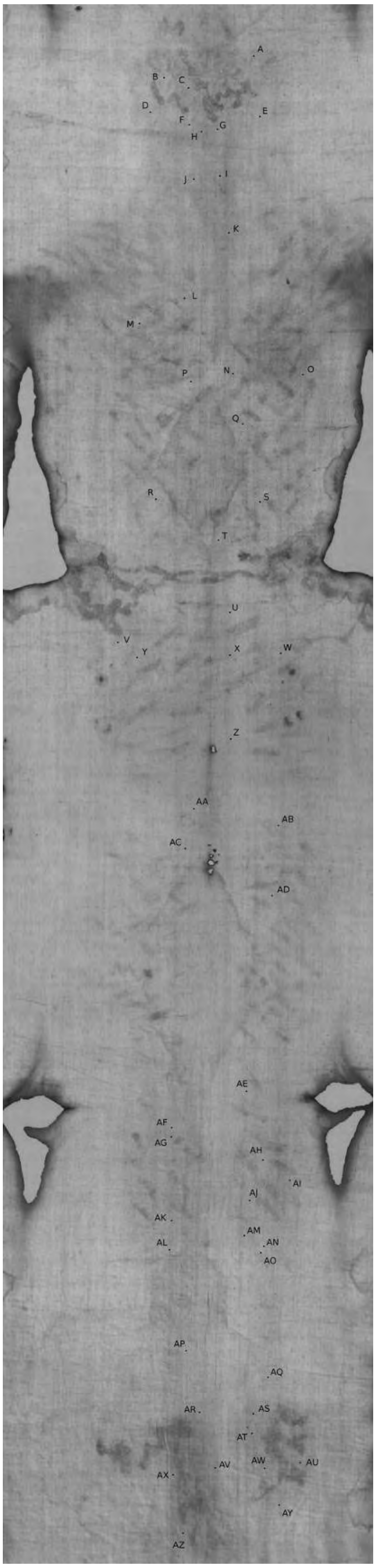

Figure 8. Image colorimetric data acquisition point in back side.

TABLE 3. Colorimetric data acquired in reference to fig.7.

Ref.	x	y	z	x/y	x/z	y/z
A	0,482	0,421	0,098	1,143	4,915	4,299
B	0,478	0,423	0,100	1,132	4,774	4,217
C	0,483	0,423	0,095	1,141	5,063	4,437
D	0,478	0,422	0,101	1,132	4,745	4,190
E	0,476	0,421	0,104	1,129	4,569	4,048
F	0,480	0,423	0,098	1,133	4,887	4,313
G	0,481	0,423	0,098	1,137	4,911	4,319
H	0,483	0,423	0,094	1,141	5,113	4,482
I	0,476	0,420	0,105	1,133	4,536	4,004
J	0,478	0,422	0,101	1,131	4,747	4,196
K	0,477	0,420	0,103	1,135	4,614	4,066
L	0,477	0,422	0,102	1,132	4,673	4,128
M	0,477	0,420	0,104	1,135	4,577	4,034
N	0,475	0,420	0,106	1,129	4,479	3,967
O	0,476	0,420	0,105	1,133	4,536	4,002
P	0,474	0,421	0,106	1,127	4,477	3,974
Q	0,474	0,420	0,107	1,130	4,420	3,912
R	0,473	0,420	0,107	1,127	4,406	3,909
S	0,475	0,420	0,106	1,132	4,489	3,967
T	0,474	0,420	0,107	1,129	4,443	3,934
U	0,475	0,420	0,106	1,130	4,482	3,966
V	0,474	0,421	0,106	1,125	4,464	3,968
W	0,477	0,421	0,103	1,134	4,628	4,082
X	0,477	0,421	0,103	1,132	4,623	4,083
Y	0,473	0,421	0,107	1,125	4,418	3,926
Z	0,474	0,421	0,106	1,127	4,458	3,954
AA	0,475	0,421	0,105	1,128	4,509	3,995
AB	0,475	0,421	0,105	1,128	4,514	4,004
AC	0,476	0,420	0,105	1,132	4,535	4,008
AD	0,473	0,421	0,107	1,125	4,425	3,932
AE	0,481	0,421	0,099	1,141	4,860	4,261
AF	0,475	0,422	0,104	1,124	4,564	4,061
AG	0,475	0,421	0,105	1,127	4,505	3,996
AH	0,477	0,421	0,103	1,134	4,632	4,086
AI	0,476	0,422	0,103	1,130	4,614	4,084
AJ	0,476	0,421	0,104	1,129	4,577	4,055
AK	0,475	0,421	0,105	1,127	4,499	3,992
AL	0,477	0,422	0,102	1,131	4,655	4,117
AM	0,475	0,421	0,105	1,129	4,525	4,009
AN	0,473	0,421	0,108	1,123	4,384	3,903
AO	0,476	0,420	0,105	1,131	4,528	4,003
AP	0,474	0,421	0,106	1,125	4,464	3,968
AQ	0,475	0,421	0,105	1,128	4,510	3,997
AR	0,475	0,421	0,105	1,130	4,533	4,010
AS	0,477	0,422	0,103	1,131	4,651	4,114
AT	0,474	0,421	0,106	1,126	4,479	3,979
AU	0,477	0,421	0,104	1,133	4,595	4,055
AV	0,475	0,421	0,105	1,128	4,546	4,029
AW	0,473	0,421	0,107	1,124	4,408	3,922
AX	0,474	0,421	0,106	1,128	4,477	3,969
AY	0,472	0,419	0,109	1,127	4,328	3,841
AZ	0,477	0,420	0,104	1,136	4,609	4,056

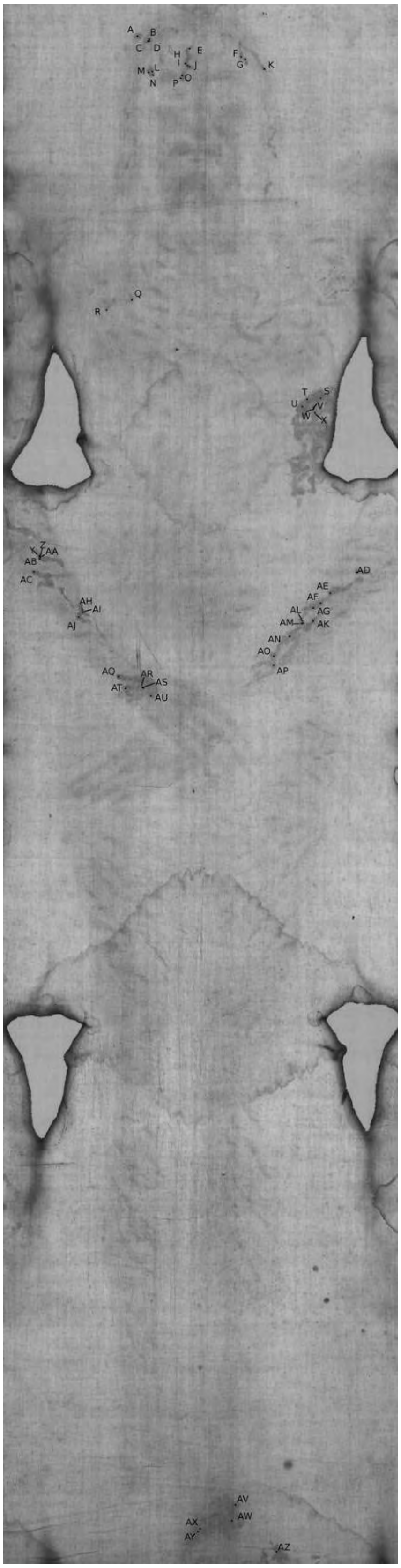

Figure 9. Bloodstains colorimetric data acquisition point in front side.

TABLE 4. Colorimetric data acquired in reference to fig.8.

Ref.	x	y	z	x/y	x/z	y/z
A	0,489	0,416	0,095	1,175	5,146	4,379
B	0,490	0,417	0,094	1,175	5,202	4,426
C	0,495	0,417	0,089	1,187	5,546	4,671
D	0,495	0,416	0,090	1,189	5,491	4,620
E	0,488	0,418	0,096	1,168	5,083	4,353
F	0,489	0,417	0,095	1,172	5,173	4,412
G	0,492	0,416	0,094	1,183	5,239	4,429
H	0,493	0,418	0,091	1,180	5,438	4,610
I	0,491	0,414	0,097	1,186	5,074	4,279
J	0,492	0,418	0,091	1,177	5,386	4,577
K	0,489	0,419	0,093	1,167	5,262	4,508
L	0,491	0,418	0,092	1,176	5,310	4,516
M	0,489	0,417	0,094	1,172	5,205	4,440
N	0,491	0,418	0,093	1,175	5,288	4,500
O	0,492	0,418	0,091	1,177	5,430	4,613
P	0,493	0,419	0,089	1,178	5,509	4,677
Q	0,491	0,421	0,088	1,166	5,564	4,773
R	0,485	0,420	0,095	1,155	5,088	4,406
S	0,488	0,416	0,097	1,171	5,021	4,287
T	0,487	0,415	0,099	1,174	4,918	4,188
U	0,487	0,415	0,098	1,173	4,965	4,232
V	0,489	0,417	0,095	1,171	5,147	4,396
W	0,489	0,417	0,095	1,173	5,174	4,411
X	0,488	0,416	0,096	1,172	5,067	4,322
Y	0,489	0,417	0,095	1,174	5,138	4,377
Z	0,488	0,417	0,096	1,172	5,077	4,334
AA	0,488	0,416	0,097	1,172	5,011	4,276
AB	0,484	0,416	0,101	1,162	4,794	4,126
AC	0,484	0,417	0,100	1,163	4,849	4,171
AD	0,492	0,420	0,089	1,172	5,526	4,714
AE	0,487	0,418	0,097	1,165	5,040	4,326
AF	0,484	0,418	0,099	1,158	4,910	4,238
AG	0,488	0,416	0,097	1,171	5,021	4,287
AH	0,487	0,414	0,100	1,179	4,880	4,141
AI	0,486	0,415	0,100	1,172	4,855	4,143
AJ	0,485	0,416	0,100	1,165	4,874	4,185
AK	0,492	0,418	0,090	1,176	5,444	4,628
AL	0,486	0,417	0,098	1,164	4,966	4,268
AM	0,485	0,417	0,099	1,161	4,893	4,214
AN	0,487	0,418	0,096	1,166	5,081	4,357
AO	0,484	0,417	0,100	1,160	4,850	4,183
AP	0,488	0,419	0,094	1,163	5,189	4,462
AQ	0,490	0,415	0,097	1,181	5,070	4,294
AR	0,488	0,417	0,096	1,169	5,067	4,336
AS	0,486	0,418	0,097	1,163	4,989	4,289
AT	0,490	0,416	0,096	1,178	5,117	4,343
AU	0,484	0,417	0,101	1,161	4,805	4,139
AV	0,486	0,416	0,098	1,168	4,955	4,243
AW	0,485	0,416	0,100	1,166	4,824	4,137
AX	0,484	0,416	0,101	1,164	4,818	4,140
AY	0,484	0,415	0,102	1,167	4,772	4,088
AZ	0,486	0,416	0,099	1,167	4,907	4,204

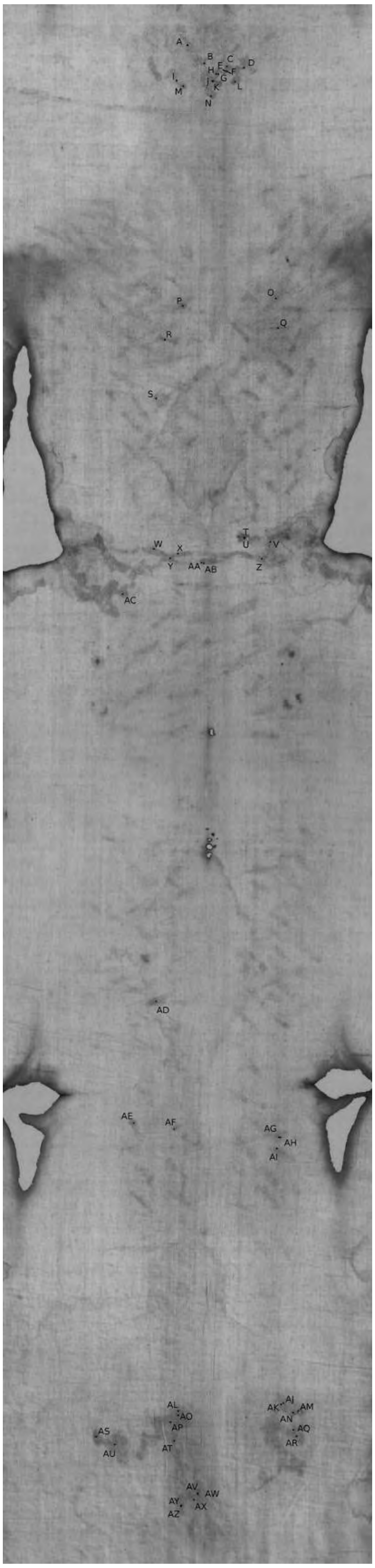

Figure 10. Bloodstains colorimetric data acquisition point in the back side.

TABLE 5. Colorimetric data acquired in reference to fig.9.

Ref.	x	y	z	x/y	x/z	y/z
A	0,490	0,420	0,091	1,168	5,373	4,600
B	0,495	0,418	0,088	1,186	5,600	4,724
C	0,491	0,417	0,093	1,176	5,279	4,487
D	0,490	0,417	0,094	1,177	5,209	4,426
E	0,490	0,416	0,096	1,178	5,106	4,335
F	0,489	0,416	0,096	1,177	5,086	4,321
G	0,495	0,417	0,089	1,187	5,548	4,675
H	0,491	0,417	0,093	1,178	5,253	4,458
I	0,491	0,419	0,090	1,172	5,436	4,637
J	0,487	0,414	0,100	1,176	4,875	4,144
K	0,488	0,415	0,098	1,174	4,970	4,231
L	0,492	0,416	0,093	1,183	5,311	4,491
M	0,489	0,415	0,097	1,180	5,019	4,254
N	0,489	0,417	0,095	1,174	5,160	4,395
O	0,489	0,419	0,093	1,168	5,240	4,487
P	0,495	0,418	0,088	1,185	5,599	4,726
Q	0,493	0,418	0,090	1,177	5,471	4,648
R	0,493	0,420	0,088	1,173	5,605	4,779
S	0,493	0,422	0,086	1,167	5,698	4,881
T	0,495	0,415	0,092	1,193	5,380	4,509
U	0,494	0,415	0,091	1,190	5,412	4,547
V	0,493	0,419	0,089	1,177	5,529	4,697
W	0,490	0,420	0,091	1,166	5,387	4,621
X	0,490	0,420	0,090	1,166	5,440	4,664
Y	0,485	0,417	0,099	1,162	4,892	4,212
Z	0,490	0,417	0,093	1,174	5,251	4,471
AA	0,489	0,418	0,094	1,171	5,180	4,424
AB	0,493	0,419	0,089	1,177	5,529	4,697
AC	0,489	0,419	0,093	1,167	5,275	4,518
AD	0,493	0,420	0,088	1,172	5,576	4,757
AE	0,487	0,421	0,094	1,158	5,194	4,487
AF	0,485	0,420	0,096	1,154	5,034	4,364
AG	0,485	0,419	0,097	1,158	4,997	4,316
AH	0,488	0,421	0,093	1,159	5,247	4,526
AI	0,491	0,421	0,089	1,164	5,534	4,753
AJ	0,487	0,417	0,097	1,166	5,013	4,300
AK	0,485	0,418	0,098	1,159	4,968	4,286
AL	0,488	0,417	0,096	1,171	5,083	4,340
AM	0,488	0,417	0,096	1,170	5,101	4,359
AN	0,487	0,416	0,097	1,170	5,000	4,273
AO	0,491	0,417	0,094	1,178	5,232	4,442
AP	0,486	0,416	0,100	1,168	4,875	4,173
AQ	0,486	0,417	0,098	1,166	4,973	4,265
AR	0,484	0,417	0,099	1,161	4,875	4,198
AS	0,494	0,417	0,091	1,184	5,442	4,596
AT	0,486	0,417	0,099	1,166	4,913	4,215
AU	0,489	0,417	0,094	1,173	5,188	4,424
AV	0,491	0,414	0,096	1,185	5,096	4,302
AW	0,491	0,416	0,094	1,182	5,209	4,408
AX	0,485	0,417	0,099	1,165	4,921	4,225
AY	0,488	0,417	0,096	1,172	5,071	4,327
AZ	0,486	0,416	0,098	1,168	4,942	4,232

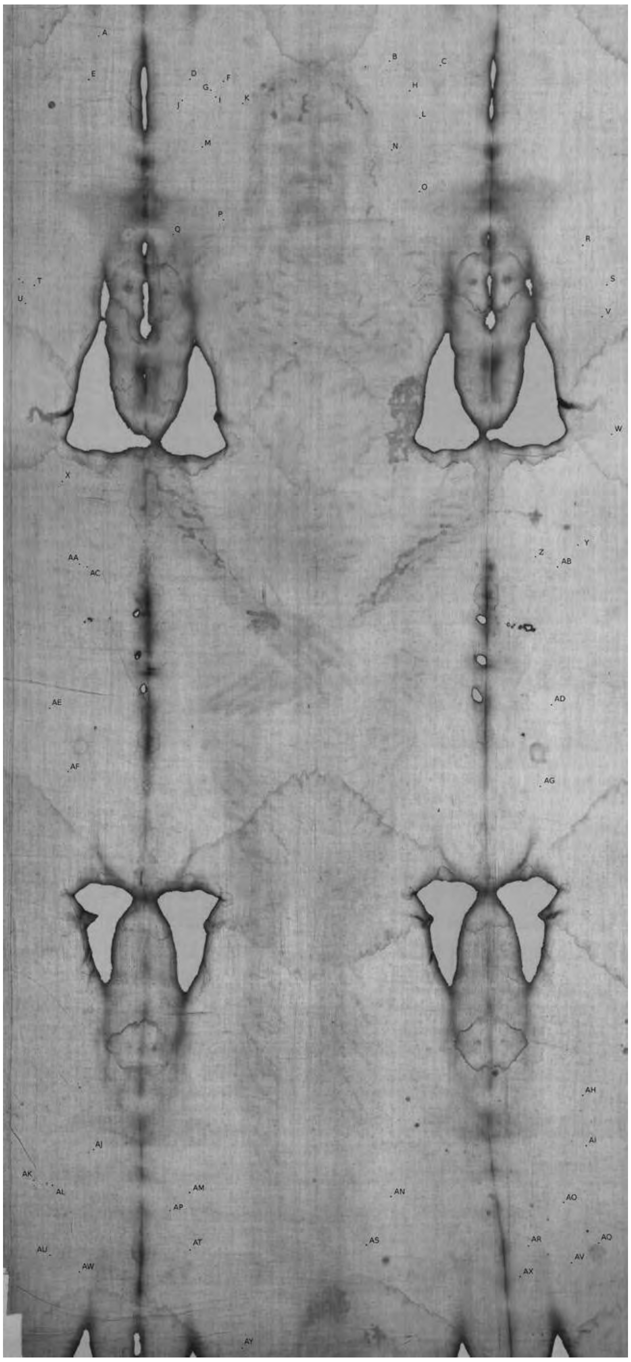

Figure 11. Cloth colorimetric data acquisition point in front side.

TABLE 6. Colorimetric data acquired in reference to fig.10.

Ref.	x	y	z	x/y	x/z	y/z
A	0,471	0,418	0,112	1,127	4,209	3,736
B	0,469	0,419	0,112	1,119	4,171	3,728
C	0,471	0,420	0,110	1,121	4,297	3,833
D	0,469	0,418	0,114	1,121	4,107	3,664
E	0,471	0,418	0,112	1,127	4,218	3,743
F	0,473	0,420	0,108	1,125	4,368	3,882
G	0,469	0,418	0,114	1,121	4,127	3,683
H	0,470	0,420	0,111	1,119	4,220	3,770
I	0,470	0,419	0,113	1,122	4,164	3,712
J	0,470	0,419	0,113	1,123	4,177	3,720
K	0,472	0,420	0,109	1,125	4,310	3,833
L	0,471	0,420	0,110	1,120	4,271	3,815
M	0,471	0,419	0,110	1,123	4,266	3,798
N	0,470	0,420	0,111	1,120	4,232	3,780
O	0,473	0,420	0,107	1,126	4,403	3,912
P	0,475	0,420	0,107	1,131	4,453	3,936
Q	0,473	0,420	0,107	1,126	4,403	3,912
R	0,474	0,420	0,107	1,128	4,436	3,932
S	0,471	0,420	0,110	1,121	4,267	3,806
T	0,469	0,419	0,113	1,120	4,136	3,692
U	0,471	0,419	0,111	1,124	4,261	3,792
V	0,474	0,420	0,106	1,128	4,463	3,956
W	0,469	0,419	0,112	1,119	4,177	3,733
X	0,472	0,419	0,110	1,125	4,283	3,806
Y	0,473	0,421	0,108	1,124	4,398	3,914
Z	0,470	0,419	0,111	1,121	4,234	3,776
AA	0,471	0,419	0,111	1,123	4,232	3,769
AB	0,469	0,420	0,111	1,117	4,211	3,769
AC	0,469	0,418	0,114	1,121	4,097	3,654
AD	0,470	0,419	0,112	1,121	4,215	3,761
AE	0,474	0,420	0,107	1,128	4,431	3,930
AF	0,475	0,420	0,106	1,129	4,465	3,953
AG	0,472	0,421	0,108	1,120	4,371	3,901
AH	0,475	0,422	0,104	1,127	4,552	4,038
AI	0,475	0,422	0,104	1,127	4,552	4,038
AJ	0,470	0,420	0,111	1,119	4,248	3,797
AK	0,474	0,419	0,108	1,129	4,393	3,890
AL	0,474	0,420	0,107	1,128	4,420	3,919
AM	0,473	0,420	0,109	1,127	4,348	3,859
AN	0,470	0,420	0,111	1,120	4,245	3,790
AO	0,473	0,421	0,107	1,123	4,423	3,938
AP	0,475	0,421	0,105	1,130	4,534	4,011
AQ	0,476	0,421	0,104	1,130	4,555	4,033
AR	0,475	0,421	0,105	1,128	4,523	4,011
AS	0,472	0,419	0,110	1,124	4,284	3,811
AT	0,475	0,420	0,106	1,130	4,467	3,953
AU	0,475	0,420	0,106	1,129	4,494	3,979
AV	0,472	0,420	0,109	1,123	4,324	3,850
AW	0,481	0,421	0,099	1,140	4,857	4,259
AX	0,479	0,422	0,101	1,135	4,758	4,194
AY	0,484	0,421	0,096	1,148	5,017	4,369
AZ	0,471	0,420	0,111	1,121	4,255	3,796

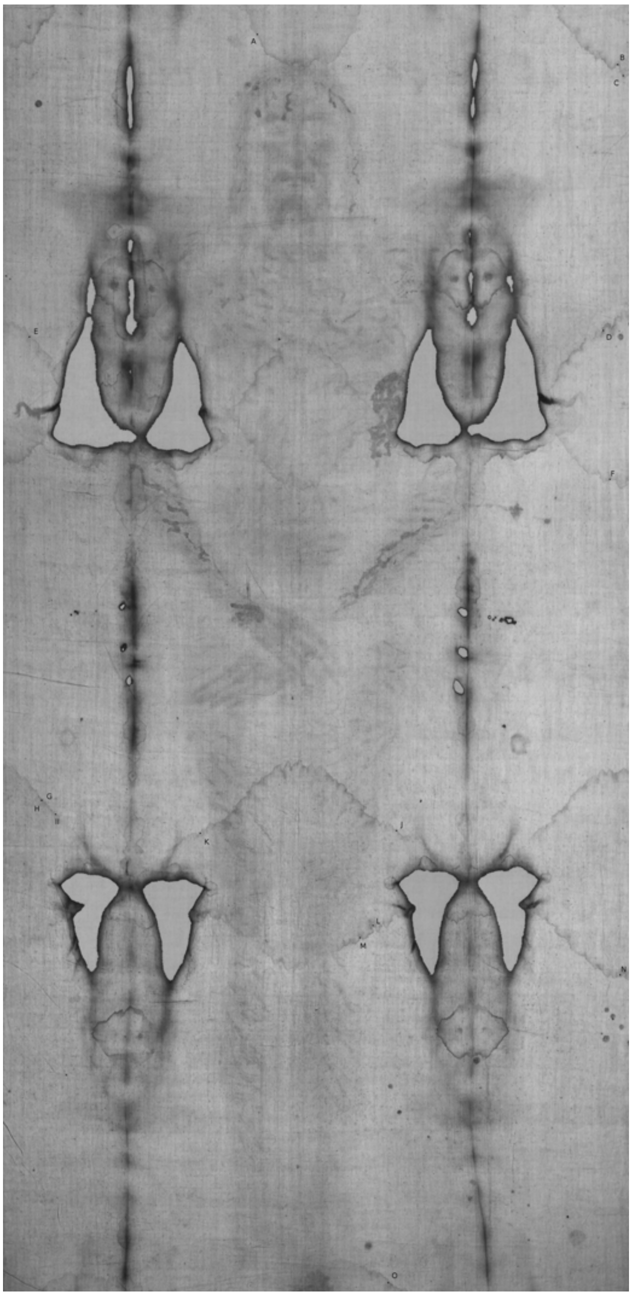

Figure 12. Water stains colorimetric data acquisition point in front side.

TABLE 7. Colorimetric data acquired in reference to fig.11.

Ref.	x	y	z	x/y	x/z	y/z
A	0,481	0,422	0,098	1,140	4,893	4,291
B	0,492	0,424	0,085	1,160	5,796	4,996
C	0,483	0,423	0,095	1,141	5,096	4,468
D	0,493	0,424	0,084	1,162	5,889	5,068
E	0,478	0,420	0,103	1,138	4,619	4,060
F	0,482	0,422	0,097	1,142	4,985	4,366
G	0,485	0,422	0,094	1,151	5,143	4,470
H	0,485	0,422	0,095	1,150	5,125	4,456
I	0,478	0,421	0,102	1,136	4,669	4,111
J	0,482	0,423	0,096	1,139	5,004	4,394
K	0,480	0,422	0,099	1,138	4,846	4,259
L	0,482	0,423	0,095	1,139	5,062	4,446
M	0,485	0,423	0,093	1,146	5,217	4,551
N	0,480	0,422	0,099	1,136	4,843	4,263
O	0,487	0,418	0,095	1,165	5,113	4,388
P	0,488	0,422	0,091	1,157	5,357	4,631

New image processing of the Turin Shroud scourge marks

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Abstract
A preliminary study presented at Columbus Conference on the Turin Shroud in 2008 identified three different types of scourge marks on the body image of the Shroud. By means of a new kind of image processing, the characteristics of the three marks have been better highlighted and the results are also verified through comparison with signs experimentally produced by different kinds of whips on a proper carton paper. It experimentally results that imprints similar to those observed on the Turin Shroud can be obtained if at least two whips are used: a bunch of flexible rods and a flagrum.

Keywords: Scourge marks, bloodstains, Flagrum, carton paper.

1. INTRODUCTION

The blood traces found on the Turin Shroud (TS) attracted the attention of many sfigcholars since 1898, when S. Pia made the first photograph. These traces have been analyzed by P. Vignon in 1902 [1], P. Barbet in 1937 [2] and others. In 1978, during the STURP (Shroud of TUrin Research Project) campaign, J. H. Heller and A. D. Adler [3], and independently P.L. Baima Bollone [4] established that the red traces are stains of human blood, transposed on the cloth by fibrinolysis [5, 6]. The bloodstain characteristics are difficult to fake and until now every attempt to fully reproduce them in a copy of the TS has been vain [7]. Numerically, the most abundant bloodstains on the double body image of the TS Man are those caused by scourging [8]. These marks cover almost the entire body surface, but in some areas of the frontal image they are fainter and it is not simple to detect them using naked eye observation. On the contrary, in other areas, as back and buttocks, they are more evident (thanks to the weight of the corpse acting on the TS), frequently appearing as small round double imprints connected by a short straight trail, with a shape similar to a dumb-bell. They have been defined "laceration-and-bruise wounds" by various forensic pathologists [9, 10].

In Fig. 1 the most evident bloodstains on the TS caused by scourging are evidenced in red. Excluding some signs of dubious origin (for example one on the head of the back image) 372 bloodstains can approximately be counted (159 on the front image and 213 on the back image). If the image is carefully examined, it can be noticed that the dumb-bell shaped marks are not the only kind of scourge trace, as they are joined and often somehow mingled with more evanescent scratches similar to elongated furrows. The scourge marks frequently cross each other and have been subsequently overlapped by other blood marks, like the so called "blood belt" or the outflows from the wrists.

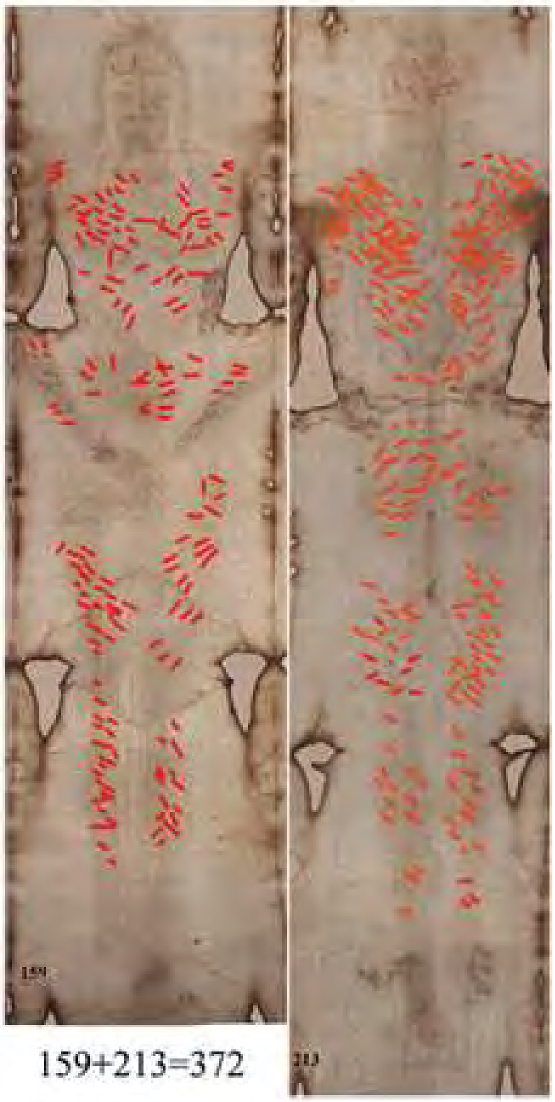

Figure 1. The most evident bloodstains relative to scourge marks, evidenced in red.

This fact indicates that they preceded other tortures in the temporal sequence of the execution of the TS Man.

2. SCOURGE MARKS DETECTION

In a previous work [11] three kinds of scourge marks had been preliminarily identified through image processing on high resolution TS images.

The first kind (Type 1) is the dumb-bell shaped mark (Figs. 2, 3); more evident and easily recognizable, it is referred to the damage of *Roman Flagrum* ending parts [8, 12] and its shape is comparable with that of a first century Roman whip.

The second kind (Type 2) is the most abundant scourge mark, but it is too faint to be correctly defined observing the TS only by naked eye. It consists of large striped bands (10-15 mm wide) of varying length (somewhere reaching 7-8 cm, for example on shoulders and upper back area) that look like deep scratches (Fig. 4).

The third kind (Type 3) is more rare (it occurs less than 15 times) and much more faint. It is found on legs, calves and close to the ankles in both frontal and dorsal image. It consists of a fan composed by 3 - 4 thin curved stripes (Figs. 6, 7).

According to Ref. [11] it was not possible to link Type 2 and Type 3 directly to the flagrum, and a different torture instrument had to be taken into account for explaining these scourge marks. Type 2 was thought to result from the damage of a whip made of thin, flexible rods, like the famous “Virgae” used both as torture instrument and as a symbol of power by the lictors. Type 3 was probably a sort of "deformed Type 2", resulting from the wrapping of Type 2 mark around the thinnest parts of the legs, around the calves and the ankles.

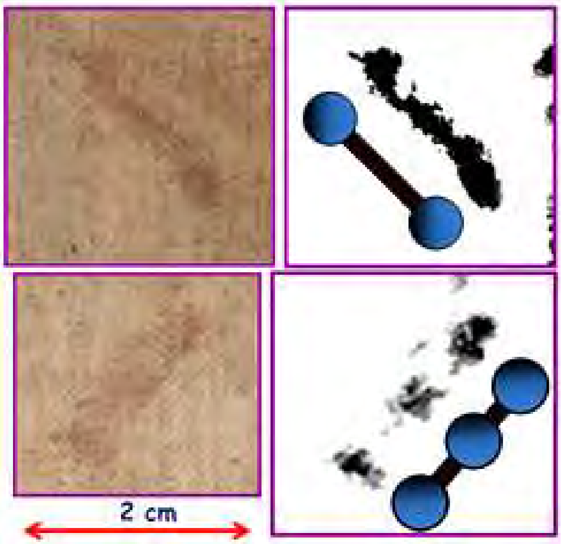

Figure 2. Two blood marks caused by the Type 1 scourge with the relative reconstruction of the shape of the torture instrument.

Figure 3. Reconstruction of the shape of the torture instrument for Type 1 scourge marks.

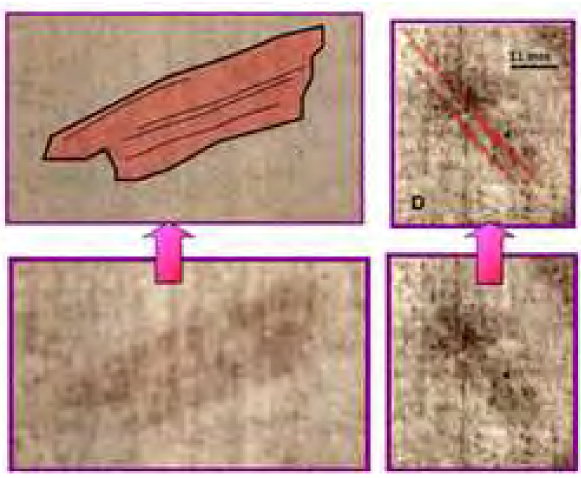

Figure 4. Two blood marks caused by the Type 2 scourge with the relative reconstruction of the shape of the blood mark in red.

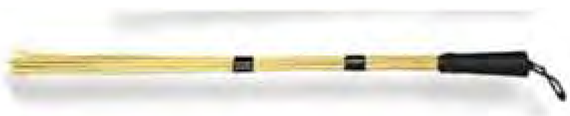

Figure 5. Reconstruction of the shape of the torture instrument for Type 2 scourge marks.

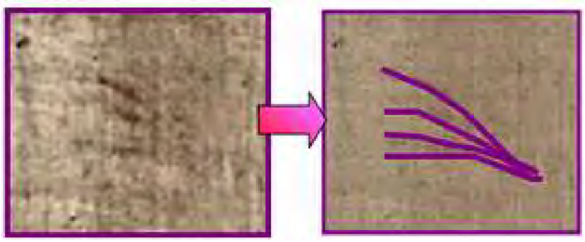

Figure 6. Blood mark caused by the Type 3 scourge with the relative reconstruction of the shape of the blood mark.

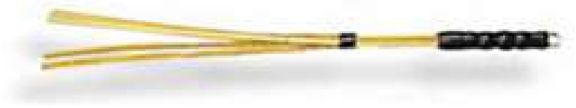

Figure 7. Reconstruction of the shape of the torture instrument for Type 3 scourge marks.

The problem of the previous image processing was mainly due to the use of different procedures, capable to enhance either Type 1 or Type 2 and 3 but not all three types together. The filters cyclically used to highlight Type 1 scourge mark often erased other kinds of noise eventually present in the same area, making not easy the identification of the relationships among the three Types.

Type 2 mark was already noticed by some Authors, for example G. Ricci [12], who charged them to the graze left by flagrum straps. In this perspective, each Type 1 mark have to be linked to a Type 2 mark, that should somehow be the "tail" of the dumb-bell shaped imprint. On the contrary, Type 1 appears independent from Type 2 and Type 3, and the experimental result confirm this, as will be shown: Type 1 terminations did not have any tail or graze attached, nor Type 2 marks end in a Type 1 sign.

The overall appearance of a random overlap between the two kinds of scourge marks has been in few cases confirmed by the previous image processing, but the problem was still unsolved for the great majority of scourge marks [11].

An image processing that could enhance both types together, without losing information, was needed and this was the first task faced in the present work.

Another way to solve the problem of the relationships between the different scourge marks could be found in the experimental reproduction of the imprints, using instruments similar to those hypothesized, and in the comparison of the results with both natural TS image and processed areas.

3. IMAGE PROCESSING

3.1 Construction of a "clean" image

A high resolution image of the TS scanned at 300 dpi [13] has been used in this new processing performed with CS 4 Adobe Photoshop®. All signs referring to fold, water stains and clots of unknown origin have been reduced/smoothed using 3 particular filters:

1. "*Noise reduction*". It smoothes the image acting on the RGB values of proper areas around each image pixel.

2. "*Clone-stamp*". It is a filter that copies a selected area into another. For folds and stains other than blood stains this filter has been used by copying a clean area immediately close to the flaw to be corrected.

3. "*Correction brush*". This filter corrects the selected area by "*dragging*" pixel of the surroundings; it automatically copies the properties of the closer pixels and further smoothes the flaw.

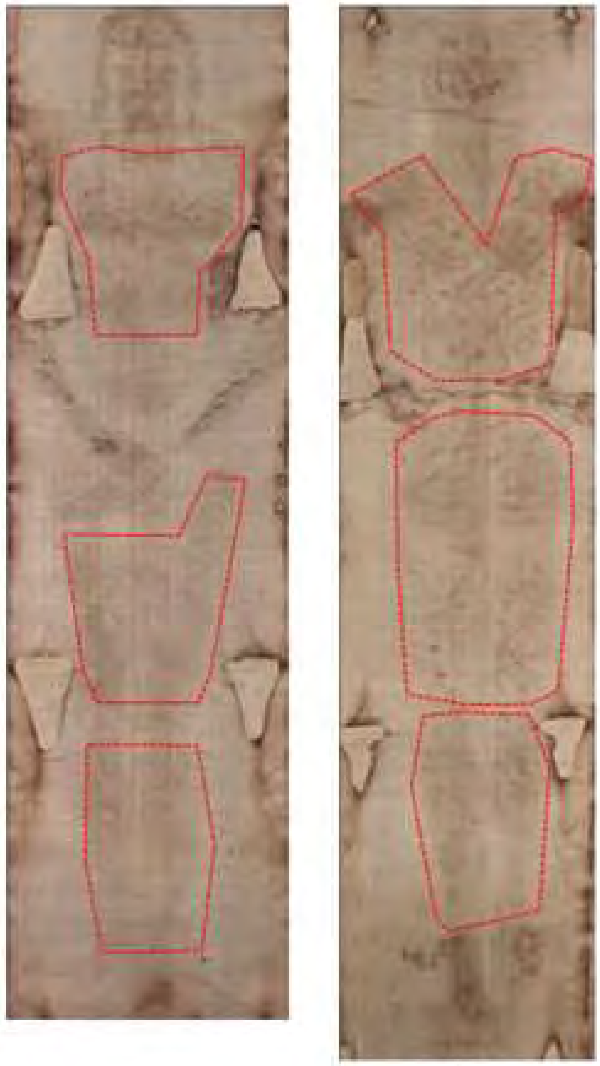

Figure 8. TS double image after cleaning process.

The image obtained is reported in Fig. 8. It was the starting point for all successive processings illustrated below.

3.2 Processing of selected areas

A two step processing has been applied on selected areas (back, buttocks and legs, and calves for the dorsal image and chest, quadriceps and shins for the frontal image) in order to identify the different scourge marks, and giving the possibility to single them out.

I) The first step was undertaken to clearly identify all Type 1 scourge marks. An image processing using false color had been used to highlight only Type 1. The results have been obtained in different steps:

1- On the clean image, a new layer has been created;

2- Application of the filter "*diffusion*". This filter operates by transferring the color of the most abundant pixel into those pixels having a similar tone but which are numerically inferiors. The result is an almost complete deletion of the fishbone texture of the linen;

3- Application of a "*contrast mask*". This step comprises an iterative enhancing of the difference between RGB tones, leading to an increase of the darker and lighter shades. At this point all scourge marks are much more visible and the background is homogenized;

4- Iterative application of "*Eraser Classic*" filter: this free-download filter allows the deletion of a single selected RGB value. It has been repeatedly applied in order to erase all those tones not directly related with the scourge marks, for example the bluish and the greenish colors due to jpeg transformation of the image. It has been also used to erase the colors referring to Type 2 and 3 scourge marks that at this stage we did not want to keep.

5- The processed level has been then exported on a white background and another free-download filter, "*Solidify C*", has been applied. *Solidify* C turns an image layer entirely 100% opaque. It reveals partially transparent areas, and it can even help to repair the corrupted transparency channels. It smears the outer edges of a shape for a harder look. This final step has been done to enhance the shape of Type 1 pattern on a uniform background.

The results are shown in Fig. 9. Each Type 1 has been marked with a symbol of the dumb-bell shape end of the flagrum, and all they constituted a further new level that was possible to export and apply elsewhere (Fig. 10).

Only few areas (blue circles) of great color intensity were not considered, as their shape did not fit the dumb-bell mark typical of all other signs. Their origin will be explained later on.

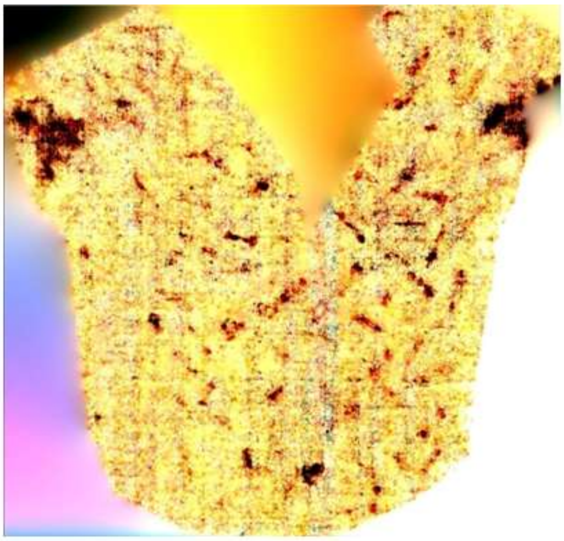

Figure 9. Detail of the back of the TS body image after processing to evidence Type 1 scourge marks.

II) The second step of the processing had the aim of enhancing both Type 1 and Type 2 scourge marks contemporaneously. Starting again from the clean image of Fig. 8, a processing sequence similar to that already described has been applied until point 3.

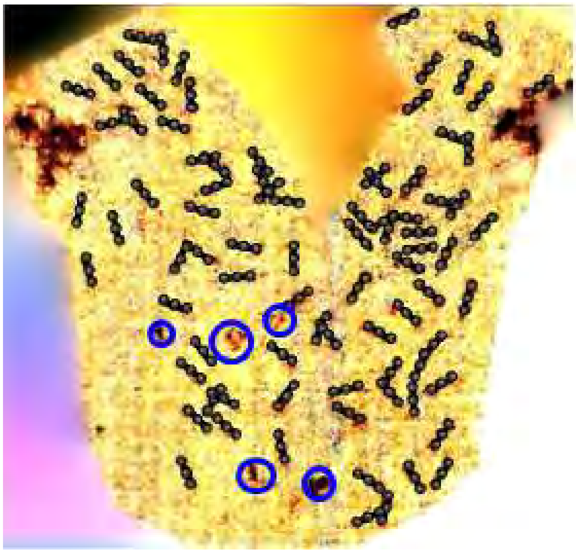

Figure 10. Type 1 scourge mark layer evidenced from the image of Fig. 9.

The contrast mask have been again applied by selecting a high contrasting factor (more than 250%), a medium pixel size (around 50%) and a null level threshold. The first two values are indicative and have been varied for each of the other selected areas for a small interval (+ 10). Results can be seen in Fig. 11.

Type 1 scourge mark layer obtained from the previous processing have been overlapped to this new image, in order to make easier the distinction between the two Types (Fig. 12).

Once that Type 1 have been located, it was simple to detect Type 2, as it can be seen in Fig. 13.

Figure 11. Type 1 and Type 2 scourge marks visible after graphic processing.

Type 1 is characterized by a more defined and short shape and it has the darkest RGB values; Type 2 instead is lighter and in most of the cases it does not have well defined contours. In particular it has to be noticed that Type 2 do not ends in a Type 1 mark, confirming that the two signs are not related each other and the interpretation of Type 2 as the graze of the flagrum leather cords is untenable.

Figure 12. Type 1 scourge mark level applied to Fig. 11.

Figure 13. Enhancing of Type 2 scourge marks as can be deduced from Fig. 12.

If the two Types are not related together as different parts of the same whip, they should be interpreted as the result of two distinct torture instruments.

Similar image processing has been applied to buttocks and legs and to calves (back body image of the TS, Figs. 14 and 15). In all cases, other bloodstains that could be classified neither as Type1 nor as Type 2 have been found (blue circles, see Figs. 12, 13, 14, 15). In buttocks area symmetrical stains not referred to scourging are highlighted in green (Fig. 14).

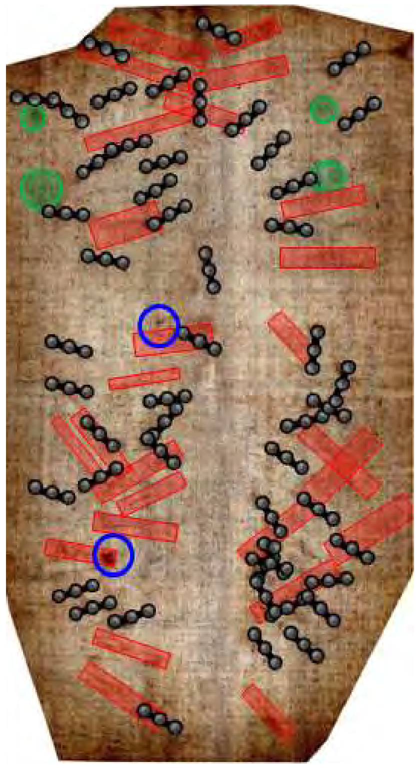

Figure 14. Detail of the back of the TS body image in correspondence of legs after processing.

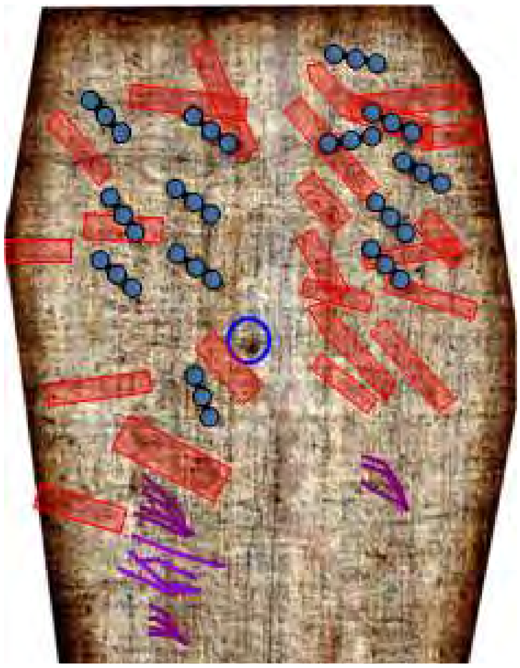

Figure 15. Calves area. Type 3 marks have been highlighted in violet.

Similar image processing has been applied to the frontal image. Here both Types are less evident and their color intensity is lighter, so a stronger contrast has been used in the "*contrast mask filter*". Results are shown in Fig. 16.

Detection of scourge marks, even after image processing, is difficult in quadriceps and shins areas, most probably because the contact between the body and the linen sheet was scarce or absent [14].

Type 1 and Type 2 scourge marks are visible together with Type 3 (violet layer) in Figures 15 and 16. It was previously supposed that Type 3 derived from the deformation of Type 2 caused by the wrapping of the flexible rods around the calve. Type 3 marks, however, are quite different from Type 2 ones and their origin is still debatable.

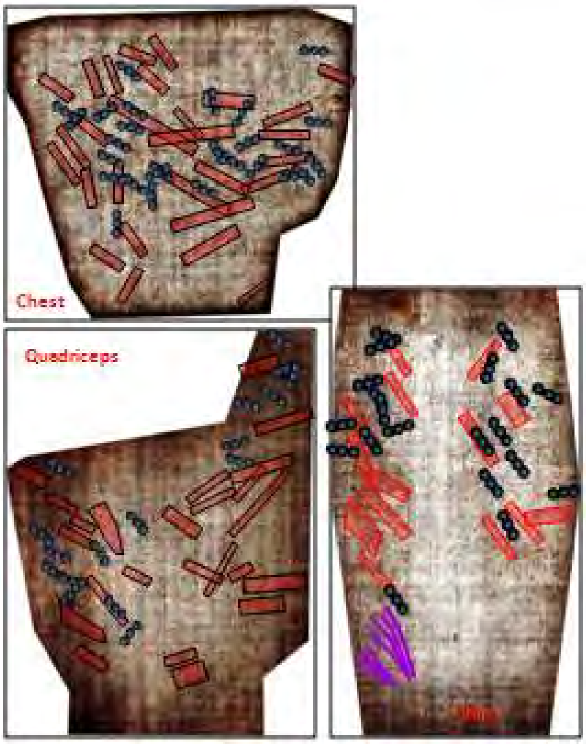

Figure 16. Type 1, Type 2 and Type 3 scourge marks in chest, quadriceps and shins.

4. EXPERIMENTS

Two experiments have been performed with the aim of reproducing the shape of the scourging marks visible on the TS. For both experiments a carbon paper has been placed on a white sheet, attached to a vertical cylinder having a diameter of 60 cm. To simulate muscle and skin, a cotton sheet has been put between the cylinder and the white sheet, and another cotton sheet has been added over the carbon paper, as reported in Fig.17.

First experiment: only flagrum.

About 50 blows were delivered with the home made flagrum replica of Fig. 18 having three leather straps armed with dumbell-shaped lead spheres.

The results of this first experiment are visibly comparable with those obtained by P. Vignon [15]. As it can be seen in Figures 19 and 20, overlapping zones of whipping generate blurred patterns, as those indicated in the blue circles of Figures 12, 13, 14 and 15, but only the metal spheres leave a mark, whereas the leather straps do not.

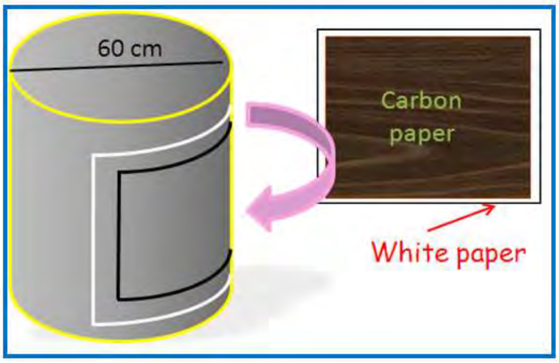

Figure 17. Experimental apparatus used to reproduce the shape of the scourge marks.

Figure 18. Flagrum replica used for the experiments.

Second experiment: rod and flagrum.

In the second experiment, the cylinder was hit by about 50 lashes delivered using a flexible pear rod (having a maximum diameter of less than 1 cm and thinning progressively at the end) and, subsequently, by about 40 lashes of the flagrum replica of Fig. 18.

The results are reported in Figs. 21, 22 and 23. Note that the elongated marks left by the rod are casually overlapped by the dumbell shape imprints relative to the flagrum replica.

Patterns generated using only the flagrum replica (Figs. 19, 20) are quite different from those observed on the TS (Figures 11, 14, 15), whereas patterns generated using both the flexible pear rod and the flagrum replica (Figures 21, 22, 23) better match the TS scourge marks.

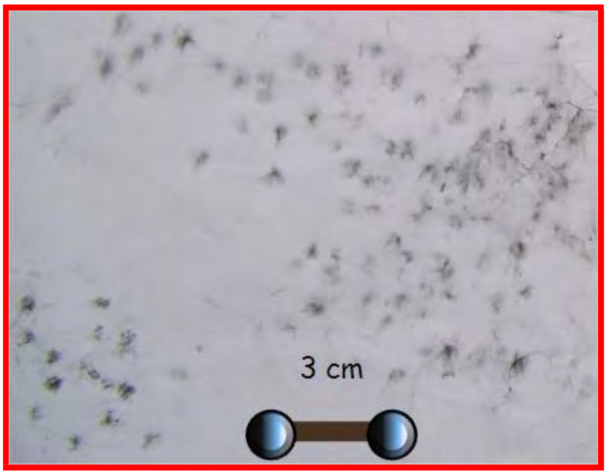

Figure 19. Experimental marks obtained using a flagrum replica.

Figure 20. Detail of experimental marks obtained using only the flagrum replica.

5. CONCLUSION

New image processing of the TS confirms the presence of 3 different kinds of scourge marks, related to the use of at least 2 different kinds of whips on the TS and much more faint; they look like a fan composed by 3 - 4 thin curved stripes.

Type 1 marks are characterized by two or three spheres (about 0.8 mm in diameter) connected by small bars, and are compatible with the signs left by a *Roman Flagrum*. Type 2 marks show relatively large and striate bands of variable length, similar to scratches and are compatible with flexible rods, like the famous "*Virgae*" used both as torture instrument and as power symbol by the lictors.

Type 3 marks are more rare (they occur less than 15 times).

Experiments simulating scourging gave imprints similar to those of the TS if both whips, the flexible rods and the

Figure 21. Experimental marks obtained using both a flexible pear rod and a flagrum replica.

Figure 22. Detail of experimental marks obtained using both a flexible pear rod and a flagrum replica.

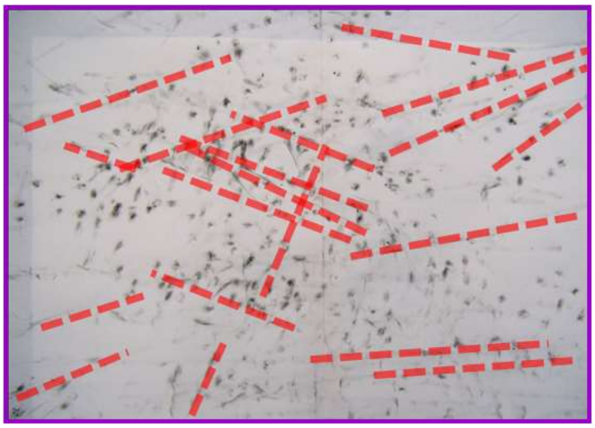

Figure 23. In analogy with Fig. 13, where Type 2 scourge marks are overlapped to the image of Fig.11, flexible pear rod patterns are evidenced with respect to the patterns let by the flagrum replica, to show the similarity of the experimental results with the TS.

flagrum, are used.

Type 1 and Type 2 marks frequently cross each other and are overlapped by other blood marks, like the so called "blood belt" and the outflows from the wrists, indicating that they preceded other tortures in the temporal sequence of the execution of the TS Man.

Type1 marks randomly overlaps Type2, leading to the conclusion that the TS Man was whipped with the Roman Flagrum, after being beaten with flexible rods.

In the hypothesis that the TS Man is Jesus of Nazareth dressed with a tunic which protected him from the next lashes, and knowing that Type 3 marks can be only found on the TS legs (probably not covered by the tunic), we can suppose that Type 3 marks are the result of the whipping of the TS Man during his uphill to the Calvary.

The number of flagrum lashes counted by the first author on the TS is 196, the minimum number of bloodstains produced by both kinds of scourging counted by the second author on the TS is 372 (159 on the front image and 213 on the back image).

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ShroudScope, a web tool to analyze high-resolution photographs of the Shroud of Turin

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Abstract
ShroudScope is a freely accessible Web tool to display very high-resolution photographs of the Shroud of Turin through a zoom-in and –out mechanism. ShroudScope, available at sindonology.org (aka dshroud.com), can also be used to do high-precision length measurements of various images and objects seen on these photographs. Predefined overlays that display various data over the photographs can be activated and deactivated at will. These capabilities can be done on two photographs: Enrie (1931) and Durante (2002). As far as we know, the ShroudScope has the highest resolution photographs of the Shroud of Turin, on the Web, worldwide.

Keyword: ShroudScope**,** Web tool, high-resolution photograph, length measurement

1. INTRODUCTION

ShroudScope is a Web tool to display high-resolution photographs of the Shroud of Turin, via a zoom-in and – out mechanism, activate diagram overlays and do length measurements over them.

By a "Web tool" we mean that the ShroudScope can be used via any popular browsers (e.g., Firefox) without any special "plug-in" or the need to install any computer software. The ShroudScope has been tested on Safari 4.0 and 5.0, Firefox 3.6, IE 7 and 8, and Chrome 6. The only constraint is that JavaScript must be turned on in the browser used; this is the default of popular browsers. Depending on the network speed connection of the user, the ShroudScope might take a few seconds before responding.

ShroudScope is accessible at the Sindonology Web site [1]. More specically, the ShroudScope is at [2]. It replaces a previous tool to do length measurements over Shroud photographs (also available at [1]).

We invite the reader to access the ShroudScope while reading this paper and try out some of the tools presented (see Figure 1 for the ShroudScope in its initial state).

The ShroudScope was motivated by the need to make accessible to a large audience, in an economical way, high-resolution photographs of the Shroud of Turin. We also believe that there is a need to provide a simple and easily accessible tool to do precise and reproducible length measurements on high-resolution Shroud photographs.

The ShroudScope can also be used to describe specific parts of the Shroud with text, graphics, diagrams, and small photographs overlaid on the high-resolution Shroud photographs. It offers permanent links that can record its current state (i.e., position, zoom level, active overlays, selected photograph) so that users can easily link what they exactly see from their own Web pages, documents, emails, or the bookmark toolbars of their own browsers.

The ShroudScope can currently display two different photographs: the 1931 Enrie photograph (shown in negative) and the 2002 Durante photograph (shown in positive).

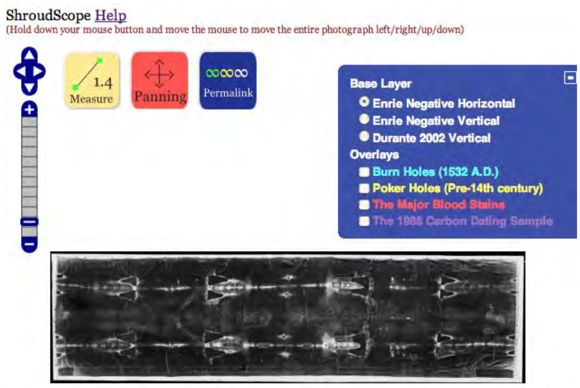

Figure 1. The initial ShroudScope Web page with the base layer selected as the Enrie Negative Horizontal photograph. The zoom level is on the second step of the ladder. The panning tool has a redish color: the photograph can be panned, that is the interface is in panning mode. At this point, the user can also click any overlay title to activate it, zoom-in or –out the Shroud photograph using the left ladder, start a measurement by clicking the measure icon, or ask for a permanent link to the current state of ShroudScope by clicking the permanent icon.

The Enrie photograph is in negative and has two versions: vertical and horizontal.

At the highest zoom-in level, the Durante photograph offers a resolution of 0.17 mm per pixel (a pixel is a dot on a computer screen).

As far as we know, this is the highest resolution photograph of the Turin Shroud publicly available on the Web.

The initial ShroudScope Web page contains several widgets, panels, and icons as shown in Figure 1. In the following paragraphs we give brief descriptions of them and more details are available in the following sections.

The *Switch Panel* is the blue rectangle panel that appears on the right side, near the top, of the Web page as seen in Figure 1. The panel can be minimized by clicking the minus icon and maximized by clicking the plus icon. The switch panel displays two lists: *Base Layer* and *Overlays*. The list of base layers is above the list of overlays. Each base layer is a photograph of the Shroud of Turin. Only one base layer is active at a time whereas several overlays can be active at the same time. Select the desired base layer and overlays by clicking their title or their radio button in the Switch Panel. Figure 2 shows one active overlay.

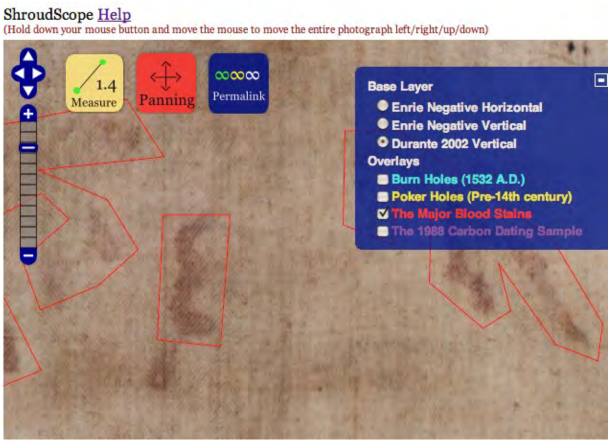

Figure 2. The ShroudScope with the Durante 2002 photograph selected. The Major Blood Stains overlay is also selected and traces the red polygons encircling the major bloodstains visible in the face, in particular the inverted “3” bloodstain. Mousing over these polygons would show tooltips.

The *ladder widget* is a blue widget in the form of a ladder with over 10 steps displayed on the left of the Web page as seen in Figure 1. It is used for zooming-in and -out the current active photograph (aka base layer). You can click on any ladder step to go directly to a specific zoom level. You can also use the plus icon to zoom-in or the minus icon to zoom-out.

The colorful rounded-square icons (see Figure 3) near the ladder and top of the Web page can be used to activate different tools. The tools are: measure, panning, and permalink. These tools are described in the following

Figure 3. The three tool icons. The yellow measure icon is to enable/disable the length measurement mode. The panning icon, shown as active, enables the panning mode to easily move the entire photograph in all directions using a click-and-hold mouse gesture. The blue permalink icon opens up a popup window displaying a URI link based on the current state of the ShroudScope; the user can save the link by drag-and-drop in an email, a browser toolbar, a document, etc.

sections. To activate a tool icon, simply click it. An icon that has a reddish hue means that it is active and that the state of the ShroudScope is in the state given by the icon. The permalink tool does not change the state of the ShroudScope. Currently, there are two states: measure or panning state. For example, when the panning tool is active no measurement can be done, and vice versa. A tool icon remains active until you click another tool icon. When you first visit the ShroudScope Web page, the panning icon is active. The panning icon enables you to move (or pan) the entire photograph on the Web page.

2. HIGH-RESOLUTION SHROUD PHOTOGRAPHS

A base layer is essentially the main Shroud photograph shown on the Web page. Currently, three base layers are provided: Enrie Negative Horizontal, Enrie Negative Vertical, and Durante 2002 Vertical. The first two base layers used the same photograph, but one is displayed vertically whereas the other is displayed horizontally. More base layers are planned for the future. The Durante 2002 photograph has the highest resolution. As far as we know, this is the highest resolution Shroud photograph available on the Web, worldwide.

The Durante photograph was done after the 2002 summer restoration. The patches that were stiched in 1534 were removed during that restoration. Some of the burned areas were also scrapped to remove the burned linen.

Note that the Durante photograph is in positive whereas the Enrie photograph is a true negative. In particular, the left side of the Enrie photograph is on the right side on the Durante photograph. For example, the right arm on the Durante photograph is on the left on the Enrie photograph.

To select a different base layer, click the title or the circle preceeding the title of the desired base layer. If the selection is different than the current displayed base layer, the current displayed photograph will be replaced with the new selected photograph at the same zoom level and at the same centered location as the current displayed one.

3. PANNING

Panning is required at some zoom levels since zooming-in will increase the level of the details and the entire photograph will become taller or wider than the size of the computer monitor.

Panning is the operation of moving the entire photograph left/up/down/right as if you were grabbing a piece of paper. When the ShroudScope is first displayed, panning can be done by holding the left mouse button and moving the mouse in the desired directions. The entire photograph will move. Therefore, the scrolling bars are not used to move the photograph. Likewise, if your mouse has a wheel, it no longer can be used to move the photograph. The wheel can actually be used for the zoom-in and -out operations (see next section).

Note that once the measurement tool is active, via the measure icon, panning is deactivated. You either need to reactivate panning by clicking the panning icon or you can use the arrow icons above the ladder to slowly pan the photograph.

4. ZOOMING-IN AND –OUT

One of the main functionality of the ShroudScope is the possibility to zoom-in or -out the Shroud photographs. This can be done in several ways: by clicking the ladder widget shown on the left of the Web page, by double-clicking on the photograph, or by using the mouse wheel. Essentially, this works in a similar manner as the well-known Google Maps.

Double-clicking always zoom-in and center the photograph at the double-clicking location. This is handy to zoom-in to a particular location on the Shroud photograph.

Clicking on any step of the ladder widget, which is on the left of the Web page, brings the Shroud photograph to the clicked level. A higher step on the ladder is a higher zoom-in. Depending on the speed of your network connection, your location (e.g., Europe vs USA), and the speed of the server, zoom-in might take sometime to display the photographs; typically it should take a few seconds (i.e., 2 to 8 seconds). Note also that caching (i.e., storing Web content locally on your computer) is typically done by a browser, so that a first visit to the ShroudScope takes longer to display the photographs than a repeated visit.

5. OVERLAYS

An overlay is a set of geometric figures drawn on a Shroud photograph that can be used to show data, text and small photographs. The geometric figures, drawn as polygons, circumscribe regions of the photograph. Each geometric figure has associated data, text, or photograph. These are shown in a small popup window, called a tooltip, when the user mouse-over the region of the geometric figure.

Each overlay can be made visible or invisible by simply clicking its title in the Panel Switcher. Figure 2 shows one active overlay on the Durante photograph.

When invisible, all geometric figures become invisible but the overlay itself is not removed from the Switch Panel. The overlay can be reactivated by clicking its title to make the geometric figures visible again. Four overlays are currently provided:

- Burn holes of 1532.
- Poker holes.
- The major blood stains.
- The 1988 radiocarbon dating sample location.

When mousing over a geometric figure a small popup window opens up to display the data, text, or small photographs associated with this geometric figure. For example, if the Major Blood Stain overlay is active and that the mouse is moved over the inverted "3" bloodstain, a small popup window opens up describing that bloodstain. Another example is the radiocarbon dating overlay. Mousing over the geometric figure showing the location of the sample of the radiocarbon dating, a popup window opens up describing that sample with a small photograph further describing the four segments of the sample, which dating laboratory received which segment, and so on.

6. LENGTH MEASUREMENTS

The icon with the label *Measure* enables you to do length measurements on any of the Shroud photographs at any zoom level. Figure 4 shows a length measurement that was done along the nose.

A length measurement is typically done using the following steps:

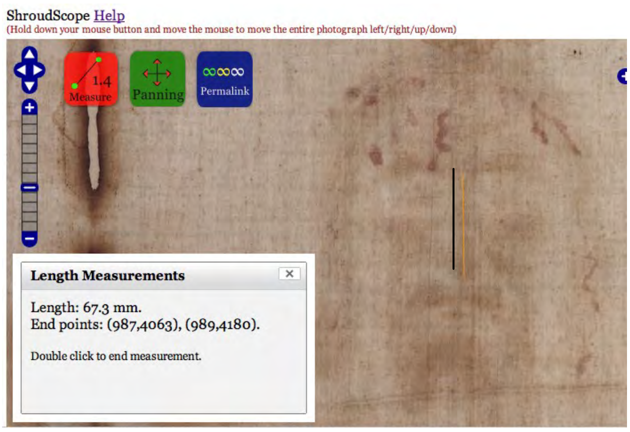

Figure 4. A length measurement was done along the nose on the Durante photograph. The measure icon has a redish hue: the ShroudScope is in measurement mode and no longer in panning mode. The black line shows the location of the measurement and the small popup window on the left shows the length as 67.3 mm (millimeter) and the two end-points of the yellow line as coordinates (987,4063) and (989,4180).

1. Select and center the photograph at the location where the measurement will be done.
2. Click the *Measure* icon; it will become redish.
3. Click on the photograph at one end of the object to measure; a small window will open showing the current length (0 mm).
4. Click, or double-click, on the other end of the object to measure; the small window will display the length in millimeters. The end-points of the measurement, in pixel locations, are also shown.
5. If on the previous step, you double-clicked, the length-measuring tool is ready for a new measurement. But if you clicked, you can continue measuring multiple segments: the measuring tool keeps adding the lengths.
6. To turn off the measuring tool, click the panning icon. You will also return to the panning mode.

To dismiss the small popup window showing the measurement results, click the small x icon in the top-right corner of the small popup window.

The end-points are given so that a measurement can be reproduced. Note that the end-points depend on the zoom level and the base layer. Therefore, not only the end-points but also the zoom level and base layer should be provided to anybody who would attempt to reproduce the measurements.

7. PERMANENT LINK (PERMALINK)

One of the useful ability of the Web is to reference any Web page with a unique address. Such an address is refered to as a URI (or URL in the specific case of the http protocol). A tool such as the ShroudScope has a URL, but this refers to the initial state of the ShroudScope. This is one of the difficulties of a Web tool such as the ShroudScope to be able to refer to a specific state of the Web page, once a series of operations have been done, such as activating some overlays, zoom-in to a specific location and/or selecting a specific base layer.

The permanent link solves this problem. When the permalink icon is clicked a small window opens up to display a Web link in blue (see Figure 5). This link was created based on the selected base layer, the overlays that are active, the zoom level, and the position of the center of the base layer.

Most importantly you can save the link by dragging and dropping it to any of the following:

- Your bookmarks folder
- The toolbar of your browser
- The desktop of your computer
- An email
- Any document (e.g., Word) that accepts the drag-and-drop operation

If you are familiar with HTML you can also embed such permanent links in your own Web pages. A Web page can describe various aspects of the Shroud and have a permalink centering and zooming on the location described.

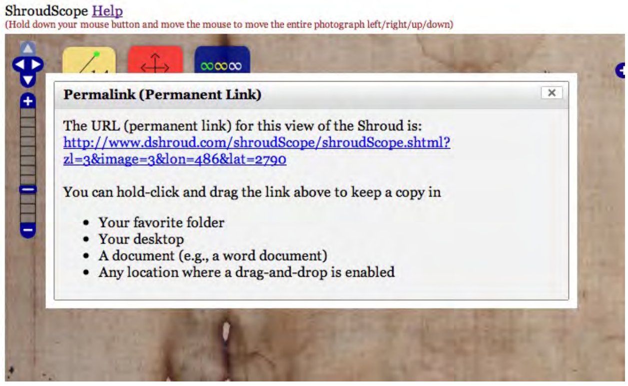

Figure 5. The permalink icon was clicked. A popup window opened displaying a URI link in blue. This link corresponds to the current state of the shroudScope. We can see that the image selected is noted "3" which is the Durante 2002 photograph; the zoom level is 3, and the central location of the image is at location (486, 2790). The link can be saved in many ways in particular by dragging it to the bookmark bar of the browser.

8. PHOTOGRAPHS RESOLUTION

It would be instructive to do a survey of details visible at the highest zoom level on the Durante photograph; the highest resolution photograph available on the ShroudScope. But this is outside the scope of this paper. We invite the reader to acces the ShroudScope tool itself to identify various details. Instead we can point out the level of the resolution of that photograph based on two examples. The first example, shown on Figure 6, shows a positive case of a clear identification: the thread used during the 2002 restoration. The second example shows a partial identification of a property often discussed by Shroud researchers: the distinction between real bloodstains and images of bloodstains or wounds. This second example demonstrates that there is a need for even higher resolution photographs available to Shroud researchers.

Figure 6 shows details that are specific to the Durante photograph because of the summer 2002 restoration. We can see the very fine threads used to fasten the Shroud to the back Holland cloth. Naturally, this is possible due to the high quality of the photograph done by Gian Carlo Durante after the restoration was done.

Figure 7 shows a famous bloodstain "image" detail on the arm. According to some researchers, what we actually see is one-half of a bloodstain, that is real blood that came in contact with the Shroud, and the other half is the image of blood or wound that gives us the impression of real blood on the Shroud. We cannot confirm yet this fact from this photograph but we can start seeing the difference between these two possible perceived images.

Photographs we higher resolution would be needed to confirm this important detail.

This detail is important as it would demonstrate the great subtlety of the relation between the image creation process and the more mundane blood tranfer that occurred due to Shroud coming in contact with a real bloodstained body.

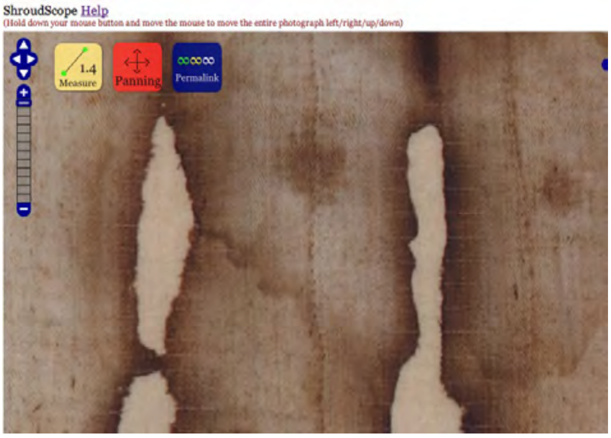

Figure 6. This is a zoom-in on two burned holes on the Durante photograph. This is the highest level of resolution available for this photograph. We can see the threads that were sewed after the 1534 patches were removed during the summer 2002 restoration. The tiny holes done to sew the 1534 patches are also visible. This closeup is from permalink [4].

Figure 7. The lower bloodstain in the form of tilted U is most likely from real blood on the Shroud, but is the segment continuing on the right real blood or an image of blood? We cannot yet confirm this fact with this photograph but this appears possible. This example shows the need for even higher resolution images. This closeup is from permalink [5].

9. IMPLEMENTATION

The ShroudScope uses an open-source JavaScript implementation of a projective mapping library called OpenLayers [3]. This library is typically used to display geographical maps with countries, cities, and roads. But in our case, only photographs are used. It is free of any commercial advertisements.

Since the entire ShroudScope is based on JavaScript and no other "plug-in," there is no need to install any software to use it. The entire ShroudScope works as a standard Web page accessible by most popular Web browsers. The ShroudScope was tested on several browsers: IE (versions 7 and 8), Safari, Firefox, and Chrome.

Each base layer and each zoom level is generated by a single photograph that was scaled and rotated appropriately then decomposed and sliced into 400x200px tiles. The appropriate tiles are fetched from the Web server and reassembled by OpenLayers when selecting a base layer and a zoom level. Tiles make it possible to send parts of the photographs at high zoom level. This reduces bandwidth and time to transfer high-resolution images, making the tool more responsive.

The Durante 2002 originial digital photograph used is a 500MB Tiff file. It was transformed into a JPG file then sliced at various scales. Zoom level 0 (the lowest) was generated by a 0.03 rescaling of the original photograph; zoom level 1 was done with a 0.05 rescaling; zoom level 2 uses a 0.1 rescaling and all subsequent zoom levels were done by increasing the rescaling by 0.1. In all, 12 zoom levels are prodvided.

The Enrie photograph was a 40MB Tiff file that went through a similar process. But since it has a smaller resolution compared to the Durante phototgtaph, the resulting zoom level photographs appear smaller.

The overlays are generated by the browser running the appropriate JavaScript code in OpenLayers. The descriptions of the overlays are encoded as JavaScript data structures. They were defined using a tool implemented in ShroudScope that is not currently available to users. In particular, the multi-line drawings describing parts of the Shroud images were done by drawing by hand over the Shroud photographs using that tool: the coordinates were generated by the tool and manually copied on the Web server.

A future version of the ShroudScope will let this drawing tool accessible to users so that they can create their own overlays.

The tooltips are actually not generated by OpenLayers but by additional JavaScript code and some Yahoo libraries.

10. FUTURE DEVELOPMENT

The actual ShroudScope (circa 2010) is a first version towards a more advanced tool to analyze Shroud photographs and data that can be overlaid on them. It is hoped that photographs with even greater resolutions will be one day accessible via the ShroudScope. Such photographs do exist, but their access is currently limited to a small number of people.

The tool is capable of handling photographs of almost any resolution. For example, a photograph with a resolution of less than 1/100 mm per pixel would allow a resolution beyond the thread level. It is possible that such photographs of the Shroud exist but we do not have access to them.

New overlays are currently being created and will be available in a future version of the ShroudScope. It is also planned to add a tool to the ShroudScope such that users can add private as well as public overlays. These user defined overlays could contain graphics, text, and photographs.

More advanced extensions are in the planning stage. For example, the ability to apply graphic transformations on the base photographs. Such transformations could be as simple as color inversion or as complex as Fourier transforms.

11. CONCLUSION

The ShroudScope is the first Web tool of its kind in Shroud research. It requires no special computer software installation and can be used with any popular browser.

The ShroudScope enables the general public, scholars, and researchers free and easy access at any time to very high-resolution photographs of the Shroud of Turin.

Using the ShroudScope, Shroud researchers can do precise and reproducible length measurements directly on the available photographs. They can also use it to pinpoint precise locations on the Shroud using the permalink tool when creating their own Web page, when communicating with other researchers via email, or in research papers.

The use of overlays allows the description of many parts of the Shroud photographs. They can be easily activated and deactivated at will without disturbing the main photograph.

Future developments include more overlays describing various aspects of the Shroud. Users will also be able to create overlays that can be saved for their own personal future reference.

ACKNOWLEDGEMENTS

We thank the Shroud scholars and researchers that provided access to very high-resolution photographs of the Shroud of Turin. The ShroudScope would not have been possible without their help. We also thank the reviewers of this paper for helpful comments.

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www.dshroud.com/shroudScope/shroudScope.shtml?zl=11&image=3&lon=2363&lat=16889

THE TURIN SHROUD TEXTILE

Dislocations in plant fibres and in Turin Shroud fibres

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Abstract

Some natural fibres contain dislocations, i.e. regions where the cell wall structure differs from that of the surrounding cell wall. Dislocations have also been found in Turin Shroud fibres. This paper gives an introduction to dislocations in plant fibres and dislocations found in flax fibres from the Turin Shroud are compared to dislocations in plant fibres of modern origin. None of the characteristics measured differed sytematically between Turin Shroud flax fibres and hemp fibres extracted from plants at harvest. However, fibres extracted from modern hemp yarn contained larger dislocations than the Turin Shroud fibres.

Keywords: Dislocations, slip planes, flax, hemp.

1. INTRODUCTION

The Turin Shroud is made mainly from flax textile fibres, and in this paper the dislocations within the cell walls of these fibres are studied. Dislocations are irregular regions within the cell wall and are present in several different plant fibres and tracheides already in the living plant. This is for example the case in flax, hemp and wood. A few natural fibres do not contain dislocations at the time of harvest. Cotton is an important example. Incidentally, neither silk nor wool contain any dislocations either. These materials originate from animals and consist of protein. Dislocations have also been called slip planes or nodes, but here the term 'dislocation' is used in accordance with [1]. Dislocations are not locations of cell wall formation / cell elongation, i.e. they contain no meristems and are thus not at all related to the macro-scale growth nodes (the so-called 'knees') present in grasses, in spite of the superficial likeness in appearances. Figure 1 shows two flax fibres from the Turin Shroud. The white bands across the fibres are the dislocations, which are here made visible by use of cross polarized light. Dislocations are normally not discernable using bright field light microscopy or using scanning electron microscopy [2], as they often affect only the inner secondary cell wall and not the outer primary wall.

The exact structure and composition of dislocations remains unknown. They are assumed to contain mainly cellulose, lignin and hemicellulose like the rest of the secondary cell wall. Traditionally dislocations are considered to contain amorphous cellulose in contrast to the surrounding cell wall, which contains crystalline cellulose. However, recent results indicate that this assumption is not correct as dislocations are birefringent just like the bulk cell wall [3], which indicates that the structure is not amorphous. By applying tensile load in the longitudinal direction of individual fibres, dislocations may be stretched and thus aligned with the cellulose microfibrils of the surrounding bulk cell wall [4], at least under some circumstances. This result indicates that the cellulose micro fibrils continue through the dislocations, i.e. dislocations may have a less 'ordered' and/or a more 'loose' structure, but they are not places where micro fibrils are discontinuous.

Figure 1. Polarized ligth microscopy image of two flax fibres from the Turn Shroud showing dislocations as white bands across the fibres.

As mentioned above, dislocations are present already in the living plant. They may however also be introduced during processing [5, 6]; compression strength applied in the longitudinal direction of the fibre will under some circumstances introduce dislocations. One may perhaps envision the process as an originally stretched accordion being pushed together. However, on the molecular level, intra-fibril and intra-fiber bonds are much stronger than inter-fibril and inter-fiber bonds. This means that both fibres and fibrils are less prone to forming dislocations than to shear (i.e. to glide past each other and breaking and reforming Hydrogen bonds, in a Velcro-like process). Which process is favoured is probably affected also by the moisture content as water is known to markedly reduce the glass temperature of lignin and hemicellulose. In other words, a dry fibre is less flexible.

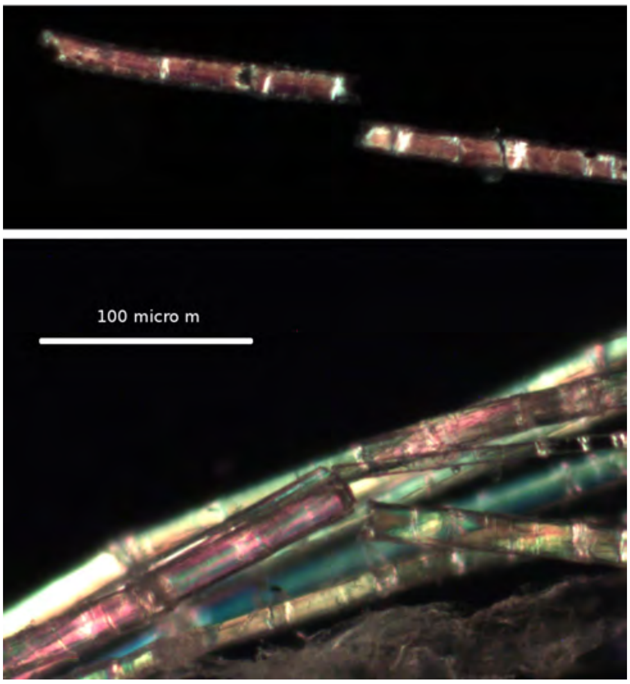

Figure 2. Two polarized ligth microscopy images of flax fibres from the Turin Shroud (top) and from a 1000 BC Lyme mummy wrapping (bottom). Both images show fibres broken in dislocations. The scale bar applies to both images.

Some of the characteristics of dislocations have been reported in the literature. Regarding long textile fibres such as flax and hemp, dislocations are known to bind dies better than the surrounding cell wall [7]. Other studies have shown that dislocations are more susceptible to hydrolysis than the bulk cell wall [3,8,9]. These results indicate that dislocations are more susceptible/reactive than the surrounding cell wall, i.e. they are in a sense the 'weak spots' of the fibres. Figure 2 shows Polarized Light Microscopy (PLM) images of Turin Shroud flax fibres and of flax fibres from a 1st century BC Lyma mummy wrapping. In both cases the fibres are seen to break into segments at the dislocations.

In the present study PLM and image analysis was used to measure the amount of dislocations, their sizes and the distance between them in five different data sets consisting of plant fibres: Turin Shroud flax fibres, hemp fibres extracted at harvest from plants grown under three different growth regimes ('wind free','windy','dry') and hemp fibres extracted from modern hemp yarn. The values are compared in order to determine whether the Turin Shroud fibres investigated differ from modern textile fibres with regard to dislocations. It is a weakness of the study that the Turin Shroud flax fibres are compared to modern hemp fibres and not to modern flax fibres. However, these two fibre types have similar dimensions and properties, which in the author's opinion justify the comparison. In a recent publication, it was pointed out that the two species may not be separated from each other using light microscopy [10].

2. EXPERIMENTAL

The modern fibres included in this study comprised four different hemp (*Cannabis sativa*, L.) fibre sets, each consisting of around 100 fibres. Three of these fibre sets were extracted from hemp stems by hand using precision tweezers. The hemp plants had been grown in a green house under three different growth conditions: 'wind free', 'wind' and 'drought'. The 'wind free' regime implied no wind at all during the growth season of the plants, and no lack of water or nutrients. The 'wind' regime implied wind night and day throughout the growth season; the wind came from constantly changing directions. The 'drought' regime implied wind free conditions, but minimum amounts of water and nutrients. For further details, please refer to [11]. The fourth set comprised fibre segments extracted from commercial hemp yarn, please refer to [9] for further details. The data used here is the reference data set of that study.

The Turin Shroud flax fibres included in the study were selected from two sets of fibre samples provided 2009 and 2010 by Professor Giulio Fanti, University of Padua. The fibres from a mummy wrapping (shown in Figure 2) were also supplied by Professor Fanti.

For the modern fibres, the dislocations in each of the fibre segments were identified by image analysis of micrographs obtained from polarized light microscopy using the automated method described in [12]. Based on the fibre and dislocation image masks produced by this method, three different parameters were calculated, all based on the 2D transmission images obtained from PLM: a) the relative dislocation area, i.e. the area of the dislocations in percentage of the fibre segment area, b) the absolute areas of the individual dislocations and c) the absolute longitudinal distances between neighbouring dislocations. The relative dislocation area was calculated for each individual fibre segment image, while all values found for each of the other two parameters were pooled for all fibre segment images within each data set.

For the Turin Shroud fibres, fibre and dislocation masks were drawn by hand and the same three parameters as for the modern fibres were calculated based on these masks. The reason why the automated method of [12] was not used for these fibres was that the method gives good estimates of mean values for populations of fibres, while values for individual fibres are less trustworthy [12]. Since only 20 fibre segments were analysed for the Turin Shroud flax fibres, the more cumbersome, but more trustworthy method of manual masking was chosen.

Table 1 gives an overview of the results. Regarding the relative dislocation area, the table shows that for hemp fibres at harvest, up to about 20 % of the cell wall consist of dislocations at harvest (the column marked 'Mean' for the 'Relative dislocation areas'). When comparing to the 12 % found in the wind free case, it can be seen that both wind and drought introduce dislocations, as reported earlier [11]. The growth conditions in this green house test were unusually harsh compared to European weather conditions, so natural textile fibres most likely contain somewhat less dislocations, but more than what was here found in the completely wind-free case, which may be seen as a lower boundary regarding the amount of dislocations in hemp fibres at harvest. The results confirm that industrial processing into yarn introduces more dislocations into the fibres. The Turin Shroud flax fibres are seen to contain the same amount of dislocations as modern hemp yarn fibres, the small difference seen in the relative dislocation area is not significant. However, when comparing the mean size of the dislocations found in these two samples, the dislocations in the Shroud fibres are seen to be significantly smaller than those found in the modern hemp yarn fibres, on average only about half the size. The size of the dislocations in the Shroud fibres is not significantly different from those found in the 'wind' and the 'drought' data sets. Perhaps the difference in dislocation sizes between the two processed fibres types is due to the modern hemp yarn being processed industrially while the textile fibres used for the Turin Shroud were manufactured by a gentler process resulting in more moderate damage. Regarding the average longitudinal distance between dislocations, the Turin Shroud fibres are not significantly different from the two harsh growth conditions, again suggesting a relatively mild processing. Surprisingly, the mean distance between neighbouring dislocations is seen to increase in the modern yarn compared to the average lengths found at harvest. A possible explanation to this is that the smaller dislocations disappear during processing due to stretching of the fibres. One can also imagine that dislocations merge with near by neighbouring dislocations, thus creating larger dislocations and removing the shortest distances. Dislocations in flax are known to sometimes cluster in certain regions rather than have an equal spread along the fibre [13].

Figures 3 and 4 give a more detailed representation of the results in Table 1. Figure 3 shows the cumulative frequencies of the dislocation sizes. The curve for the Turin Shroud fibres is seen to be close to the curves for the unprocessed fibres, but less smooth, again due to the smaller sample size. For these four sample sets almost all dislocations are seen to be smaller than approximately 200 μm^2. The dislocations in the yarn fibres are also mostly below this size, but about 15 % of them are larger than 200 μm^2.

Figure 4 shows the cumulative frequencies of the longitudinal distances between dislocations. For the two harsh growth conditions almost all distances are shorter than about 30 µm. The curve for the Turin Shroud fibres follows these two samples except for the last part as the maximum distances found are lower than for the two harsh growth conditions. However, the curve for the Turin Shroud fibres is based on a smaller data set and is consequently less smooth, so this result could be a coincidence. The wind free conditions resulted in longer distances between dislocations. For the three unprocessed fibre types as well as for the Turin Shroud fibres about 50% of the distances found are seen to be below 5 µm, while only about 20% of the distances are below this

TABLE 1. Data on dislocations in four different hemp fibre data sets. Mean values in the same column marked with the same letter are not significantly different (5% level or better according to t-tests). Columns marked 'n' give the number of observations, columns marked 'Std' give the standard deviations. Results marked +) are from [11].

Fibre source	Relative dislocation areas			Areas of dislocations			Longitudinal distances between dislocations		
	n	Mean [%]	Std [%]	n	Mean [μm^2]	Std [μm^2]	n	Mean [µm]	Std [µm]
Wind free (hemp)	96	$12.0^{a+)}$	8.5	1903	29^{a}	56	771	10.4^{a}	12.1
Wind (hemp)	98	$18.5^{b+)}$	12.8	2635	35^{b}	112	923	8.1^{b}	10.6
Drought (hemp)	114	$21.3^{bc+)}$	12.3	2783	41^{c}	116	959	8.0^{b}	9.4
Yarn (hemp)	95	24.0^{c}	9.6	1253	80^{d}	132	798	15.1^{c}	12.7
Turin Shroud (flax)	20	21.8^{bc}	10.1	267	38^{bc}	60	213	7.2^{b}	6.4

number for the modern hemp yarn.

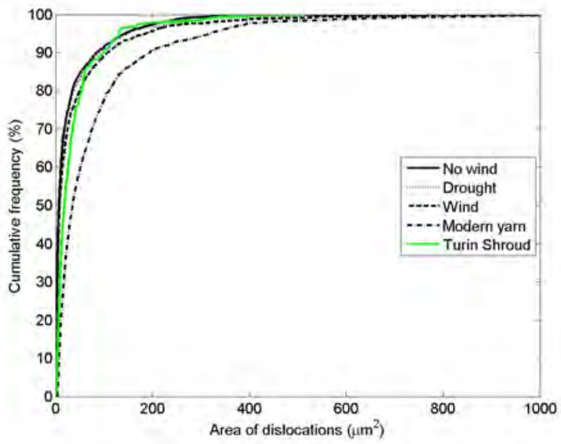

Figure 4. Cumulative frequencies for the absolute dislocation areas.

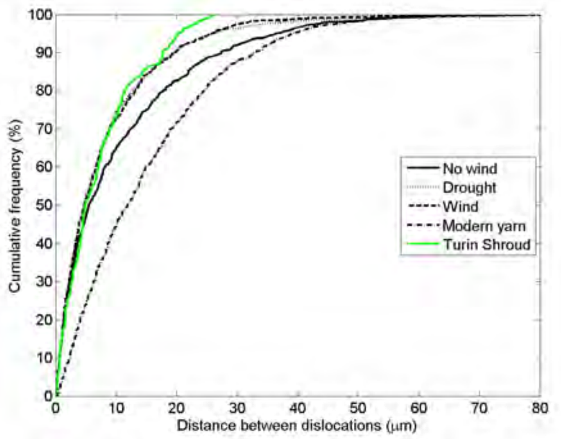

Figure 5. Cumulative frequencies for the longitudinal distances between neighboring dislocations.

3. CONCLUSIONS

Analysis of the dislocations in 20 flax fibre segments from the Turin Shroud indicated that the dislocations in Turin Shroud flax fibres appear to be similar in amount, sizes and distances to dislocations in modern hemp fibres. Regarding dislocations there is thus no indication that these fibres are different from other bast fibres. Dislocations are the weak spots of fibres, and some of the Turin shroud fibres investigated were seen to be broken into segments at the dislocations. This draws attention to the importance of handling these samples with care.

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List of Evidences of the Turin Shroud

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Abstract
This paper derives from a very wide discussion in the Shroud Science Group and from an in progress paper published in 2005. It has the aim to present all the evidences detected on the Turin Shroud that can be useful for a discussion about the problem of the body image formation. Many hypotheses about the image formation have been proposed, but, up to now, none, scientifically testable, simultaneously satisfies all the facts detected on the Shroud. For this reason this paper will be helpful for future researchers who will study and propose new hypotheses.
A list of facts directly related to the Turin Shroud is synthetically presented. They are subdivided in Type A that are, in the authors view, unquestionable facts and in Type B that are confirmed observations or conclusions based on a proof made in reference to Turin Shroud studies; in addition other facts or observations that were evidenced by some researchers but that are not accepted by others are also reported for completeness.

Keywords: Turin Shroud, Body Image, Characteristics.

1. INTRODUCTION

The Turin Shroud (TS) is believed by many to be the burial cloth of Jesus of Nazareth when he was put in a tomb in Palestine about 2000 years ago. It has generated considerable controversy but unlike other controversial subjects (e.g. ghosts), the TS exist as an archaeological material object: it can directly and objectively be observed [1, 2]. The results of studies can be analyzed by scientific methods [3].

The TS is a linen sheet about 4.4 m long and 1.1 m wide, in which the complete front and back body images of a man are impressed. The cloth is hand-made and each yarn (diameter about 0.25 mm) is composed of 70-200 linen fibers. It has been shown by many scientists that the linen sheet enveloped the corpse of a man who had been scourged, crowned with thorns, crucified with nails, and stabbed by a lance in the side. Also impressed are many other marks due to blood, fire, water and folding, which have greatly damaged the double body image.

The "Shroud of Christ" appeared in 1355 in Lirey, France. Before the sacking of Constantinople in 1204 there are some documents that refer to the presence of the TS: for example some characteristics of the Christ reproduced in some Byzantine coins (gold-solidus) of the 7th-13th century A.D. are very similar to those of the TS body image.

The TS has a front and a back image separated by a non-image zone of 0.18 m; the images show an adult male, nude, well proportioned and muscular, with beard, moustache, and long hair.

The TS has been radiocarbon-dated to 1260-1390 A.D. [4] but many scientists believe that the reliability of radiocarbon dating is not satisfactory because the linen underwent many vicissitudes (e.g., fires, restorations, water, etc.) [5, 6]. Recent robust statistical evaluation showed the presence of a non negligible bias in the data published [7]. It was also demonstrated that the 1988 sample is not representative of the whole TS [8].

Many hypotheses and experimental tests have been carried out on linen fabrics to explain the formation of the body image, both in favor of authenticity, and *vice versa* [1]. Despite macroscopic resemblance to the TS image which has often been achieved limited to the face, no individual or group has come close to reproducing all the characteristics found in the TS image. At first sight, the image, is similar to that of the TS Man, until now no experimental test has been able to reproduce all the characteristics found in the image impressed on the TS.

After the publication of an in progress paper [9] originally developed by the first author, and amended and agreed to by various members of the Shroud Science Group (SSG), presenting various characteristics of the TS, this paper presents in a more concise and organized form a revised and updated list of TS facts and observations.

2. LIST OF FACTS AND OBSERVATIONS

The following list is subdivided into Type A which refer, in the authors' view, to unquestionable facts and observations made on the TS and Type B which refer to confirmed observations or conclusions based on a proof made in reference to the TS. They are numbered as "An" or "Bn" where n is the evidence number.

Seeing things and not seeing things, is perhaps the biggest problem in legitimate Shroud research. "*I think I see*" and "*I don't see*" seems to be the underpinning of many "scientific" analyses. The brain-eyes system may plays tricks on the researcher. Because of a priori assumptions, it may be that he perceives things that conform to something searched for and conversely, he may fail to perceive images because of not knowing what various objects look like. In addition goal-oriented studies and experiments done without following all the standards, which are not rare in this field, can lead to debatable results. Some data or observations are not numbered because the observations are controversial supported by some researchers and contested or rejected by others.

The list of facts is subdivided in five categories to which the statements are related: General; Body image; Optics; Chemistry & physics; Blood & body fluids.

In consideration of space limitations, the facts have been stated in very synthetic terms, but the rich bibliography enclosed will allow the reader to go far more in depth in reference to the argument of interest. It must be added that for space problems, among the many bibliographic references relative to each statement only the first in time has been reported.

2.1. GENERAL

A1) **Traditional dimensions** of the TS of 436 x 110 cm [10] are changed after 2002 "restoration": one side (the lower considering horizontal the body image, with the frontal side on the left) measured 437.7 cm in 2000 and 441.5 cm in 2002; the opposite side measured 434.5 cm in 2000 and 442.5 cm in 2002; its height of 112.5 cm and 113 cm respectively on the left and on the right in 2000 but 113.0 cm and 113.7 cm in 2002 [11]. A measurement made in 1610 reports the following dimensions: 410 cm x 137 cm [12].

A2) The TS samples examined have **herringbone 3:1** twill weave [13].

A3) The **thickness** of the cloth measured by J. P. Jackson [28] with a micrometer is variable from 318 to 391 micrometers; the first author confirms this measurement [6].

A4) The yarn used to weave the Shroud was spun with a "Z" **twist** [14].

A5) After weaving, the TS yarns were **washed** with a very mild, natural material because of the presence of **flax wax** on the fibers and the specular reflectance of the non-image fibers [15].

A6) **Earthy material** (limestone composed of aragonite with strontium and iron) was found on the **feet** of TS Man [16]. Earthy material was also found in correspondence with the **nose** and the **left knee** [17].

B1) The TS linen has a **lustrous** finish [15].

B2) The so-called **side strip** is a linen band 387 cm long; the **sewing** connecting this strip to the TS is very particular and typical of very old manufacture [18].

B3) Some **water stains** are older than the 1532 fire because they indicate a **different folding** of the TS [19].

B4) **Cotton** fibers were found in the Raes samples and they were identified as *Gossypium herbaceum*, a common Middle East variety [14]. The first author also found 1-3% of cotton fibers in threads adjacent to the sample used in 1988 for dating.

B5) There appears to be more variation in the **diameter** of warp yarns than weft [15].

B6) The TS weave is **very tight** [14].

B7) The **limestone** found on the feet contains calcium [20] in the form of **aragonite**. Similar characteristics were found on samples coming from first-century tombs in Jerusalem [16].

2.2. BODY IMAGE

From a microscopic point of view.

A7) The body **image color** resides only on the **topmost fibers** at the highest parts of the weave [17, 21, 40].

A8) Body image **color** resides only on the **thin layer** that is probably the primary cell wall (pcw) of outer surfaces of the fibers; the **color is uniform around all the fiber circumference;** relatively long fibers show variation in color from non-image to image area [6, 40].

A9) Photomicrographs and samples show that the image is a result of **concentrations of yellow to light brown fibers** [17, 40].

A10) There is a very thin coating (probably the pcw) on the outside of all superficial linen fibers on Shroud samples that was named "**Ghost**"; "Ghosts" are colored (carbohydrate) layers pulled from a linen fiber by the adhesive of the sampling tape and they were found on background, light-scorch and image sticky tapes [22, 40].

A11) According to M. Evans' photomicrographs [21], the color of the image-areas have a discontinuous distribution along the TS thread: **striations** are evident. The image has a distinct preference for running along the individual fibers making up a thread, coloring some but not others

[17, 40]. Fibers further from a flat surface, tangent to the fabric, are less colored, but a color concentration can be detected in correspondence to crevices where two or three yarns cross each other [6, 40].

From a macroscopic point of view.

A12) The body image is **very faint**: reflected optical densities are typically less than 0.1 in the visible range [3].

A13) The body image has a **resolution of 4,9±0,5 mm at the 5% MTF value** (for example the lips); the resolution of the bloodstains is at least ten times better (for example the scratches in the scourge wounds) [23].

A14) The body image shows **no evidence of image saturation** [24].

A15) The image-formation mechanism **did not char the blood** [15].

A16) The body image **does not have well defined contours** [23].

A17) The **finger image** shows an intensity decreasing from the center (contact point) to the edges letting the space among them uncolored [6, 40].

A18) There is a **darker spot** in correspondence of the back of the Man's hand near the knuckle of index finger [2].

A19) The **thumbs** are not visible in the hand image [34].

A20) In correspondence to the **middle of the nose** there is a **swelling** [6].

A21) Detailed photographs and microscopic studies of the cloth in the nose image area show **scratches and dirt** [25, 34].

A22) The **hair** on the frontal image shows **high luminance levels** relatively to the face: for example the anatomically left hair is darker than the cheeks [6].

A23) There is **no** evidence of **lateral body images** and of **image between** the tops of the front and dorsal **heads** [26].

A24) In the positive photograph of G. Durante (2000), the **luminance levels** of the front and back body images (face excluded) are **similar**; the front image is generally about 15% darker than the dorsal one [27].

A25) The image of the **dorsal side** of the body does **not penetrate the cloth** any more deeply than the image of the ventral side of the body [28].

A26) The **luminance level of the head** image in the positive photograph of Durante (2000) is about 50% **darker** than that of the whole body image [27].

A27) The **image-forming mechanism** operated regardless of different body structures such as skin, hair, beard [2].

A28) The **thermograms** did not show part of the mouth image [29, 46], even if it clearly appears in visible light [30].

A29) After a heavy image processing, filtering and contrast enhancement, a body image **color** is visible on the **back surface** of the cloth in the same position of some anatomic details as for the body image of the frontal surface of the TS. The **hair** appears more easily to the naked eye [11] but also other details of face and perhaps hands appear by image enhancement [31].

A30) **No image** color is visible on the **back surface** in correspondence of the **dorsal** image [11].

A31) The nose image on the back surface of the TS presents the same extension of both nostrils, unlike the **frontal**, in which the **right nostril** is less evident [31].

A32) Image details corresponding to face **grooves** are more faintly represented (e.g. eye sockets and skin around the nose), convex "**hills**" on the face (e.g. eyeballs and nose tip) however are more clearly represented [32].

A33) Although anatomical details are generally in close agreement with standard human-body measurements, some measurements made on the Shroud image, such as **hands, calves and torso**, **do not agree with anthropological standards** [33].

A34) The body image shows **no** evidences of **putrefaction** signs, in particular around the lips. There is no evidence for tissue breakdown (formation of liquid decomposition products of a body) [34].

A35) **No image formed under the blood stains** [35].

A36) The front image shows **hair** that **goes down to the shoulders** [36].

A37) The image of the TS Man, appears as if he was **scourged** [34].

A38) The image of the TS Man, appears as if he was **crucified:** it appears with nail holes and corresponding blood at the wrists and top of the feet [34].

A39) The image of the TS Man demonstrates no evidence of **maiming** or disfigurement [34].

B8) The enveloped body was a **corpse** [34].

B9) The **hair** on the front image is **soft** and not matted as would be expected if it were soaked with a liquid [6].

B10) When their lengths are measured, the **dorsal image is longer** than the ventral image in a manner similar to the imprint on a sheet of a man having the head tilted forwards, his knees slightly bent, and his feet extended [37].

B11) The **frontal body image** (195 cm long) is **compatible**, within an uncertainty of +/-2 cm, with the **dorsal** image (202 m long) if it is supposed that the TS enveloped a corpse having the head tilted forward, the knees partially bent and the feet stretched forwards and downwards [37].

B12) Based on traditional cloth measurements [10], the image corresponds to **a man 175+/-2 cm tall** [37].

B13) The body image has the **normal tones of light and dark reversed** with respect to a photograph, such that body parts nearer to the cloth are darker [38].

B14) The luminance distribution of both the frontal and dorsal images has been correlated to the clearances between a **three-dimensional** surface of the body and a covering cloth [39].

B15) The luminance distribution of the body image can be correlated with a **highly directional mapping function** [24].

B16) The body image shows **non-directional light sources** in the sense that there are no shadows, cast shadows, highlights, and reflected lights in or on the body image [41].

B17) The absence of saturation implies that the **image formation did not "go to completion",** i.e. it did not produce the maximum number of conjugated carbon-carbon double bonds [42].

B18) In correspondence of image sections of cylindrical elements such as legs, the **luminance levels variation** approximates a **sinusoidal law** [6].

B19) In reference to a cloth wrapping a body, there is **no** evidence of body **image** formation at the **sides** of the body on both the frontal and dorsal TS images [26].

B20) The **Fourier transform** of the body image shows a nearly continuous spectrum in correspondence to the spatial frequencies up to 100 [1/m] [43].

B21) The body image indicates the **absence of brush strokes** [44].

B22) The frontal image, at least in correspondence to the head, is **doubly superficial** [31].

B23) The **fingers** in the image appear to be **longer** than average for a man, but they are still within the normal range (Gaussian distribution) [35].

B24) **Image distortions** of hands, calves and torso on the TS of are very close to those obtained by a man enveloped on a sheet [23].

B25) The very **high rigidity of the body** is evident on the back image especially in correspondence of the buttocks: the anatomical contours of the back image demonstrate minimal surface flattening [34].

B26) The **most of the prominent parts** in the vertical direction (nose, beard, sole, calf) of the body image **are marked** [6].

B27) The image of the TS Man, shows the effects (wounds) of many **pointed objects** [34].

B28) The **tibio-femural anthropometric index** of the image of the TS Man is 83%-84% [43].

B29) **No broken bones** are evident on the body image [34].

B30) There is a **swelling** on the **face** over the right cheek [34].

B31) There is a slight **deviation of the nose** and at the tip of the nose is an area of discoloration [34].

B32) A **body image** is visible in areas of body-sheet **non -contact zones,** such as those between nose and cheek [6].

B33) Characteristics of the TS face and right foot are close to those found on some **Byzantine coins** (gold-solidus) of the 7^{th} -13^{th} century A.D. [45].

2.3. OPTICS

A40) Optical measurement showed that the color is an extremely thin layer, about 200 nm thick (pcw has just this thickness) [40].

A41) The colored fibers in non-image (background) areas show the **same type of superficial color** as body image fibers, their spectra are the same, and the cellulose in them is not colored [42].

A42) The body **image does not fluoresce** in the visible under ultraviolet illumination [42].

A43) The **non-image** area **fluoresces** with a maximum at about 435 nanometers [17].

A44) A **redder fluorescence** can be observed around the **burn holes** from the 1532 A.D. fire [17].

A45) The cloth does **not** show any **phosphorescence** [15].

A46) All the chemical and microscopic **properties** of **dorsal and ventral** image fibers are **identical** [38].

A47) An emission **image** was clearly **visible in the 8-14 micrometers infrared** range, but the image appears as positive while it appears as negative in visible light [46].

A48) **IR emission** of the image at a uniform **room temperature**, and in the **3-5-micrometer range** was **below** the instrument **sensitivity** [46].

A49) The cloth shows **bands** of slightly different colors of yarn that are best observed in ultraviolet photographs. For example between face and hair there are two non-colored bands that continue along the warp direction [47].

A50) There is a **correspondence** (even if not complete) between cloth **bands** of slightly different colors of yarn of the front and **back surface** [11].

A51) Reflectance spectra, chemical tests, laser-microprobe Raman spectra, pyrolysis mass spectrometry, and x-ray fluorescence all show results **not compatible** with those relative to **painted** images with any of the expected, historically-documented pigments [3].

A52) There are **no pigments** on the body image in a sufficient quantity to explain the presence of an image [17].

A53) The cellulose of the **medullas** of the 10-20-micrometer-diameter fibers in image areas is **colorless** because the colored layer on image fibers can be stripped off, leaving colorless linen fibers [35].

B34) The **chiaroscuro** effect is caused by a different **number of yellowed fibers** per unit of surface, so that this is an image with 'areal' density [41].

B35) **Crease** below the **chin** of the image: on the frontal surface of the TS, the inside part of **crease** has a lighter color similar to the background, but it has darker margins similar to the image-color. On the back of the cloth, the same crease is darker in correspondence of the lighter color of the frontal surface and the margins are confused with the background: the darker margins are of the same straw-yellow color of the body image [15].

B36) In the **ultraviolet** emission and absorption photographs the **background** cloth shows a light **greenish yellow** emission [26].

B37) Where one of the **image-thread crosses over another**, there is often **no color** on the lower one [48].

B38) The image of the **dorsal side** of the body shows fairly the **same color** density and distribution as the ventral [38].

B39) **IR photograph** of the face made by G. B Judica Cordiglia, see Figure 1, if compared with visible photographs of the face indicates the **low absorption near the IR** of the products of image formation [49].

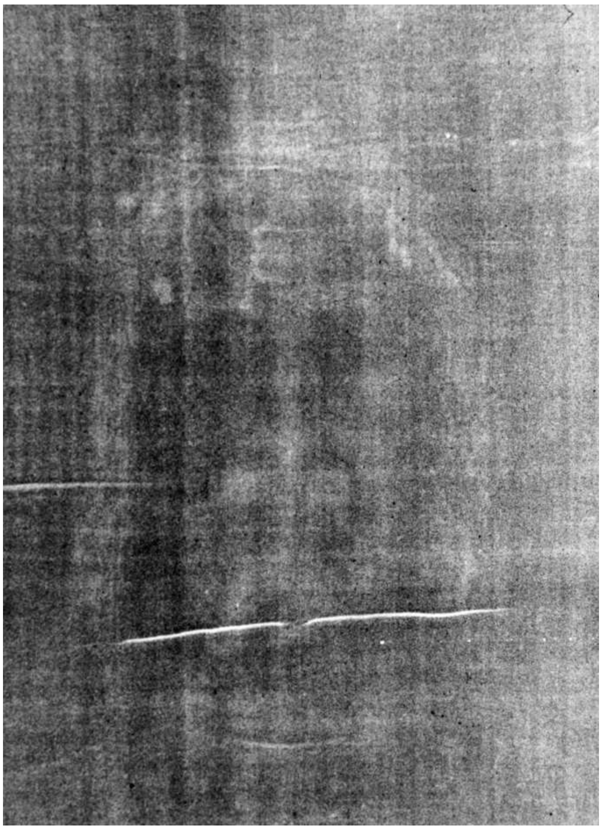

Figure 1. Unpublished IR photographic negative of the face of the TS Man, made by G. B. Judica Cordiglia [49] in 1969 using a Mamya camera and Nitraphot lamps. Due to the lack of time, an IR 24x36 film was used instead of a flat plate. If compared with a photo of face made in visible light, this IR photo evidences the lack of details and therefore the lower absorption near the IR due to the pronounced superficiality of the TS body image. (Courtesy of G. B. Judica Cordiglia).

2.4. CHEMISTRY & PHYSICS

A54) The colored coating cannot be dissolved, bleached, or changed by standard chemical agents, but it can be **decolorized** by reduction with **diimide** (hydrazine/hydrogen peroxide in boiling pyridine); the residue from reduction is colorless linen fibers [35].

A55) The pyrolysis/ms data showed the presence of **polysaccharides of lower stability** than cellulose on the surface of linen fibers (pcw) from the TS [15].

A56) The image was formed at a relatively **low temperature** (<200 °C) [15].

A57) The 1978 quantitative **x-ray-fluorescence-spectrometry analysis** detected significant uniform amounts of **calcium, strontium** (a normal impurity in calcium minerals) and **iron** concentrations in the Shroud [50].

A58) The **lignin** that can be seen at the wall thickenings and/or so called dislocations of the linen fibers of the TS does **not** give the standard **test for vanillin** [51].

A59) There is **no cementation** signs among the image fibers [17].

A60) **No painting pigments or media scorched** in image areas, or were rendered water soluble at the time of the AD 1532 fire [52].

A61) **No fluorescent pyrolysis products** were found in image areas [15].

A62) **Silver** traces were found around the burn holes in the scorch area of the TS [48].

A63) **Aldehyde and carboxylic acid functional groups were detected** in the TS fibers [35].

A64) There is **no** observed microscopic, chemical, or spectroscopic evidence for the presence of any **dry powder** responsible for the body image on the TS [8].

B40) The chemical **properties of the coatings (pcw layer)** are the **same** as the image color on image fibers. All of the color is on the surfaces of the fibers [35].

B41) The **crystal structure** of the cellulose of image fibers has **not visibly changed** with respect to that of the non-image fibers (scorches have) [15].

B42) Although yarns and design of Raes sample look like the main part of the cloth, linen fibers from the **Raes sample** that was cut in 1973 are chemically **different** (from reflected spectroscopy and chemical analysis) [53].

B43) Chemical tests showed that there is **no protein painting medium** or protein-containing coating in image areas [3].

B44) The image fibers do **not** show any sign of **capillary** flow of a colored or reactive liquid [21].

2.5. BLOOD & BODY FLUIDS

A65) Body fluids percolated into the TS by **capillary imbibitions** from the "warp side" to the "weft side" of the TS and they filled the mesh apertures [6].

A66) There is a class of particles on the TS ranging in color from red to orange that test as blood derived residues. They test positively for the presence of protein, hemin, **bilirubin**, and albumin; give positive hemochromogen and cyanmethemoglobin responses; after chemical generation display the characteristic fluorescence of **porphyrins** [8].

A67) The blood on the TS is **not burnt**. Therefore both the image-formation mechanism and the 1532 fire did not involve processes that would denature the blood [15].

A68) The **blood** from the large flow on the back **darkened** (scorched) at an adjoining **scorch** [15].

A69) The **red flecks** W. C. McCrone [54] claimed were hematite had an **organic matrix** [48].

A70) Microscopic observation of **blood flecks** of sample 3EB showed specular reflection: **the blood went onto the surface as a liquid** [15].

A71) **Blood** spots are much **more visible on the TS by transmitted light** than by reflected light; this implies that the blood saturated the cloth and it is not a superficial image as the body image is [15].

A72) Many **blood traces** visible on the frontal image are also visible **on the back** side in the **same position** [6].

A73) Blood traces on the back surface of the TS are less intense (or in some cases absent) when compared with the corresponding traces on the frontal side, showing that **blood was transposed** onto the cloth **touching the frontal** side of the TS [6].

A74) Some human **blood** stains appear on and **outside of the body image** (right elbow) [55].

A75) In proximity to the **knees** on the dorsal image, there are scourge marks in correspondence to **lower luminance levels** of the body image [6].

A76) The **blood** on the TS **does not fluoresce** under ultraviolet illumination (no porphyria and no fluorescent pigments) [15].

A77) The **blood** on the TS can be removed with a **proteolytic enzyme** [8].

A78) **No smears** and no broken crusts are evident in the blood traces [34].

A79) **No potassium** signals could be found in any of the blood area data [50].

A80) In UV fluorescence the **scourge** marks appear with **dumbbell shapes** [34].

A81) In UV fluorescence the **scourge** marks are resolved into **fine scratches**: three, and in some cases four, parallel scratches can be distinguished [34].

A82) The blood stain corresponding to the right side of the **chest** 6th ribs shows **separation of blood** from a clearer liquid material [34].

B45) There is a first **type of blood** stain that corresponds to the blood **exudated from clotted wounds** and transferred to the cloth by being in contact with a wounded human body such as scourging and crown of thorns wounds or wrists wounds [8].

B46) There is a second **type of blood** stain that came out after the death such as feet wounds or side wound with blood separation in a dense part and a serous part [56].

B47) The UV photographs of blood stains show a distinct **serum clot retraction ring** [8].

B48) The chemical and physical parameters of the **blood stains are different** than mineral compositions proposed by **artists** [8].

B49) The maintenance of the **red bright color** of the TS **blood** with time was observed, but the explanation of why the color is so red is not definitive [56].

B50) There are **blood traces not consistent** with scalp hair traces soaked with blood in correspondence to the image of the **hair** on the front side [57].

B51) The **wrist wound position** can be referred to as the hand nail used for the crucifixion [6].

B52) The **blood clots** were transposed to the linen fabric during **fibrinolysis** [58]. The process of fibrinolysis could cause clots to liquefy sufficiently for the blood to transfer to the cloth as a serous-laden liquid rather than a moist jelly-like substance [59].

B53) Some blood stains are comparable to transfers that would be expected if the arms were posed in **non horizontal position** [57].

B54) Some **bloodstains** such as those on the arms and the “reverse-3” on the forehead present a **discontinuity** in which a more attenuate region is evident [60].

B55) Some blood stains are comparable to transfers that would be expected if a person was posed in the **vertical position** [57].

2.6. OTHER

Among the many facts and observations made by some scholars, but not confirmed by others, listing them can be useful to suggest and motivate new studies.

The TS face shows no sign of pain, in spite of the horrible mistreatment of the body [61].

The **radiocarbon dating** of 1988 states that the TS linen dates back to 1260-1390 A.D. [4], but further statistical studies [5, 6, 7] demonstrated the presence of a linear bias which makes the sample not representative of the whole TS. Preliminary estimates of the kinetics constants for the loss of **vanillin** from lignin indicate a much older age for the cloth than the radiocarbon analyses [51].

Aloe and myrrh were recognized by microscopic analysis [62]. A **ponytail** (also interpreted as "banding" by others) is visible on the back image [2]. There is the image of an identified **coin** (dilepton lituus) on the right eye [63]. Perhaps there is also another an image **coin** (Pilate lepton simpulum) over the **left** eye [64]. There are various **writings** around the Face [65].

There are many identified **floral images** on the TS, which indicate that the Shroud originated in the vicinity of Jerusalem in the spring of the year, and which have the appearance expected from corona discharge. Some images are consistent with the **fruits** of pistacia plants, which were used as burial spices [66]. **Pollen grains** relative to the zones of Palestine, Edessa, Constantinople and Europe were found [67, 68].

Some **teeth**, the **skull**, some **bones,** a **sponge**, a large **nail,** a **shaft** and a **crown** of thorns have been recognized on the image [30]. Traces of **saliva** [32] and of **tears** can be seen on the image [69].

The human blood is of **AB group** [70]. **Human DNA** is present in Riggi’s blood samples taken from the TS; three gene segments were cloned and studied but it is highly **degraded** [71]**.**

3. CONCLUSION

The first goal proposed by R. Rogers in 2002 and accepted by many researchers of ShroudScience Group in order to better understand the TS, has been reached. A list of evidences of the TS upon which to base their further debate on the body image formation hypothesis has been defined according with the authors’ view, even if the TS characteristics are not definitive. Some open questions will be easier to solve if the Turin officials will be open to share their TS data, and especially those obtained from

2002, with e.g., the Shroud Science Group and to any credible researcher interested in the study about the most important Relic of Christianity.

Many hypotheses are still under investigation and new ones will be proposed. The facts reported in this paper will be useful for the proponent of a new hypothesis who should test it against the reported facts in order to be sure that his hypothesis will not be immediately eliminated by a simple scientific control.

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ARCHAEOLOGY AND HISTORY

Akeldama repudiation of Turin Shroud omits evidence from the Judean Desert

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Abstract
The claim by noted British and Israeli archaeologists that shroud fragments recently excavated at the Akadelma tombs site in Jerusalem disprove the authenticity of the Turin Shroud is shown to be false on the basis of ancient textile evidence from the Judean Desert and elsewhere. In addition, the frequent criticism by skeptics that the size of the Shroud is too large to have been produced on first-century looms is conclusively refuted.

Keywords: Akadelma, cave, tomb, textile.

1. A FALSE COMPARISON

On December 17, 2009, the world press erupted with new denunciations of the Shroud of Turin [1].

"Shroud of Turin Not Jesus's, Tomb Discovery Suggests," read the headline in *National Geographic News*. "The newfound shroud was simply woven linen and wool textiles (....) The Shroud of Turin, by contrast, is made of a single textile woven in a complex twill pattern, a type of cloth not known to have been available in the region until medieval times, [archaeologist Shimon] Gibson said." "Assuming the new shroud typifies those used in Jerusalem during the time of Jesus, the researchers maintain that the Shroud of Turin could not have originated in the city" [2].

"There have now been only two cases of textiles discovered in Jewish burials from this period," said archaeologist Amos Kloner of Bar Ilan University. "And both appear to contradict the idea that the Shroud of Turin is from Jesus-era Jerusalem" [3].

The *Daily Mail*: "Archaeologists have discovered the first known burial shroud in Jerusalem from the time of Christ's crucifixion - and say it casts serious doubt on the claimed authenticity of the Turin Shroud.... It was made with a simple two-way weave - not the twill weave used on the Turin Shroud, which textile experts say was introduced more than 1,000 years after Christ lived" [4].

This type of "reporting" was based on one research article, "Molecular Exploration of the First-Century *Tomb of the Shroud* in Akadelma, Jerusalem" [5]. The article never referred to the Shroud of Turin, nor did the concurrent news release from The Hebrew University [6]. Probably this discovery of shroud fragments would not have garnered such attention if the popular press had not connected it with the Turin Shroud.

2. DISCOVERY

The Akadelma shroud fragments were found entirely by chance, not unusual in the realm of archaeological discovery. As Professor Shimon Gibson describes it [7] "It was during an excursion I made in 2000 with a colleague, James Tabor, and some of his students to the well known ancient cemetery of Akeldama situated in the lower Hinnon Valley. (....) One of the students drew our attention to... broken stone ossuaries lying scattered about outside a tomb entrance..." They found it was a fresh break-in, with destruction and plunder.

"It was while clambering around in the lower chamber of the cave that I noticed the blackish remains of what looked like a shroud, mingled with a layer of fragmentary human remains, in one of the side loculi. (....) I immediately realized that a relatively well preserved burial shroud in a first-century tomb in Jerusalem would be a unique find" [8].

Figure 1. Wool textile fragment from Akeldama, radiocarbon dated to 50 B.C.E. - 95 C.E.

3. ATYPICAL OF JEWISH BURIAL CUSTOMS

The tomb is said to have all the typical features of first-century tombs in Jerusalem, except for one striking feature. This and other burials in the cave tomb, later found to contain members of the same family, were sealed with hard white sealing plaster – "quite rare," according to Gibson [9]. White plaster around the edges of the openings of several adjacent loculi clearly indicates that they also were originally sealed shut. The sealing plaster indicates that the family had not intended the customary secondary burials in ossuaries, which in fact did not take place. These were atypical burials, differing from what is known to have been usual in first-century Jewish practice.

Subsequent molecular DNA analysis determined that the remains were of an adult male who had been infected with both leprosy and tuberculosis. Tuberculosis was most likely the cause of death. Mitochondrial DNA analysis showed that this was definitely a family tomb. Three other tomb occupants, two of whom were infants, were also shown to have suffered from tuberculosis. It is reasonable to conclude that the reason for the atypical, sealed burials was fear of contamination.

4. THE BURIAL TEXTILES

A sample of textile from the tomb was tested by AMS radiocarbon dating at the University of Arizona. It was reported to reveal "without question that the shroud was from the beginning of the first century C.E." Some fragments were determined to be of wool, either of sheep or goat hair. Others from the head area, the largest of which "was about 16 cm. in size," were of plant origin, probably flax. Since various fragments of both groups, plant and wool, varied according to S or Z twist, it appears that the wrappings were composed of not two, but at a minimum four pieces of cloth. Thus it was not a "shroud" at all. Probably, the man was buried in various pieces of his clothing, as there is historical evidence in rabbinic sources as well as clear archaeological evidence for burial in multiple garments of clothing [10].

The assumption by Gibson, Kloner and others that the burial textiles from the "tomb of the shroud" at Akeldama typify those used in Jerusalem during the first century is over-reaching, without foundation and contradictory to abundant archaeological evidence. Any attempt to extrapolate from these fragments alone, out of no doubt many thousands of burial cloths that did not survive, that all must have been of multiple pieces, and that all must have shared the same type of weave, and therefore any burial textiles differing from these fragments cannot be authentic, is statistically invalid.

Although these archaologists have been careful to stipulate burial textiles "from Jerusalem," abundant evidence from ancient burial cloths from excavated sites in the Judean Desert and elsewhere contradicts their claim that the Turin Shroud differs remarkably from other documented burial cloths. Twill-weave textiles, shroud fragments, and intact or nearly intact shrouds have been excavated at various sites.

5. CAVE OF THE WARRIOR

The Cave of the Warrior, so-called, just two miles northwest of Jericho, is a small narrow fissure in a cliff. Owing to its small dimensions, it could never have been used for habitation. It was found by Israeli archeologists in 1993 during a search for additional Dead Sea Scrolls near Wadi el- Makkukah [11]. Were it not for the chance discovery of a Hasmonean coin near the entrance, it is unlikely that the cave would have ever been found and excavated. Another accidental discovery, this time of a 6,000-year-old burial.

Against the background of relatively plain and fragmentary cloth remains such as those from Akeldama, the textiles from this nobleman's burial are unique both aesthetically and technologically. Three separate textiles comprise the bundle that was found along with sandals, mats, a wooden bowl, a staff and the skeletal remains. When the bundle was opened, conservators discovered a long, narrow sash with an intricately woven fringe, a rectangular cloth, presumably some sort of kilt, and a

Figure 2. Calcholithic linen shroud *ca.* 4000 B.C., 7 m. × 2 m. (22' 11" x 6' 6").

large wrapping sheet, apparently a shroud used to wrap the body, as indicated by the pattern of disintegrated areas.

This 6,000-year-old shroud is a large, rectangular linen cloth, 7 meters (22' 11") long and 2 meters (6' 6") wide. Even though about a third of it is missing, it could still be reconstructed on the basis of surviving parts. The pattern of the stains and the missing areas creates a mirror image, indicating that the textile had been folded twice in antiquity, forming a four-layered wrapping, in which the body of the deceased was placed. The four layers were then sewn together, "as is evident from rows of small holes in each layer" [12].

One might think from size of the cloth that it had been assembled from several pieces. However, it was designed and manufactured as a single sheet. The edges were decorated by bands of a more elaborate weave, incorporating brown and black threads. These were further enhanced by a fringe of long tassels, tied by hand after the cloth had been woven.

Figure 3. Team of Bedouin weavers using a ground loom.

The impressive width of the cloth indicates that it was woven on a ground loom with beams of more than two meters long. This "could not have been accomplished by a single weaver, nor even by two, as often depicted in Egyptian wall paintings" [13]. Three, even four weavers would have been required, as is still practiced by Bedouin weavers. The weavers are thought to have been exceptionally experienced to have produced textiles of such high quality. Dr. Tamar Schick, author of the textiles section of the Israeli Antiquities Authority Report on this discovery, comments: "The warrior's textiles are exceptional in size, accomplishment, refinement and state of preservation. It is, however, unlikely that they were unique in their time" [14]. In other words, she believes that it is likely there were other such exceptional textiles from the Chalcolithic period.

The Turin Shroud has been disparaged by skeptics for being too large to have been produced as early as the first century. These textiles from the Cave of the Warrior, produced 6,000 years ago, absolutely nullify this objection. Large textiles of one design and manufacture are also known from Egypt [15].

6. QAZONE, JORDAN

Burials in Jerusalem in the second-temple period and later tend almost always to be cave burials, unlike the vast cemetery of shaft graves at Qumran, considered to be remains of an Essene community. At Khirbet Qazone, Jordan, located on the eastern shore of the Dead Sea, 3500 such shaft graves were recently discovered. These have been dated to the second and third centuries C.E. [16].

Forty-two pieces of textile shrouds have been found from the fifty graves that have so far been excavated at Qazone. Some burial textiles, mantels and scarves remained in intact or almost intact condition. This includes an intact burial shroud dating from the second century, C.E. It is difficult to tell from the photograph whether this consists of one piece which wrapped the entire body, or whether there was also a second piece wrapped around the head. In any case, it appears to involve at least one large piece of cloth. I might add that some of the Qazone bodies were buried in leather shrouds made from several animal skins stitched together. Thus we can't say, as the Akeldama excavators maintain, that fragmentary remains of one burial must be the paradigm for many thousands of other burials.

Figure 4. Woolen burial shroud, *in situ,* Qazone, Jordan, *ca.* second century C.E.

7. MURABBA'AT

At Murabba'at, the site of numerous manuscripts and artifacts in line with the finds from Qumran, archaeologists and textile experts Grace M. Crowfoot and her daughter Elizabeth Crowfoot recorded seven twill-weave fabrics, including a dark blue cloth of fine and regular *herringbone* twill weave (2:2) with Z spun warp threads and mixed S and Z spun weft threads, probably imported [17]. The report did not include a photograph of this textile.

8. MASADA

Numerous textile fragments were discovered at Masada by the Yadin excavations in 1963-65. Avigail Sheffer and Hero Granger-Taylor, archaeologists with the Israel Antiquities Authority, recorded in their preliminary report fourteen twill weave textiles [18]. These include several textiles in diamond twill weave, which is actually a more complex variation of the herringbone pattern, as the direction of the diagonal is reversed periodically, ultimately forming diamond patterns in the cloth [19]. Most of the textiles found at Masada were imported from Anatolia and farther north, from Germany, according to expert textile analysts. The worn and patched condition of these imported textiles of intricate weave indicates well-to-do people fallen on hard times.

Figure 5. Complex diamond twill, Masada. Wool, red dyed with madder, 7 × 3.5 cm.

It is a good question why we have so many fragments and so few intact cloths. In areas such as Jerusalem, with its very wet and humid winter, consequent deterioration of virtually all textiles is to be expected. The shroud fragments from Akeldama were a fortuitous exception because that particular loculus was placed very high in the cave wall, well above a small fissure of seeping water which infiltrated the cave. Moreover, it was tightly sealed with plaster, and so was not exposed to the same degree of humidity as it might otherwise have been [20].

But what of the many textiles in the Judean Desert, namely, at Masada? We remember that the soldiers who crucified Jesus threw dice for his robe, apparently an unusual, seamless (John 19:23) garment of high quality. Cloth of any kind was the work of months of toil and consequently even the plainest tended to be expensive and was prized booty in the Roman world. Complete garments, even if worn or patched, whenever and wherever they could be found, were taken by Roman soldiers as part of their expected, unofficial compensation.

9. CAVE OF LETTERS

In his monograph, *The Finds from the Bar Kochba Period in the Cave of Letters,* Yigael Yadin listed among the textile fragments found there a woolen cloth woven in a twill pattern, the only twill textile found at that site [21].

10. CAVE OF TREASURE

In the Cave of Treasure, at the archaeological site of Nahal Mishmar, located just southwest of Masada, numerous textiles were found, including linen shroud fragments. These were probably clothing of the deceased used to wrap the body. These were dated to the 3rd millennium B.C.E., on the basis of archaeological evidence and C-14 tests on other objects found in the cave. More than a hundred linen and woolen samples were uncovered in the Chalcolithic stratum from this cave. Superbly decorated art objects were found in this and nearby caves from the same period. The cave of "treasure" was so named due to the hoard of artifacts, including ivories, found wrapped in a mat and hidden deep in a crevice [22].

11. ADDITIONAL CORROBORATING EVIDENCE

My primary purpose has been to draw attention to evidence from the Judean Desert, which was overlooked, if not suppressed by the excavators of the Akeldama fragments, but there is much corroborating evidence from elsewhere of early twill and herringbone weaves.

The Tyrolian Hiker – Dr. Mechthild Flury-Lemberg has shown that the herringbone pattern existed not only during the first century of our era, but long before. She has published a study of woolen leggings (54.6 cm. x 15.7 cm,) found on the frozen remains of a man discovered in the permafrost of South Tyrol in 1994 [23]. They are made of coarse goat hair, and woven in a 2:2 herringbone pattern. The leggings have been dated to *ca.* 800 to 500 B.C.E.

Figure 6. Legging discovered in permafrost, South Tyrol. Wool, 2:2 herringbone weave, c*a.* 800 – 500 B.C.E.

Herringbone Textiles from Northern Europe -- John Tyrer discussed the high development of spinning and weaving "at the dawn of history" [24] pointing to the early production of linen textiles in Europe, where the Z spin predominated. In this diagram, he compares the herringbone pattern of the Shroud of Turin with those of two cloths from northern Europe woven in herringbone patterns. On the left is the pattern of the Shroud of Turin. In the middle is the pattern of a fragment of a silk shroud with a reversing five-shaft satin weave that was found in a child's coffin in Kent, dating from Roman times. The third is the herringbone pattern of a cloak found in a peat bog at Gerumsberg, Sweden, woven in a 2:2 herringbone pattern and woven without seam. It has been dated to early in the first millennium, about 900 B.C.E. The threads of both these textiles were spun with a Z twist.

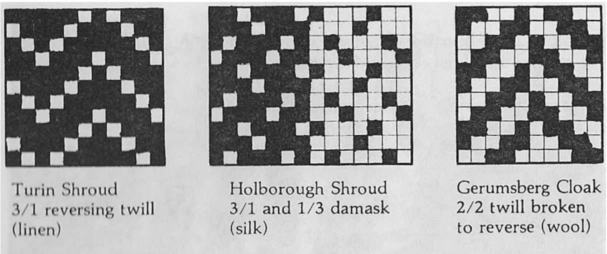

Figure 7. Ancient Herringbone Variations.by John Tryer.

Dura Europos -- Archaeologists R. Pfister and Louisa Bellinger catalogued numerous twill weave textiles among fabrics excavated at Dura Europos, *ca*. 300 B.C.E. to 256 C.E. [25].

Egyptian Herringbone Linens -- There is a super-abundance of very well preserved linen textiles from Egypt. Pietro Savio published a cloth woven in a herringbone pattern, dated to 130 C.E., discovered in the excavations of the necropolis at Antinoë [26]. Among the many examples described by Petrie and Mackay are a number of pre-dynastic burials involving large textiles with the characteristic selvedge fringe. In one example, a long cloth lay below the body and was folded over it in the same manner as the Shroud of Turin [27].

Figure 8. Linen Sash of Rameses III, *ca.* 1180– 1150 B.C.E. Alternating herringbone patterns of 3:1/4:1/5:1

Another important example is the girdle (or sash) of Rameses III, who reigned during the middle of the twelfth century B.C.E. It is characterized by an intricate design and excellent workmanship. It is woven in five colors, in a design consisting of 3:1 herringbone twill, alternating with 4:1 and 5:1 herringbone twills. This sash is 17 feet in length and tapers in width from 5 inches down to a little less than 2 inches [28].

Pompeii – Vignon published a photograph of a textile woven in 2:2 herringbone twill from the first century C.E. [29] and listed several other comparable twill textiles, including diagram [30].

12. CONCLUSION

Archaeologists who have asserted that the weave of the Turin Shroud was unknown until it was introduced in Europe a thousand years after Christ possibly have been misinformed, despite evidence which should be very well known to textile experts working with them.

We may also ask if the herringbone pattern was so unusual in ancient times as to have been an anomaly. Gilbert Raes, renowned expert on ancient textiles, wrote: "At the beginning of our age both cotton and linen were known in the Middle East. The type of weave [the herringbone pattern of the Turin Shroud] is not particularly distinctive and does not enable us to determine the period in which it was produced" [31].

We conclude with some unintentionally ironic remarks by Dr. Gibson's colleague and chance excavator of the shroud fragments at Akeldama – Professor James Tabor of the University of North Carolina at Charlotte: "Thousands of ossuaries have been found in Israel, especially in the rock-hewn tombs outside Jerusalem. But finding a skeleton still laid out in a loculus and wrapped in its burial shroud was a first.... Gibson and I began to comb the ancient literature for evidence related to the use of burial shrouds and ossuaries among the Jews of Judea and Galilee in the Roman period. As it turns out, the references in the New Testament to the shrouded burial of Jesus provide us with some of our most valuable evidence related to the Jewish customs in use in the early 1st century A.D. in Jerusalem…. After all, Jesus' body was washed and wrapped in a two-piece linen shroud and laid out... in a rock-hewn family tomb just outside the walls of the Old City of Jerusalem. Our man of the shroud must have been similarly prepared for burial" [32].

We began with the claim by archaeologists that the shroud fragments from Akeldama "prove" that the Turin Shroud must be medieval. Now we learn that the New Testament accounts of the burial of Jesus provide the "most valuable evidence" for context of the burial of their "man of the shroud" from Akeldama.

Objections disputing the first-century date of the Turin Shroud – in this case, its herringbone weave and its large size – in fact may corroborate the antiquity of the cloth.

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Figure 8. World Museum, Liverpool.

Documenting the Shroud's missing years

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Abstract
History proceeds from documents, not arguments from silence. Besançon alone, of all the major theories of the Turin Shroud's whereabouts during the missing 150 years, has documents to support its possession of the Shroud after the Fourth Crusade until about 1350, after which the Shroud's history from Lirey to Turin is well established. No other hypothesis for the Shroud during this time—whether that of the Templars, the Smyrna Crusade, or the Sainte-Chapelle—even mentions Jesus' shroud. Nor can any other theory document a path of the Shroud from Constantinople to the ever-silent Geoffroy I de Charny.

Keyword: Othon de la Roche, Jeanne de Vergy, Geoffroy I de Charny, Chateau de Ray

1. INTRODUCTION

I continue to regard Ian Wilson's 1978 book as my Shroud bible [1]. Without his insights about Edessa and its imaged cloth, Shroud history might well begin with Robert de Clari in 1203, for all documents before 1203 emanate only from Edessa. Ian is the first to applaud the scholar who makes a good case for a hypothesis, even though it may depart from his own position. Therefore, I will begin with a strong statement and try to back it up in the rest of my paper. *If the Shroud was not at Besançon where it is named—and claimed to have been—during the famous gap in its record (expanded to about 1200-1400), it was somewhere else, unnamed, unclaimed, unattested, and undocumented.*

At least three popular hypotheses may be briefly discussed.

2. THE KNIGHTS TEMPLAR HYPOTHESIS

The above statement means that the words "shroud of Jesus" are not found in all the documents of the trials of the Templars. The hypothesis that they possessed the Shroud during the missing years hinges on their worship of an idol in the form of a head.

In 1911, before the Shroud was ever a Templar issue, Salomon Reinach noted, from the records of the trial, that no two members gave the same description of their supposed idol, and some said it was a skull or had three heads [2].

More recently, other scholars have echoed this. They also noted that some interrogated Templars were not fighting knights but menials who were never present at the secret meetings when the idol was supposedly exposed. Yet these, too, proffered a description.

Based on this, one could say that the real issue is not a Templar possession of the Shroud but the very existence of an idol.

It may be useful to notice that the inquisitors must have used the same questions in the trial of the Cathars. How else to explain the fact that at least one Templar testimony said the idol had the power to make trees flourish and the land to be fertile, which resonates exactly with one of the responses of the Cathars with regard to their mysterious "treasure" in the inquisition of Toulouse in 1235?

Such a Templar response could only have been a reply to a question which had already been posed by the inquisitors to the Cathars seventy years previously. Frale has included this point in her list of 127 charges against the Order.

On the basis of this, it seems possible that the inquisitors themselves intruded the idol into the interrogations, and the members of the Order described one in hopes of receiving leniency.

It should also be noted that the most respected histories do not place the Templars in Constantinople during the Fourth Crusade [3]. In short, no clearly acceptable specifics have ever been proposed regarding their receipt of the Shroud or their transfer of the Shroud to Geoffroy I de Charny.

3. THE SMYRNA HYPOTHESIS

Regarding the Smyrna theory, one can be sure that Geoffroy de Charny did not join the Smyrna Crusade in 1346 in order to get the Shroud. Again, the Shroud was not mentioned by any of its supposed owners in the Greek East during this period. Most conclusively, in 1902 the evidence was manipulated, and modern advocates of the Smyrna hypothesis have not noticed it [4].

4. THE SAINTE-CHAPELLE HYPOTHESIS

Finally, no shroud was ever inventoried among the relics placed by King St. Louis IX in his new Sainte-Chapelle in Paris, where the *Grande Chasse* ("Great Reliquary Chest") housed the Crown of Thorns and other relics that arrived from Constantinople in 1247.

King St. Louis IX obtained the relics of the Byzantine emperors in perpetuity when they were ceded to him by Baldwin II, the last and war-weary Latin Byzantine emperor, in the famous Golden Bull of 1247, in which the relics were listed [5].

The shroud of Jesus was not mentioned. (As we will see, it had been removed to Athens already by 1205.) Rather, the Bull merely listed among the relics ceded to Louis "part of the shroud in which Christ's body was wrapped in the tomb" (*partem Sudarii*) and the "holy towel inserted in a frame" (*Sancta Toella in tabule inserta*). Neither of these is the Shroud.

Again, one finds in the inventories of the *Grande Chasse* the same list and these same two items, but listed here as *du St-Suaire* (a piece of the shroud) and *une ste-face* (a holy face). The more common Latin wording *Sancta Toella in tabula inserta* appeared in the inventories only after 1363 [6].

This had been a term for the Mandylion from Edessa. However, that "towel" had already been unfolded in Constantinople in 958 to reveal its full size as the Shroud. From then on we must consider that the venerable 900-year-old Abgar legend and Mandylion, with its image of the face of Jesus, had to be preserved (especially after its celebrated arrival in Constantinople in 944). Thus *something,* presumably a copy of Jesus' face made from the Shroud to perpetuate the legend of Edessa's imaged "towel", was kept separately in the Pharos Chapel relic treasury of the Great Palace.

It is here that crusader knight Robert of Clari says he saw its gold container (*vaissiau d'or*) hanging from the high ceiling.

The Shroud (the unfolded "towel" or Mandylion) had by then been moved to the Blachernes Imperial Palace. It was there that Clari saw it "raised up" every Friday and identified it as Jesus' imaged *sydoines* (singular), i.e., the Shroud. Let there be no doubt about this, since Clari adds "in which He was wrapped" [7].

In the meantime, in Europe Ordericus Vitalis (1130) and Gervase of Tilbury (1211) already described a shroud with the full-body image of Jesus long before 1247 [8]. Yet the "towel in a frame" continued to be named in Sainte-Chapelle inventories until at least 1575, when we know the actual Shroud was already on its way from the Savoys in Chambéry to Torino [9].

These three scenarios—Knights Templar, Smyrna, and Sainte-Chapelle—each plausible in its own way, are built on foundations of silence regarding the shroud of Jesus. Historiography, however, proceeds by documents.

5. THE BESANÇON HYPOTHESIS

The hypothesis which identifies the Turin Shroud with the cloth said to have been previously used in the Easter liturgy at the cathedral of St-Étienne (St. Stephen) at Besançon in 1253 has been scrutinized by scholars, but it has never been refuted [10]. In fact, the Besançon hypothesis has been revived often in the past 20 years, by the present writer in 1989 and by others named herein [11] and *passim*, who have given Besançon even more supporting evidence.

Here let us all be reminded that the Shroud remains, overall, relatively free of historical documentation prior to 1353. Even Geoffroy de Charny, owner of the Lirey-Chambéry-Turin Shroud about 1349-1354, never gave any sign that he had ever heard of it. Long after his death his descendants said, vaguely, that he acquired the Shroud as a "reward freely given". This is true enough, though one gets the feeling that something is being held back.

Moreover, the official papers of the foundation of Geoffroy's church at Lirey from 1343 to 1353 mention other relics but no shroud. Still, the cloth at Lirey has been vindicated by Bishop d'Arcis's *Memorandum* in 1389, the Shroud's first firm document 34 years after its arrival in Lirey [12]. The Besançon hypothesis is defined by a series of documents and runs as follows.

6. OTHON DE LA ROCHE

Othon de la Roche, a Burgundian nobleman who emerged as a leading figure of the Fourth Crusade, was awarded the important fief of Athens and somehow acquired the shroud of Jesus along with other relics in Constantinople in 1204.

First we must ask: who was Othon de la Roche, that he, of all the illustrious French knights of the Fourth Crusade, should be the recipient of Jesus' shroud, the most striking relic in Christendom? In 1983 Pasquale Rinaldi published a thirteenth-century copy of a letter asserting that the shroud of Jesus from the relic collections in Constantinople was in Athens. Othon had been the lord of Athens since late in 1204 [13].

The letter is dated August 1, 1205. Theodore Angelos, brother of Michael, who was the despot of Epirus, wrote to Pope Innocent III, complaining that the shroud of Jesus had been taken to Athens. Michael was one of only a few remaining Greek rulers after the capture of Constantinople by the Fourth Crusade. Is the letter to the pope authentic [14]? Importantly, in 1205 Pope Innocent III was still threatening to excommunicate the leaders of the western crusading forces for the looting of *Christian* Constantinople. It was a time when a leading spokesman of the Greeks might yet hope that a pope's intervention might result in the return of Jesus' shroud and other relics into Greek hands.

In 1989 I uncovered a second support of the Shroud's presence in Athens. In the years immediately after the Latin takeover of Constantinople in 1204, Nicholas of Otranto (1155-1235) [15], abbot of Casole Monastery in southern Italy, was the personal translator for the newly seated Latin patriarch, Benedict of Santa Susanna. Together they held discussions with Greek clergy, hoping to reconcile disagreements over dogma and papal primacy. These differences included the Greek use of leavened bread as opposed to the Latin Church's use of unleavened (*ázymos*) host in the Eucharist.

Nicholas' reports were written by him both in Greek and Latin. His reference to the Shroud comes in the midst of a discussion in 1207 of the Communion bread. The Byzantines had asserted that a portion of the original (leavened) bread used by Jesus had been present in the imperial relic collection, but had been stolen. Notice below that among the lost relics of the Passion, which Nicholas now enumerated, were that lost leavened bread and Jesus' burial linens. Here is the crucial passage written by Nicholas:

"When the city was captured by the French knights, they entered as thieves, even in the treasury of the Great Palace where the holy objects had been kept, and they found among other things the precious wood, the crown of thorns, the sandals of the Savior, the nail [sic], and the burial linens, *which we later saw with our own eyes* . . . and that bread which Christ divided among his disciples with his own pure hands at the Last Supper". (Italics are mine.)

The question must be asked as to just where it was that Nicholas actually saw the linens. To answer this, we must add what he says in another context: that, in 1206, he and Benedict had traveled to Athens and to Thessalonica debating the same questions of Church unification with the Greek theologians. It may therefore have been in Athens that Nicholas saw the burial linens "with our own eyes", which is such a peculiar part of the passage just cited. Most significantly, he says he saw them *after* the rush of pillaging of the precious relics by the crusaders. For the linguists among us, it is crucial to notice that the Latin pluperfect *ubi sancta posita erant* ("where the holy things *had been kept*") and the Greek imperfect *en tois ta hagia ekeinto* ("in which places the holy objects *used to be kept*") argue strongly that the linens were no longer in the Great Palace and that Nicholas did not see them *there.* (Emphases are mine.) Theodore of Epirus and Nicholas of Otranto thus provide mutual support for the Shroud in Athens [16].

Yet a third witness has materialized. In 1982 Antoine Legrand announced another document, also found by Pasquale Rinaldi "in the Vatican archives in the library of Santa Caterina a Formiello in Naples" [17]. It is a letter reputedly from Byzantine emperor Alexius V Mourtzouphlus himself to Pope Innocent III after his flight from Constantinople in April 1204. Mourtzouphlus was one of the Byzantine emperors who had been dethroned in the hectic years before, during, and after the Fourth Crusade. In his letter he complained that, in the sack of the city, he lost his throne, he is in exile, the crusaders have taken the gold and treasure of the empire, and "his" Holy Shroud has been stolen and taken to Athens by Othon de la Roche. Legrand expresses his own certainty that this letter is proof of Othon's and Besançon's possession of Jesus' shroud, no longer in Constantinople after the Fourth Crusade.

We should not omit the testimony of the Besançon "MS 826", favoring the one-time presence there of Jesus' shroud. This little-read eighteenth-century document, which is difficult to obtain, also singled out Othon as the recipient of the Shroud and as the one who conveyed it to Besançon. The anonymous writer cited three medieval sources for his contention. But, to my knowledge, these have not been found.

How did Othon get the Shroud? Besançon historian Dom François Chamard (1902) [18] said that during the second siege of Constantinople, which effectively placed the crusaders in control of the Byzantine government on April 14, 1204, Othon was among the Burgundians following Henry of Flanders and garrisoned in the Blachernes Palace. If so, and since the Shroud was in this palace—and accessible, as Robert of Clari attested—then Othon could have gained possession of it that very day. Official ownership would be earned later. Unfortunately, I could not confirm Chamard's or any other assertion of Othon in Blachernes by any document, but Theodore's letter (above) about the shroud of Jesus in Athens in 1205 does indicate Othon's possession prior to 1205.

By summer 1204 Othon had emerged as a personal representative of the Marquis Boniface of Montferrat, who nearly became the first Latin Byzantine emperor. Baldwin of Flanders was elected, and Boniface was compensated by possession of Thessalonica. This, in effect, made him the overlord of a kingdom comprising most of mainland Greece, for which he paid feudal homage to Baldwin [19]. In November 1204 he appointed Othon lord of Athens.

In 1205 Baldwin was killed, and his younger brother Henry was crowned emperor in August 1206. Soon afterwards, Othon was personally entrusted with a special mission to the new emperor bearing the offer of Boniface's daughter Agnes in marriage [20]. It is an attractive possibility that, in the joyous generosity of this event (ceremony in Hagia Sophia, reception in the Imperial Palace), Henry officially awarded (or confirmed) the Shroud to Othon's protection. The question is not so much whether Othon received the Shroud, but only about when and how he received it.

In April 1209, after helping to reduce Greek resistance led by the same Theodore of Epirus in the Peloponnese, Othon arrived as a conqueror at Henry's big council at Ravenika. The following month Henry visited Othon for two days in Athens. He was accompanied by Pons de Chaponay de Lyon, his fiscal agent and "shuttle diplomat", who had already accomplished missions in the West to profitably dispose of relics, precious fabrics, and imperial jewels in France. The bonding of the men continued when Othon escorted Henry on the continuation of his journey from Athens to Euboea.

Logic demands that Othon would have shipped or carried the Shroud home to the safety of his Chateau de Ray-sur-Saône in Burgundy, near Besançon. Michel Bergeret and Alessandro Piana have provided evidence that this was the permanent home of the Shroud. There can be seen an old wooden chest with a label naming it as that in which the Shroud, brought by Othon from Constantinople in 1206, was preserved. Othon's presumed journey to France at this time would not have been impossible, but it is likely that the planning for Henry's wedding to Agnes would have precluded Othon from delivering the Shroud personally.

Another possibility was suggested by the Byzantine scholar Riant, who noted that Pons de Lyon was sent to Burgundy in 1219 on an undefined but important mission. Given Pons's other special assignments and the relationship that existed between him, Emperor Henry, and Othon, it is not too brash to suppose that in 1219 Pons might have delivered Othon's precious relic to his Chateau de Ray. Longnon refers to this mission and adds "*avec un sauf-conduit et une créance* ["with a safe-conduct and a letter of credit"] *de 500 livres*" [21]. The significant outcome is that the Shroud did reside in the Chateau de Ray-sur-Saône in Burgundy during the famous missing years, as Bergeret and Piana have explained [22].

A short historical digression may serve to indicate what major events could have become factors in the itinerary of the Shroud in France. From 1309 to 1377 the papacy resided at Avignon; French popes pursued a French foreign policy. By 1377 there must have been few alive who had ever known a papacy that was truly the spiritual leader of all Europe's Christians. After 1377 rival popes in Rome and in Avignon claimed the allegiances of Catholics in what is called the "Great Western Schism".

The location of Besançon rendered it a hotbed of all the political and religious dichotomies of those times. Sometime capital of Burgundy, the city straddled France and the German Holy Roman Empire in its geography and politics. A French party constantly worked for the city's annexation by France and for the legitimacy of the French anti-popes. A German party strove for Besançon's continued attachment to the Empire and, not surprisingly, supported the return of the popes to Rome.

The family of Vergy, descendants of Othon, were among the pro-French faction in Burgundy. They carefully, if quietly, guarded their relic in their Chateau de Ray until about 1354, when Geoffroy I de Charny certainly possessed it in Lirey.

7. COULD GEOFFROY HAVE ACQUIRED THE SHROUD IN THE 1340s?

In the interest of intellectual discussion, let us consider if Geoffroy could have obtained the Shroud in the 1340s. During most of that decade Geoffroy was pursuing his career as a fighting knight in western France. He suffered his first British imprisonment in the battle of Morlaix in 1342. During this time, as a man of modest means—not yet advantaged by Vergy wealth through his marriage to Jeanne and not yet appointed as King Philip VI's *porte-d'oriflamme* (banner-bearer)—he considered praying for a miracle. The tradition is well known that he vowed to build a church to the Virgin if he should ever be freed. He was, in fact, released from that imprisonment—whether by ransom or escape—in 1343, when, with financial aid from the same King Philip, work began on his Lirey church [23].

In 1345-1346 he was present on the Smyrna (Turkey) Crusade. Back in France he again saw battle, this time as the banner-bearer for King Philip from 1347 to 1349. In April 1349, with work on his new church at Lirey now completed, he requested permission from Pope Innocent VI to add a cemetery for the canons and townspeople. Curiously, his own remains were to be divided and buried in several places. The end of the decade found him again imprisoned from December 31, 1349, until mid-1351. This time his ransom was paid by Philip's son, King John the Good, and Geoffroy needed no miracle. All this leaves little time for a wedding [24].

In August 1354, during a period of relative quiet, Geoffroy again requested his cemetery, but "changed his mind", as Dorothy Crispino has put it, about where he wished to be buried—and his new choice was in his new graveyard. I have found this letter in the writings of Ulysse Chevalier [25]. This request may signal two significant facts: by now Geoffroy and Jeanne de Vergy had wed, and the Shroud had come into his possession and been deposited in the church. Crispino's valuable evidence places any acquisition of the Shroud by Geoffroy in the 1340s in serious doubt.

8. THE YEARS 1351 TO 1354 MARK THE WINDOW WHEN GEOFFROY OBTAINED THE SHROUD FROM JEANNE DE VERGY

When, in 1624, Besançon's first historian, J. J. Chifflet [26], began writing the story of the shroud once residing in his proud city, the shroud of Jesus from Constantinople had long since departed from Besançon. Assuming that it had been housed in St-Étienne Cathedral, he related that on March 6, 1349, a fire in the cathedral resulted in the loss of all church documents and the apparent destruction—certainly, the disappearance—of their shroud. Since all documents attesting to the circumstances of its arrival in that city had been consumed in the fire, Chifflet could only guess.

In reality, safe in Chateau de Ray, the Shroud survived the fire and was accessible to Jeanne de Vergy (ca. 1320-1388), descended from Othon and with her family's proper claim to ownership. In 1349 the powerful Vergy family could deal with the Shroud in the same way that the Savoys exercised their family's ownership of the Shroud well into the twentieth century. Bro. Hilary de Crémiers, especially, has supported my findings (largely from my research done in the Wuenschel Shroud archives, always with thanks to Fr. Adam Otterbein) that, in the confusion of the times, Jeanne carried the Shroud out of Burgundy to her marriage to Geoffroy I de Charny between 1351 and 1354 [27]. All the evidence for the ever-silent Geoffroy's acquisition of the Shroud leads neatly to his second wife, Jeanne de Vergy. This is likely what was not said in the Charnys' vague "reward freely given". It would have been unwise to announce that Lirey now possessed Besançon's lost precious relic.

In 1929 Noguier de Malijay suggested a variation on this theme, namely that Jeanne de Vergy brought the Shroud out of Burgundy, thereby saving it for France. Malijay argued further that she presented it first to the French king, Philip VI de Valois (d. 1350), who in turn awarded it to Geoffroy de Charny, his trusted *porte-d'oriflamme* [28], possibly as a major relic to be placed in the new church at Lirey, one that was—again—"freely given". In any case, the question of the shroud of Jesus in Besançon and its transfer to Lirey has a decidedly political dimension.

Ian Wilson [29] has noted that in 1355 Geoffroy gave a receipt "as lord of Savoisy and Montfort" for the temporary removal of the Shroud from Lirey on account of the dangerous presence of the British in the Hundred Years' War (1337-1453). In 1356, after Geoffroy's death, ownership of the relic was exercised by his wife Jeanne. It remained safe in the castle of Montfort until about 1389.

Jeanne's death must have occurred before 1389, since Bishop d'Arcis's *Memorandum* of 1389 named their son, Geoffroy II, as displaying the cloth in Lirey—falsely—as the true shroud of Jesus.

The absence of any mention of a shroud in the earliest documents (1343-1353) of the Lirey church and also the presence of the Vergy crest on the Seine medallion with its twin image of Jesus point to Vergy ownership and Jeanne's delivery of the Shroud from Besançon. No other theory of the missing 150 years has ever explained so efficiently—or at all—how Geoffroy acquired the Shroud.

9. SHROUD CONFUSIONS

Chifflet, convinced that the original shroud was consumed in the St-Étienne fire, wrote that in 1377 it was miraculously rediscovered in a niche in the restored cathedral. In 1902, based on the illustrations of the Lirey and Besançon shrouds from Chifflet's book, Vignon wrote that the shroud of Besançon was clearly a replica of that of Lirey, made between the years 1349 (the fire) and 1375. Chamard agreed, though he was not forthcoming about how Lirey had obtained the original [30].

Shroud *aficionados* remember how Bishop d'Arcis complained in 1389 that in Lirey an artist had "painted" an imaged shroud. Now we can demonstrate that there really was a copy of the true Shroud painted by an artist. It was most likely commissioned by Jeanne, now the lady of Lirey, and sent in 1377 as a replacement for the one she had taken out of Besançon between 1349 and 1354.

10. BASIS OF OPPOSITION TO THE BESANÇON HYPOTHESIS

Opposition to Besançon is largely the result of the loss of records. What shall we make of the fact that local scholar Chifflet in 1624 knew nothing of Othon? (It is time to play the "lost documents card", and we will understand the reasons.) Recall the loss of all church records in the fire in 1349. This means that in Chifflet's time there were no documents attesting to the role of Othon in the Shroud's arrival in Burgundy.

This destruction of Besançon's ecclesiastical records before 1349 immediately announces the obstacles in the path of Chifflet as he attempted to reconstruct the history of the Shroud in his city. Not surprising, we have no record of Jeanne's role in the removal of the Shroud.

My next point is supremely important: it needs to be understood that writers who reject the Besançon hypothesis have focused *only* on the replacement copy of 1377 with its frontal-only image, which was the Lirey "painted" copy. In short, their arguments have not disproved the authenticity of the original cloth sent to Burgundy from Athens.

This present fresh approach to the Besançon hypothesis provides answers to some major issues in Shroud history. Besançon's possession of the replacement shroud solves the issue of why the city did not more strenuously claim prior ownership of the Lirey shroud. They had the copy and believed it to be the rediscovered original. In 1624 poor Chifflet, well aware of but never having seen Lirey's shroud, believed that there had been two real shrouds, one for wrapping the body and the second one for carrying it to the tomb.

A frequently used argument against Besançon's one-time possession of the present Shroud of Turin is that the earliest extant record of it in the city dates from 1523. However, to be accurate, this was a reference to the city's Easter ritual when the replacement shroud was displayed. No primary sources have ever claimed that Besançon first received a shroud in 1523. Chifflet thought that the ritual already was used in Besançon "before the union of St. John and St. Stephen in 1253" and that it was "renewed" in 1523 [31].

In this regard, finally, the question has never been asked as to why, given the Shroud's adverse notoriety in Lirey in the fourteenth century deriving from the accusations of d'Arcis and its possession in 1523 by the powerful Savoy family in Chambéry, Besançon should seriously enter the "shroud business" in that year. Besançon's claim on the shroud of Jesus makes sense only if the city previously had possession of the original.

The loss of Besançon's ecclesiastical records is a given. Chifflet did not mention Othon. But he was clear—and honest—when he wrote, "The fire burned up the [shroud and] the details of the shroud's arrival, i.e., the means, the time, and the carrier" [32].

The next episode seems to be a patent and deliberate conspiratorial contrivance. However, instead of destroying the Besançon hypothesis, it rather strengthens it. Chifflet wrote that in 1377 the cloth in its chest was rediscovered by means of a strange light coming from a hidden part of the cathedral. (Remember, it was almost certainly that which was made by the artist in Lirey as claimed by d'Arcis.) Judging from the lapse of twenty-eight years (1349-1377) between the fire and "rediscovery", there could not have been many in Besançon who knew precisely what the original had looked like.

In 1377 Archbishop Guillaume III de Vergy (1371-1391) was the fifth in line since the fire. That is to say, four archbishops, who might have been able to compare the replacement cloth with the original, had died. In order to determine if it was the same true burial shroud of Christ previously lost, Chifflet relates that the cloth newly found in 1377 was placed upon a corpse, which miraculously revived. It was thus a Vergy who "verified" by a "miracle" that the new Besançon replacement shroud was indeed the original Besançon shroud. A family cover-up to exonerate Jeanne's departure with the true Shroud is a strong possibility.

Nobody doubts that the new cloth residing in Besançon until its destruction in 1794, when it was singled out in the official account of the events of the French Revolution as having been torn into bandages, was only the painted copy. It is obviated by the history of the shroud at Lirey, the shroud whose continuity extends to the present day, the shroud which is beyond a doubt identifiable as the Shroud of Turin. Besançon's claims to possession of the true burial wrapping of Christ thus gradually evaporated.

11. CONCLUSION

All of the mysteries surrounding the initial appearance of the Turin Shroud in the West are by no means solved by these historical revelations. As the venue for the Shroud during the missing years, Besançon alone offers documents that actually name the Shroud, which other hypotheses do not. It has a reasonable—and documented—provenance from Constantinople via Othon. It affords us the moment and circumstance for Geoffroy de Charny's acquisition of the cloth, which no other hypothesis has been able to do.

The Besançon hypothesis is the most likely to hold the truth about the "missing 150 years" of the Shroud's history.

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2. S. Reinach, "La Tête Magique des Templiers", Revue de l'Histoire des Religions, vol. 63, pp. 25-39 (1911); M. Barber, "The Templars and the Turin Shroud", Catholic Historical Review (April 1982); *ibid.,* "The Templars and the Turin Shroud", Shroud Spectrum International, no. 6, pp. 16-34 (March 1983); *ibid., The Trial of the Templars,* Cambridge University Pr., Cambridge (1978); B. Frale, *L'Ultima Battaglia dei Templari*, Viella, Rome (2001); P. Partner, *The Murdered Magicians,* Oxford Univ. Press (1982); R. Barber, *The Holy Grail: Imagination and Belief*, Harvard Univ. Pr., Cambridge, MA, ch. 19 (2004), especially should be read in this connection.

3. Frale, *ibid*., p. 317; on pp. 118-132 and in ch. 3 she has revealed the accusatory protocol initiated by King Philip the Fair as "fluid", a work always in process, the charges capable of increasing as the poor knights and lowly brothers uttered statements that permitted new avenues of interrogation. So, an initial basic list of 7 charges had grown to 127 in some places.

Frale has recently related (*L'Osservatore Romano*, April 5, 2009) that Arnaut Sabbatier testified in the trial process of the Templars that in 1287 he kissed the feet of a figure of a man imprinted on "a long linen cloth".

Considering that Arnaut's deposition remains merely one among dozens of differing descriptions of the alleged "idol" of the Templars, his words do not seem sufficiently descriptive or definitive to indicate that he was looking at the Shroud of Turin. Still, we must wait for the consensus of Shroud scholars to see if the suggestion that the idol was the Shroud will carry the day.

Also militating against the Templars' possession of the Shroud is the fact that respectable histories do not place the Templars in Constantinople in the Fourth Crusade, when, if ever, they might have acquired the Shroud. This absence speaks loudly in the 895 pages of R. L. Wolfe and H. W. Hazard, eds., *The Later Crusades, 1189-1311,* vol. II, of K. M. Setton, ed., *A History of the Crusades,* Univ. of Wisconsin Pr., Madison, Wisconsin, and London (1969).

4. D. Scavone, "Did Geoffroy I de Charny Obtain the Present Turin Shroud on the Smyrna Campaign of 1346?", available for reading in its entirety at <http://www.shroud.com/pdfs/scavone2.pdf>

5. P. E. Riant, *Exuviae Sacrae Constantinopolitanae*, 2 vols., Ernest Leroux, Paris, vol. II, pp. 133-135 (1878)

6. Pere A.-M. Dubarle and H. Leynen, *Histoire Ancienne du Linceul de Turin*, tome II, *944-1356*, François-Xavier de Guibert Pr., Paris (1998); H. Leynen, "À-propos du Mandilion", Soudarion, Bruges (1991). Her paper, which discusses the *Grande Chasse,* is an extract from this Flemish journal, here translated into French.

7. Robert de Clari, "La Conquête de Constantinople", chs. 83 and 92, in C. Hopf, *Chroniques Gréco-Romaines Inédites ou Peu Connues,* Impression Anastaltique Culture et Civilisation, Brussels (1966; rp. of Paris, 1873); H. McNeal, tr., *Robert de Clari, The Conquest of Constantinople,* Columbia Univ. Pr., New York (1936). His description in ch. 83 of a painting of St. Demetrius is evidence that he did not "see" the *sydoines* as a painting. Important on this issue is P. F. Dembowski, "Sindon in the Old French Chronicle of Robert of Clari", Shroud Spectrum International, vol. 2, pp. 13-18 (March 1982). Fuller discussion in D. Scavone, "The Shroud in Constantinople: The Documentary Evidence", Sindon, N. S., vol. I, no. 1, pp. 113-128 (1989).

8. C. M. Mazzucchi, "La Testimonianza piú Antica dell'Esistenza di una Sindone a Costantinopoli", Aevum, vol. 57, pp. 227-231 (1983), notes the first clear reference to the Shroud itself in Constantinople in 958. Yet there exists no record of the arrival of the Shroud. The most plausible conclusion, hypothesized by Ian Wilson already in 1978, is that it was the Mandylion unfolded in 958.
In any case, awareness of the full-body image on cloth had reached Britain by the twelfth century: S. E. Banks and J. W. Binns, *Gervase of Tilbury, Otia Imperialia: Recreation for an Emperor,* Clarendon Pr., Oxford (2002); for Ordericus: E. von Dobschütz, *Christusbilder,* 3 vols., J. C. Hinrichs'sche Buchhandlung, Leipzig (1899).

9. A. Vidier, "Le Trésor de la Sainte-Chapelle", *Mémoires de la Socièté de l'Histoire de Paris et de l'Ile-de-France*, vols. 34, 35, 36, 37, H. Champion, Paris (1907-1910)

10. Among opponents of this Besançon hypothesis, D. Crispino, "Doubts Along the Doubs", Shroud Spectrum International, no. 14, pp. 10-24 (March 1985), and more recently, G. M. Zaccone, "Sindone di Torino e Sindone di Besançon, Appunti per una Ricerca Parallela", Sindon, N. S., vol. 9-10, pp. 107-116 (1997), and D. Raffard de Brienne, "Review of Dom François Chamard", Revue Internationale du Linceul de Turin, Sommaire no. 15-16, p. 53 (2000), all focusing entirely on the post-1377 Besançon shroud, have rightly denied its authenticity. P. Vignon, *The Shroud of Christ,* Constable, Westminster, pp. 64-76 (1902), said the replacement shroud pictured in Chifflet's volume was a copy of Lirey's. The Bibliotheque Municipale de Besançon possesses "MS 826", dating to 1700-1750. It has two parts: one in favor of the authenticity of Besançon's shroud and the other opposed to authenticity. The latter also focused almost entirely on the replacement shroud. None of the above have proven the original shroud (from Othon in Athens) to be a fake.

11. M. Buttigieg, "La Lettera del Vescovo Pierre d'Arcis", Collegamento Pro Sindone, pp. 33f. (Sept.-Oct. 1990); H. de Crémiers, "The Holy Shroud Refound—From Constantinople to Lirey (1204-1354)", Catholic Counter-Reformation, no. 238, pp. 42-47 (April 1991); M. Bergeret, "Le Trou Historique: 1204-1357", paper presented at the C.I.E.L.T. Symposium in Paris in 1993; A. Piana, *Sindone gli Anni Perduti,* Sugarco Edizioni, Milan (2007)

12. Translation of the *Memorandum* in Wilson, *op. cit.* (Ref. 1 above), pp. 230-235; original in Fr. L. Fossati, *La Santa Sindone: Nuova Luce su Antichi Documenti*, Borla, Turin, pp. 213-219 (1961)

13. Pasquale Rinaldi, "Un Documento Probante sulla Localizzazione in Atene della Santa Sindone dopo il Sacheggio di Costantinopoli", in L. Coppini and F. Cavazzuti, eds., *La Sindone, Scienza e Fede*, Editrice CLUEB, Bologna, pp. 109-113 (1983); D. Scavone, "The Shroud in Constantinople: The Documentary Evidence", Sindon, N. S., vol. I, no. 1, pp. 113-128 (1989)

14. D. Polemis, *The Doukai*, Univ. of London Athlone Pr., London, pp. 89f. (1968), has written about the nomenclature of Theodore of Epirus. His thesis is that Theodore would have used the name Doukas and would not have sent the letter from Rome. But other scholars are not so insistent. Theodore himself used Doukas, Angelus, and Comnenus, sometimes together and sometimes interchangeably.
J. Longnon has identified Theodore as "Angelus Comnenus" in his chapter, "The Frankish States in Greece, 1204-1311", p. 240, in Wolfe and Hazard, *op. cit.* (Ref. 3 above). The use of the name Angelos and the credibility of Theodore's letter in 1205 are supported by the following: In 1202, when the Western princes launched the Fourth Crusade, Alexius IV, the son of the deposed Isaac II, promised to end the schism of East and West and to pay for their transport if they helped him to retake his father's throne and depose his uncle, Alexius V Doukas Mourtzouphlus. This latter, a Doukas, had initially led the resistance to the crusading forces. It would not have been wise for Theodore of Epirus to use the name Doukas.

15. On this learned man, see A. Acconcia Longo and A. Jacob, "Poesie di Nicola d'Otranto nel Laur. Gr. 58.2", Byzantion, vol. 54, pp. 371-379 (1984); J. W. Hoeck and R. J. Loenertz, *Nikolaos-Nektarios von Otranto, Abt von Casole. Beitrage zur Geschichte der Ost-Westlichen Beziehungen Unter Innocenz III und Friedrich II,* Buch-Kunstverlag, Ettal (1965); W. Norden, *Das Papsttum und Byzanz: Die Trennung der Beiden Mächte und das Problem Ihrer Wiedervereinigung bis zum Untergange des Byzantinischen Reichs*, Burt Franklin, New York, pp. 183-187 (1958; rp. of Berlin, 1903)

16. Riant, *Exuviae*, *op. cit.* (Ref. 5 above), pp. 233f., gives both the Greek and Latin versions: *quum capta esset a*

Francingenis regalis civitas . et in scevophylachium Magni Palacii tamquam latrones, ubi sancta posita erant, scilicet: preciosa ligna, spinea corona, Salvatoris sandalia, clavis, et fascia (que et nos postea oculis nostris vidimus) aliaque multa invenerunt . .(Riant's parentheses.) The Moscow MS published by Bishop Arsenij, Greek only with Russian translation, Novgorod, p. 41 (1896), does not have the word *ὕστερον,* "later", which is in Riant's original text.

17. A. Legrand, "Du Nouveau pour le Suaire de Turin: Une Lettre de l'Emperor Alexis V", Notre Histoire, Librairie Taillandier, Paris (December 1982); on Othon's career, W. Miller, *The Latins in the Levant*, London (1908)

18. Dom F. Chamard, *Le Linceul du Christ*, Oudin, Paris, pp. 40-41 (1902)

19. Villehardouin, in M. R. B. Shaw, tr., *Joinville and Villehardouin: Chronicles of the Crusades,* Penguin, New York, pp. 94-97 (1963)

20. Villehardouin, ch. 19, pp. 146-148, in Shaw, *ibid.;* J. Longnon, ed., *Henri de Valenciennes: Histoire de l'Empereur Henri de Constantinople,* Librairie Orientaliste Paul Geuthner, Paris, pp. 106-108 (1948)

21. P.E. Riant, *Depouilles Religieuses Enlevées a Constantinople au XIIIe Siècle par les Latins et des Documents Historiques Nés de leur Transport en Occident,* Paris, p. 87 (1875); Riant, *Exuviae, op. cit.* (Ref. 5 above), vol. I, pp. cil and clxiii, in which latter place he suggests the delivery in Burgundy of the cloth from Constantinople and Athens in 1219; Chamard, *op. cit.* (Ref. 18 above), pp. 43f., thought this was the natural explanation of the presence of Othon's *Suaire* in Burgundy; Longnon, *ibid.,* p. 106

22. Bergeret, *op. cit.* (Ref. 11 above); Piana, *op. cit.* (Ref. 11 above)

23. D. Scavone, "Geoffroy's Vow and the Church at Lirey", Australian Shroud News, vol. 40, pp. 4-7 (1987); the same in Sindon, N. S., vol. I, no. 1, pp. 129-132 (1989); Pere A.-M. Dubarle kindly cited my paper in his article "La Première Captivité de Geoffroy de Charny", Montre Nous ton Visage, no. 8, pp. 6-18 (Dec. 1992), and in ch. 5 in Dubarle and Leynen, *op. cit.* (Ref. 6 above), pp. 71-83.

24. P. Contamine, "L'Oriflamme de Saint-Denis aux XIVe et XVe Siècles", Annales de l'Est*,* vol. 7, pp. 179-244 (1973)

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26. J. J. Chifflet, *De Linteis Sepulchralibus Christi Servatoris Crisis Historica,* Antwerp (1624)

27. Crémiers, *op. cit*. (Ref. 11 above); Chamard, *op. cit.* (Ref. 18 above), p. 49; Legrand, "Linceul de Turin: Quinze Siècles de Voyages", Notre Histoire, vol. 17, pp. 6-11 (Nov. 1985); Wilson, *op. cit.* (Ref. 1 above), p. 173, also thought Jeanne may have originated the Shroud's expositions at Lirey in 1357, after Geoffroy's death.

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29. I. Wilson, *The Blood and the Shroud*, The Free Press, New York, pp. 278f. (1998)

30. Vignon, *op. cit.* (Ref. 10 above), pp. 64-76; Chamard, *op. cit.* (Ref. 18 above)

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32. Chifflet, *ibid.*, p. 50

"Missing years" of the Holy Shroud

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Abstract
The Holy Shroud disappear from Constantinople during the Crusade in 1204. Two elements confirm the presence of the Shroud in Athens since 1205 when, after the splitting up of the Byzantine Empire, Otho de La Roche, baron of Ray-sur-Saône, became Lord of Athens. Many tracks suggest that, after 1225, Otho come back in France with the Shroud. After his death, in 1234, the Shroud remaine in Ray-sur-Saône family hands until its handing over to the de Vergy family. Thanks to Jeanne de Vergy, related in the fifth generation with Otho, the Shroud would have been shown in public in Lirey.

Keyword: Constantinople, Otho de La Roche, Athens, Ray-sur-Saône, Jeanne de Vergy.

1. INTRODUCTION

Even if it is accepted that the Turin Shroud and the cloth observed in Constantinople by the crusader knight Robert de Clary ("Among other astonishing things there is a church called Saint Mary of Blacherne, where there is the sydoine (*Shroud*), in which Our Lord Jesus was wrapped and that every Holy Friday is lifted up vertically, so that the shape of Our Lord could be seen very well" [1].) were one and the same object, there still remain difficulties in establishing a chronology for the relic during the historical gap of more or less one hundred and fifty years, from 1204 in Constantinople to its re-appearance in Lirey in the fourteenth century. Different hypotheses have been formulated about these "Missing Years" [2].

In this paper, the author presents an additional hypotesis in an attempt to explain that intervening period during which the Shroud completely disappeared.

2. A TRACE IN ATHENS

Two elements confirm the presence of the Shroud in Athens in the summer of 1205.

First of all a letter written on August 1st 1205 by Theodor Angel Comnenus, nephew of Isaac II, Byzantine Emperor, during the plunder of 1204, to Pope Innocent III. In this missive Theodor begged the Holy Father to retrieve as soon as possible precious relics that had been missing for over a year and wrote about the presence of the Christ's shroud in Athens [3].

Moreover, the papal legate Benedict of Santa Susanna, in the summer of 1205 was in Athens, with his interpreter and counselor Nicolas of Otranto, abbot of Casole, to attend an inter-religious meeting. Then, Nicolas, wrote in 1207 about relics stolen in 1204 that he saw subsequently with his own eyes. Nicolas of Otranto was indeed in Athens and so it is possible that he saw the Shroud [4].

3. OTHO DE LA ROCHE, MÉGASKYR OF ATHENS

After the splitting up of the Byzantine empire came the birth of the Eastern Latin Empire, Otho de La Roche, baron of Ray-sur-Saône, become Lord of Athens [5]. Among the Burgundy knights taking part in the siege of Constantinople was [6] Otho de La Roche [7], counsellor for Marquis Boniface of Monferrato, knight commander of the Fourth Crusade. He was gifted of a great strategic and organizational skill as well as a hard perseverance; he certainly was one of the high profiler character of the whole crusade arm.

Born around 1170 into a branch of the noble family of Ray [8] enthusiastic about liberating the Holy Land, Otho, giving a good example to many of his compatriots "took the cross" at the Cistercian abbey of Cîteaux in 1201 [9]. Various sources state that in 1205 Otho married his cousin Isabelle, the last heiress of the principal branch of the family [10]. A few years later Otho was widowed and married Elisabeth de Chappes in Greece [11].

Considering the route and the battles faced, we hypothesise that Otho arrived in Attica, and afterwards in Athens, around the end of 1204 or the beginning of 1205 [12]. Otho, with some faithful friends, stayed there to domesticate the fief, while the remaining platoon set off for the Peloponnese. Among the opposition the new lord of Athens had to face was the local church, especially Metropolitan Michael Coniatus who, after a long negotiation, agreed to participate in a religious meeting in Athens in the summer of 1205. After the meeting, considering Otho's steadiness and perseverance Michael left the site where he had lived for thirty years and went into exile on the island of Kos in the Dodecannese [13].

It is at about this time that, as already noted, Theodor Angel Comnenus mentioned, in a letter to Innocent III, that Christ's shroud was present in Athens.

Otho organised his lands on the strength of the French feudal model. Athens became the nominal capital and for this reason Otho built his house on the Acropolis while Thebes became the political and military capital. We still have a picture representing the tower of Otho *château-fort*, destroyed in 1879. It was square, about twenty-height meters high with a base of seven meters on the side and was erected on the southern side of the Propilei [14].

Otho, as a crusader, did not ignore religion in his lands and mainly monks "colonised" his new properties. In 1207, orthodox monks were banned from Daphni monastery, dedicated to the "Dormition of the Virgin", which was assigned to monks from the French abbey of Bellevaux [15]. They converted the monastery into a Cistercian abbey that remained Cistercian until 1458 when, after the Turkish invasion, it returned to Orthodox monks.

The abbey of Bellevaux, founded by Pons de La Roche on March 22nd 1119, was the referent point for all travels between East and West after 1204 [16]. The de La Roche family would preserve always importance in events of the religious complex, trhough donations and members of the family obtained the right of been buried there [17]. After Othon's father died (1203) Bellevaux and La Charitè abbeys contended his mortal remains; they went to La Charitè abbey, while Bellevaux obtained an economical indemnity[18].

4. BLOOD-LINE OF OTHO DE LA ROCHE

Extending his properties, the lord of Athens parcelled out his land to his offspring. Guy, designated successor, settled in Beocia, assisted by Nicolas de Saint-Omer, righthand man of his father. Guillaume, son of his second wedding, was elected governor of Argolide. Otho II received Argos and Nauplie, but he let his brothers control his lands while he devoted himself to Ray-sur-Saône. On his father's death Otho II reached an agreement with his cousin Pons de Cicon and gave up his rights over La Roche-sur-l'Ognon fief. In the "Nauplie Charter", dated April 19th 1251, Otho II gave up his fiefs of Argos and Nauplie for some money and some rights of Guy over family properties in Burgundy and Champagne, thus centralising power in Ray-sur- Saône [19].

King Louis IX of France, in 1258, confirmed what he had obtained from Otho during the crusade, admitting the Lordship and the noble title for his descendants. Other Lords of Athens were: Guy (1225-1263); Jean (1263-1280); Guillaume (1280-1287); Guy II (1287-1308); Gauthier V de Brienne (1308-1311). The reigning branch of the dukedom was extinguished after more or less one century, in 1311, when the fifth generation married into to the Brienne family. Guy II, in fact, died without male heirs. Gauthier de Brienne, sixth and last duke of Athens, was killed during a battle near lake Copaïs.

For our interest, Otho II is very important, in fact he is the son who controlled Ray-sur-Saône, the place to which the Shroud was allegedly taken by his father [20].

5. RAY-SUR-SAÔNE CASTLE

Ray-sur-Saône castle is today in a small village of around two hundred people. In this place, restructured in eighteenth century, lives Countess Diane-Régina de Salverte, direct descendent of Otho de La Roche [21].

In the ancient tower of the castle are preserved numerous family treasures. Among these they have objects from the Fourth Crusade, taken there directly by Otho de La Roche [22]. Our attention is immediately caught by some cross shaped relics. One of these contains a fragment of the True Cross, taken by the first Lord of Athens in 1204 [23] and placed in a relic container from Pope Pius IX in 1863. Another two relic containers, shaped like a Greek cross, preserve a fragment of the True Cross withsoil from the Holy Land, while the other contains only soil from where Christ had stepped. These relic containers could prove the direct origin from Constantinople.

Behind these objects there is a wooden coffer with a label, put on it in the twentieth century, on which there is written:

13th century coffer in which was preserved in Ray Castle
the Shroud of Christ brought by Otho de
Ray from Constantinople. 1206.

Figure 1. The wooden coffer preserved in Ray-sur-Saône castle (Ph. © Alessandro Piana).

The front side of the coffer is simply chiselled, while in the middle of the sides there are inlaid shields. It is parallelepiped, 45 centimetres long, 25 wide and 30 deep. It is on a base and closed by a lid. A hole in the lid and four on the front side could be the place for a padlock. At present, it is not possible to pinpoint for how long the coffer presence can be documented in the castle, even if we have a lot of data on it.

Examining the coffer we can see that the cut is characteristic of the second half of fourteenth century. Actually we know that the only original part of it is the bottom [24]. A superficial examination of the coffer has been carried out. Illuminating it with ultraviolet light they did not see traces of human blood [25]. There did seem to be some traces of textile fibres, hower these may only be the residue from a sheet that was put inside the coffer some years ago by Antoine Legrand, to see how the coffer would match the dimensions of the Turin Shroud [26].

It would be of interest to widen researches, looking particularly at the bottom, searching for other tracks, for example pollens. It could be also useful a carbon-dating, just to confirm that the only original part of the coffer is the bottom.

As far as the label put on the coffer, according to which the Shroud was in Ray-sur-Saône castle in 1206, it refers to an hypothesis guessed years ago from local historians, Dunod de Charnage and Perreciot. They stated that Otho, after appropriating of the Shroud, would have gifted it to the Besançon cathedral just in that year [27]. Besides Perreciot adds that Otho would have sent the Shroud to his father who, in 1206, gifted it. Clash with this belief is the fact that, as described below, Pons de La Roche died in 1203. It is therefore impossible that he received the Shroud in 1206. Moreover, it is unlikely that de La Roche family deprived itself of a relic stolen in Costantinople, gifting it to the local Church. In this way they would have proven the ownership of a relic, that was a punishable fact.

All these things make this hypothesis unreliable and thus suggest that the Shroud could have reached Ray-sur-Saône castle after 1206.

6. HOW, WHEN AND WHY THE SHROUD ARRIVED IN RAY-SUR-SAÔNE

We have to answer three questions. First of all how the Shroud came to Otho's hands and was then transferred to France; then, when did it arrive in France and finally if the folded Shroud could be kept in the coffer just described.

As far as the first question, during the siege of April 14th 1204, Othon was among the Burgundians following Henry of Flanders in the Blachernes Palace [28]. In my opinion it is not sustainable that in the days of savage depredation Otho went to the church in Blacherne, where Robert de Clary attested and took the Shroud. In fact, there were numerous death warrants against people who plundered [29]. It is more plausible that during the sharing out of the plunder, Otho de la Roche was given the Shroud [30]. This could explain how the pious Otho obtained the most important treasure of Christendom without illegal acts. Unfortunately, the Shroud is not mentioned in the inventories of relics taken from Constantinople and distributed among French crusaders, but Theodor's letter about the Christ's Shroud in Athens in 1205 (discussed below) does indicate Otho's possession.

Where could the Shroud have been kept during its stay in Athens? The most logical place seems to be in the fortress on the Acropolis, a well guarded place. In the period immediately after its arrival in Athens it was certainly kept somewhere else as the tower had not yet been built probably in a religious building [31].

When was it taken to France [32]? We have a lot of data regarding this fact.

The latest record signalling the presence of Otho in Athens is a papal bull of Honorius III dated February 12th 1225 [33]. It is interesting to note that just from this year the Lordship was transferred to Otho's son Guy and the first Lord of Athens returned to France and contributed to the enrichment of Bellevaux abbey [34]. It is plausible that Otho took the Shroud with him when he returned home. It is highly unlikely that he would have left such a valuable piece of loot in Greece when he could easily take it during his cruise back home. Even if the father would not have brought It with him and the Shroud was still in Athens, it is not plausible that Otho II, his heir on Ray-sur-Saône feud, would have left in Greece a so important object.

Otho died some years after. In a paper kept in Charlieu abbey, dated 1234, his son Otho II stated:

"*Notum fit omnibus presentes litteras inspecturis, quod Otto de Roca, Dominus de Rayi, filius quondam Domini Ottonis, Ducis Athenarum*" [35].

But this confirm only that in 1234 he was already dead. To understand if Otho was in France at the time of his death we have to consider a document in the archives of the diocese of Langres. This states that Otho died in 1234, while his second wife Elisabeth died two years later [36]. In that period Langres was part of the county of Burgundy, in the region of Fouvent-Dampierre-Baujeu, west of Saône, part of the ecclesiastical ward where the Ray family had their properties [37].

The fact that this paper is kept in Langres diocese could prove that Otho and Elisabeth lived in France to the end of their lives.

Despite that, some studies state that after having obtained the Lordship of Athens, Otho de La Roche never returned to France [38] but no one should explain, if he remained in Athens why he was not buried, as his successors were, in Daphne monastery.

Otho was not buried in Athens or in his own town but in the church of *Saint Laurent* in Seveux [39], a small village near Ray-sur-Saône, where his headstone is.

A close replica of this is can be seen in Ray castle, in the middle of the tower floor, near to the case. The plate reproduces Otho's arms. He is represented with hands joined in prayer, wearing an ermine gown, a sign of royalty. The plate has the following epitaph:

MOLA SUB ISTA CI PREMITUR OM(ni)S RAIANI OTHO ROGATE DEUM NE PREMAT HOSTIS EUM

The translation is: *Under this rock is buried Otho of Ray, pray God that the enemy will never surprise him again.*

Figure 2. Reproduction of the tomb headstone of Otho de La Roche,, Baron of Ray and Lord of Athens, present on the floor of Ray-sur-Saône castle tower (Ph. © Alessandro Piana).

It has been suggested that this plate does not represent Otho but his nephew Othenin, who lived almost one century later; because we can not imagine why on his plate there is not written "Lord of Athens" [40]. Instead Bergeret thinks that this is Otho II's tomb [41], but this is not possible because till the end of his days Otho II was armed as de la Roche, so it is strange that there is not a reference to the la Roche family. Another fact is very important. Seveux is in the region of Fouvent-Dampierre-Baujeu where Otho and his wife should have spent their last days.

Now we come to the last question: could the Shroud have been kept in the coffer present in Ray-sur-Saône castle and which is described below? Once opened its inner dimensions are more or less 37.5 centimetres long, 16.5 wide and 25 deep. The most suitable folding pattern for the coffer dimensions is in 96 [42]. This can be obtained with twelve folds in the length and eight in the width. So we obtain ninety-six rectangles, 36.33 centimetres long and 13.75 wide.

We have a lot of witnesses regarding the existence of coffers in which the Shroud was preserved during its movements in different centuries. At the Shroud Museum, in Turin, we can see the coffer used for moving the Shroud from Chambéry to Turin in 1578. Its shape and dimensions are very similar to that of the one found in Ray-sur-Saône castle [43].

It is likely that the two coffers could have preserved the Shroud in different historical periods.

7. A COPY OF THE SHROUD IN RAY CASTLE

Further proof supporting the hypothesis of a link between Lords of Ray-sur-Saône and the Shroud is the fact that the family's show cabinet which conteins the coffer also features a drape, 50 centimetres long and 30 wide, with floral ornaments. On the fabric is painted the frontal part of a male human being, extremely similar to the man of the Shroud.

Figure 3. Painting on canvas preserved in Ray-sur-Saône castle (Ph. © Alessandro Piana).

This piece look a lot like the painting of the "Besançon Shroud" [44]. It would be interesting to know the epoch of the painting to understand if it is coeval to the transit of the Shroud in Ray-sur-Saône, otherwise is a subsequent attestation.

Figure 4. The "Besançon Shroud". From: J.J. Chifflet, (1624), quoted in References.

In any case, it is striking that this object is really in the castle of Ray-sur-Saône with the coffer, and could be a further connection between the Shroud and de La Roche family.

Papal sanctions on traffic of relics stolen in Costantinople could justify absence of documents regarding this period. Moreover, among decisions made during twelfth Ecumenical Council, the fourth Lateran, started on November 11th 1215 [45], they stated that: "*Saint relics should be shown in reliquaries and new ones could not be venerated without Roman church authorization*" [46] .

Basing on this statement, it would have been difficult to explain, to ecclesiastic autorithies, the presence in the family hands of this important relic stolen in Costantinople.

This aspect should be studied with further researches.

8. THE SHROUD AND THE DE VERGY FAMILY

After one hundred and fifty years the Shroud was kept in a collegiate church not far from Ray-sur-Saône castle. Geoffroi I de Charny is considered the first owner of the Shroud in Lirey in the fourteenth century. Different elements make us think this was not completely true. It is quite strange that de Charny family did not publicly show this precious treasure until the middle of the fourteenth century. It was not by chance that Geoffroi I, a well-known knight in France for his bravery, a friend of kings and popes, waited until his wedding with Jeanne de Vergy, before Shroud exhibition [47].

We need to point out that if Otho de La Roche had descendants, one of them was Jeanne de Vergy and not Geoffroi I. Jeanne probably brought the Shroud for the wedding with this personality. In fact Geoffroi I became Lord of Lirey and Savoisy only after his marriage to Jeanne. Moreover, on the brass plaque found in the Seine in the nineteenth century, there are coats of arms of both families, not only de Charny [48]. Besides, in not even one document about Geoffroi I de Charny was the Shroud mentioned. In fact, his son, Geoffroi II, did not inherit a Shroud when his father died [49], as in documents related to the foundation of the collegiate church a lot of relics are mentioned but not the Shroud [50]. In the end, the chance that the Shroud was property of Jeanne de Vergy is supported by the fact that in the period between 1360 and 1389 the Shroud was preserved in Monfort-en-Auxois, a de Vergy property [51].

It is plausible that the decision to exhibit the Shroud in Lirey was made in the period after that in which Geoffroi I obtained the Shroud, that is after his wedding with Jeanne de Vergy.

To prove the relationship between Jeanne de Vergy and Otho de La Roche we have to analyse family trees of some noble families from Franc-County and Burgundy between the twelfth and fourteenth centuries.

9. FAMILY TREES

Otho de La Roche married his cousin Isabelle, latest heiress of the principal branch of the family and, in this way, he obtained the title of Baron of Ray. From their marriage three heirs were born: Guy, Bonne and Otho II. From the marriage with Elisabeth de Chappes Guillaume was born.

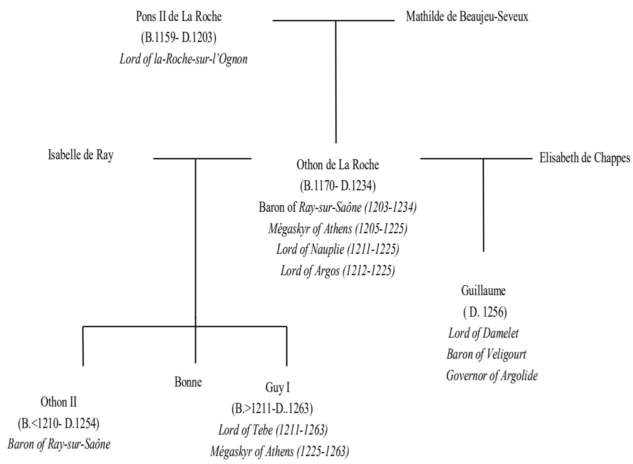

Figure 5. Otho's family tree (Ph. © Alessandro Piana).

As said below, for our interest Otho II is important. He died in 1254 leaving two daughters, Guillermette and Isabelle (or Elisabeth) [52], who would marry into the family of Oiselay and de Vergy respectively [53], and a son, Jean, who would become Baron of Ray-sur-Saône [54].

Let see now the de Vergy family [55]. Jeanne de Vergy was Guillaume's and Agnès de Durnay's daughter. Her father was the son of Jean I and Marguerite de Noyers. Jean I was son of Henry I de Vergy and Isabelle de Ray, daughter of Otho II de la Roche and sister of Jean, Lord of Ray [56]. These genealogical trees show how Jeanne de Vergy was related, in the fifth generation, to Otho de la Roche.

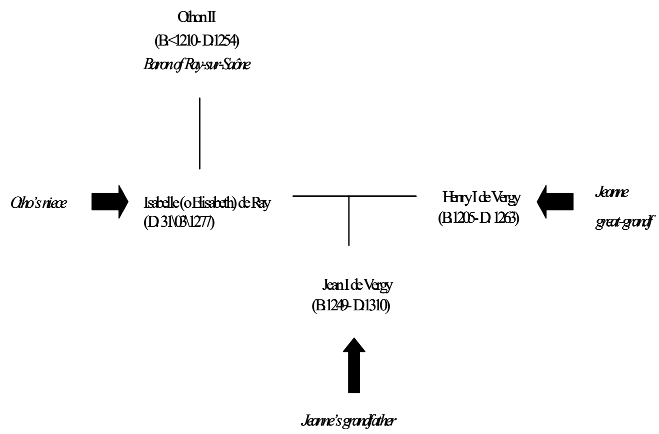

Figure 6. Family tie between Lords of Ray-sur-Saône and de Vergy (Ph. © Alessandro Piana).

It was this woman, descendant of the first Lord of Athens, who married Geoffroi I de Charny. It is through this wedding that "the most loyal and valorous of all knights", obtained the Shroud that, through different generations, we can suppose came in the hands of the de Vergy from the de La Roche family.

But this relationship on its own does not explain when, how or why the Shroud changed ownership from Ray-sur-Saône to de Vergy. At the moment we can just hypothesize.

We can start considering destiny of families involved in these events. While the de La Roche family declined, in 1386 we do not find any trace of la Roche sur- l'Ognon in genealogies [57], the Lords of Ray-sur-Saône, descendant of Otho de La Roche, were prospering. Their apogee was in the XIV century when two barons, Gauthier (who died in 1357) and Jean II (died in 1394), became "Guardian of Burgundy County", that is they were the people in charge during the king's succession or during the king's absence.

The transfer of the Shroud from the Lords of Ray could be linked to the murder of the sixth and last Duke of Athens, Gauthier V de Brienne, that took place on May 13th 1311, around lake Copais. This event ended the history of the French dukedom of Athens that the Ray family had maintained for a long time. This was certainly a difficult period for the family, a period in which they needed money to fortify dukedom. Most simple way to obtain a good amount was to give up a valuable thing.

In this period the Lord of Ray-sur-Saône was Aymé; the heiress of Ray and Henry I de Vergy were already married, so the link between the two families was already established, as described below. The fact that the Shroud arrived in the hands of the de Vergy family, rather than in other families' related with de La Roche, could be linked to the fact that in 1191 the de Vergy family became *Senechal* of Burgundy [58], a very important political position. The transfer could also have taken place while Jeanne was going to marry Geoffroi I de Charny, a well known and trustworthy man in France.

It is so possibile that, in a difficult period, de La Roche family, was compelled to give up the Shroud in hands of a trustworthy family and particularly of a family able to guard the secret regarding the origin of this object.

10. CONCLUSIONS

What I have tried to prove in these pages about the "Shroud's Missing Years" would be one more piece in the puzzle of the history of the Shroud.

A set of elements make suppose transit of the Shroud in Athens, thank to Otho de La Roche, at the beginning of thirteenth century. To this Burgundy noble family are linked a series of attestations that, if further confirmed, would help to set Shroud arrival in Europe a long time before the middle of fourteenth century.

At present this hypothesis appears the most likely, well-documented and able to give a series of ideas for further researches that other hypothesis can not suggest.

I do not think we can say that the missing period is definitely solved as we still have a lot of research to do, as suggested in the paper. This work has to be considered as the seeds of ongoing research, not the end but just the beginning.

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4. D.C. Scavone, *The Shroud in Constantinople: The documentary evidenc*e, pp. 35-38, in R. F. Jr. Sutton, *Daidalikon*, Bolchazy-Carducci, Wauconda (IL) (1989).
5. Monk Aubry de Trois-Fontaines, in his *Chronicon*, adressed Otho de la Roche as Duke of Athens (Aubry *Chronicon* is mentioned from: P. Vignon, *Le Saint Suaire de Turin devant la science, l'archéologie, l'histoire, l'iconographie, la logique*, Masson, Paris, p. 107-108 (1938)). Really it is from Jean de la Roche

(1263-1280) that the title of Duke is used as an alternative to *Mégaskyr*. Under Guillaume (1280-1287), his successor, only the title Duke of Athens was used.

6. G. de Villehardouin, *Histoire de la conquète de Costantinople*, N. de Wailly, ed., Librairie Hachette, Paris, pp. 146-149 (1872).
7. Lord of La Roche-sur-l'Ognon, village located around Ognon river, not far away from Besançon.
8. Noble family of Ray-sur-Saône, village of Franc-County in department of Haute-Saône.
9. H. de Salverte, *Historique du Château de Ray,* Ed. Sequania, Besançon, p. 15 (1999).
10. F. I. Dunod de Charnage, *Histoire des Séquanais*, eighteenth centhury. Quoted also in family trees.
11. Born from Clérembault IV de Chappes and Elissande de Trainel, coming from the noble families of Bar-sur-Aube region, related to Guarnieri of Trainel, bishop of Troyes, took part in the Fourth Crusade as a spiritual leader.
12. According to Scavone (D.C. Scavone, *La Sindone di Torino, Otho de la Roche, Besançon, e il Memorandum d'Arcis: Un'elaborazione e una sintesi*, in *Collegamento Pro Sindone*, p. 37 (January-February 1993)) he arrived in Athens bewteen the end of October and the beginning of November 1204.
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Were sixth-century natural catastrophes factors in the transfer of relics from Palestine?

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Abstract. *The suggestion that the Shroud now in Turin is the same cloth as the Image of Edessa, known there from the mid-sixth century, is generally accepted by sindonologists. But no credible reason has been adduced for removal of the imaged cloth at that time from its place of origin, Roman Palestine. The mid-sixth century was marked by numerous natural catastrophic events which resulted in profound social upheaval as terrified multitudes moved from town to countryside, countryside to town, city to city, seeking safety and food. These events correlate with the timeline of the emergence of the Shroud in Edessa and appearance of the Sudarium in North Africa, and may be considered among possible factors in the peregrinations of the cloths.*

Keywords: desertification, plague, volcanic eruption

1. INTRODUCTION

Several years ago, Professor Zvi Ben-Avraham, the Israeli geophysicist, pointed out that much of the Judean Desert had been a thriving agricultural area until it was transformed rather suddenly into an arid desert in the mid-sixth century [1]. Both the Shroud of Turin and the Sudarium of Oviedo reappeared in the historical record about this time, after a hiatus of several centuries [2]. Also during the mid-sixth century, the earth was devastated by numerous natural disasters – famine, plague, earthquakes, a volcanic eruption with global consequences. These concomitant events combined to produce massive societal dislocation. For the people who lived then, these catastrophes were of unparalleled proportions, Procopius wrote, "From the time this happened, men were not free from war, nor pestilence nor anything leading to death." [3]

The mid-sixth century is critical to provenance of the Shroud. Iconography considered as reflecting the facial image on the Shroud has been dated to precisely that time. This includes the Homs Vase of hammered silver, *ca.* 570, now in Musée du Louvre, Paris, and the encaustic Pantocrator of the Monastery of Saint Catherine at Mount Sinai, *ca.* 560. Towards the end of the sixth century, reference to the "Image of Edessa" (adduced as the same cloth now known as the Turin Shroud) [4] appeared in the historical record [5]. The Sudarium is said to have been removed from Palestine to North Africa early in the seventh century, The drastic environmental changes of the sixth century, with resulting societal upheaval, coincide with historical evidence for these timelines for the transfers of both the Shroud and the Sudarium.

These cloths, whose origin is associated with Jesus at Golgotha in Jerusalem in the first century, may very well have been moved to the Dead Sea area during the Jewish revolt of 65 – 71 C.E. Just as many Jewish insurgents fled to that area from the Roman troops, so we may expect that the keepers of the Shroud would likewise have fled there.

We suggest that social dislocation induced by natural catastrophic events beginning in the mid-sixth century may be considered among possible factors in the peregrinations of the cloths.

2. AGRICULTURE AND VERDANCY

Numerous paleoclimatic studies involving geology, hydrology, palynology, seismology, meteorology, archaeology remains and historical evidence indicate that the Dead Sea region, verdant from about the first century B.C., became desert rather abruptly in the sixth century [6, 7, 8].

In view of the extremely arid climate of the Dead Sea region today, one may wonder if this really could have been a thriving agricultural area 2,000 years ago. In fact, archaeological and palynogical evidence confirms that it was [9, 10, 11]. Further, it has been shown that even minor climatic changes in certain areas can result in dramatic environmental changes [12].

In the period we are discussing, approximately two thousand to fourteen hundred years ago, rain-fed agriculture was the general method of food production in the Near East. Apart from areas such as Egypt or Mesopotamia, which contain great rivers, agriculture dependent on rainfall was the economic basis in Palestine and elsewhere -- cities of the Levant, for example, which flourished during the Roman and Byzantine periods [13].

Rainfall, evaporation and humidity work together to affect the natural flora of the region and its suitability for cultivation. Rainfall, with its periodic fluctuations, affects long-term fluctuations of the Dead Sea water level. The water level and the associative areal surface of the Dead Sea not surprisingly rise following seasons of abundant rainfall and decline during drought years. [14] Evaporation rate based on greater or lesser areal surface of the lake in turn affects humidity of the region, and in this manner intensifies climatic change caused by fluctuating rainfall, closing the circular effect.

The year-to-year water level would be steady if the volume of water leaving the Dead Sea by evaporation were equal to the volume flowing in from perennial streams, flash floods in the wadis, and draining groundwater [15]. But historically, the consistency of the exchanges has fluctuated over time.

In various studies, historic water-level records were reconstructed using evidence from rainfall and tree ring widths, sedimentology, history, archeology, botany, and morphology. The largest change in estimated water level of the Dead Sea occurred between about 100 B.C. and A.D. 40. [16] Within this period, the water level of the Dead Sea rose some 70 meters, from about 400 meters below sea level to about 330 meters below sea level. [17]

The evidence shows that agriculture flourished during this humid period of greater rainfall, and was sustained for several hundred years. Palynological analyses of cores retrieved from Dead Sea sediment layers confirm increasing percentages of cultivated plants from the first century to about 600 A.D. [18] Radiocarbon dating of embedded plant fragments to around 2000 years BP support this conclusion. [19]

Analysis of core extractions of Dead Sea pollen indicates an increasing cultivated agricultural overprint on the arid vegetation background during this time, which indicates increasing rainfall and humidity. [20] The occurrence of abundant pollens of *Cerealia* (cereals), *Olea* (olive), *Juglans* (walnut), and *Vitis* (grape) reflects climate conditions supporting intensive cultivation of these Mediterranean plants. The latter two were grown, in particular, during the Roman and Byzantine periods (*ca.* 70 B.C. – 600 A.D.) [21].

3. DESERTIFICATION

This period of agricultural fecundity was followed by an abrupt drop in rainfall, a lowering of the water level of the Dead Sea and an increased rate of evaporation, with consequent desertification and inability of the land to sustain agriculture: "Interpreting the lake level changes as monitors of precipitation in the Dead Sea drainage area and the regional eastern Mediterranean palaeoclimate, we document... multiple abrupt arid events during the Holocene." [22] Repeated episodes of desertification in this area, including the cycle which began in the sixth century, have been shown to be related to these climatically induced environmental changes.

Palynological studies show widespread abandonment of agriculture. This is indicated by reduced percentages of *Olea* (olive) pollen and increased pollens of vegetation natural to arid and semi-arid plains and desert. [23] This decline of agriculture triggered a process of forest regeneration starting with pine trees (*Pinus*), followed by evergreen oaks (*Quercus ilex*) and other Mediterranean plants replacing *Olea* in the hills around the Dead Sea [24].

Moreover, the increasingly drier climate, with the continuing demise of agriculture, favored the transition from sedentary life of cultivators to nomadism, also coinciding with the rapid spread of Islam [25].

4. VOLCANIC ERUPTION

In 535 – 536, mankind suffered one of the greatest natural disasters ever to occur. It blotted out much of the light and heat of the sun for eighteen months, and the climate of the entire planet began to spin out of control. The result, direct and indirect, was climactic chaos, famine, massive migration, war and political change, not only in the Byzantine Empire, but on virtually every continent. The contemporary Roman historian Procopius wrote of the climate changes as "a most dread portent.... The sun gave forth its light without brightness like the moon during this whole year, and it seemed exceedingly like the sun in eclipse, for the beams it shed were not clear." [26] John of Ephesus, also a sixth-century contemporary of these events, wrote, "The sun became dark and its darkness lasted eighteen months. Each day it shone for about four hours, and still this light was only a feeble shadow" [27].

Not only the light, but also the heat of the sun was diminished. Unseasonable frosts disrupted agriculture where it had not been disrupted by the process of desertification, and famines afflicted some parts of the Empire. We have other accounts of the darkened sun from Zacharias of Mytilene, [28] John the Lydian [29] and the Roman Senator Cassiodorus [30].

Scientists have determined that a massive volcanic explosion took place in the year 535. Mile-deep ice core samples from both Greenland and Antarctica show that acid snow was falling on both ice caps at relatively the same time during the sixth century. This acid precipitation had to be delivered by the two totally separate high altitude wind systems that operate in the Northern and Southern hemispheres. Only an eruption from a tropical zone could have achieved this to any substantial extent [31].

The location of this volcano was the Sunda Straits between Java and Sumatra near present-day Krakatoa, which erupted massively in 1893. The sixth-century eruption was enormously greater than that of the nineteenth century, however, and probably caused the separation of Sumatra and Java into two islands. [32] A vast cloud of ash would have billowed forth, followed by a column of red-hot magma that would have shot out of the mountain like a fountain. A huge mushroom cloud of ash and debris would have penetrated far into the stratosphere, carried round the world at hurricane-force speeds.

It is clear how this eruption would bring about the drastic climate changes of the sixth century. But the volcano also indirectly brought about the devastating bubonic plague that followed. Modern research has concluded that most plague outbreaks are caused by sudden and severe climate change. [33]

5. THE "JUSTINIAN" PLAGUE

In the year 640, bubonic plague broke out in the port city of Pelusium, Egypt, where it had been carried by rats originally from ports on the eastern coast of Africa, at that time a great source of ivory for the Empire. After devastating Pelusium, it spread quickly to Alexandria, then to Constantinople, then throughout the whole empire and eventually to the Far East, where it was recorded by Chinese historians. [34] Up to a third of the empire's population died in the first massive outbreak, and in the capital city of Constantinople, more than 50 percent of the population is thought to have died. [35]

John of Ephesus, who tried in vain to flee from the pandemic, wrote of its devastation in the countryside as much as in the cities. "We saw desolate and groaning villages and corpses spread out on the earth,,, and cattle abandoned and roaming scattered... with nobody to gather them." In Constantinople, John recorded in considerable detail the scale of the catastrophe, noting that when the dead had reached 230,000, officials gave up counting the corpses, which, when burial space ran out, were thrown into the sea from barges. Finally, Justinian ordered the digging of vast mass graves. [36] The church historian Evagrius survived the plague when just a youth and lived through four great plague epidemics. In the year 593, he wrote: "I believe no part of the human race to have been unafflicted by the disease," as it occurred in some cities "to such an extent that they were rendered empty of almost all their inhabitants." "During the course of the various visitations [of the plague] I lost to the disease many of my children and my wife and many of the rest of my relatives, Now, as I write this, I am 58 years old and it is not quite two years since the fourth outbreak of plague struck Antioch and I lost my daughter and the son born to her in addition to those [lost] earlier." [37]

After a century of repeated plague epidemics, population levels in Europe declined dramatically. Constantinople shrank from a city of over half a million inhabitants to one of fewer than a hundred thousand. [38] Meanwhile, the mid-sixth century climactic crisis and its consequences had been generating further mechanisms through which the Empire and Europe were transformed. The ongoing invasions of "barbarians," so-called, were greatly accelerated by migrating peoples from the north and east attempting to find pastures and arable land. The reduced population and destabilization of the Empire left it in a weakened condition militarily and opened the way for the precipitous ascent of Islam. In less than sixty years, the empire shrank to less than a quarter of its former extent under Justinian. [39]

6. SEISMIC EVENTS

Historical records reveal a cluster of devastating earthquakes in the early Byzantine period from the fourth to the sixth centuries. In 551, a strong earthquake occurred in the Levant and caused extensive damage in the Galilee and in the cities of Jerusalem, Gerasa and Petra. [40] While earthquakes are generally not an adequate reason to explain the abandonment of settlements and the collapse of economic systems, as residents tend to remain and rebuild, the coincidental occurrence of recurrent earthquakes with drought, famine, and virulent pestilence may well have combined to exacerbate the plight of inhabitants and reduce them to refugees fleeing from one city to another in a vain search to escape these terrors.

7. SOCIETAL DISLOCATION

The various crises discussed above – desertification and resulting famine, devastating earthquakes, chaotic climatic change, terrifying pestilence resulting in sharp population decline – combined to bring about societal dislocation and decline of urbanism throughout the Empire.

In the Judean Desert, this same process of societal upheaval has been traced directly though water levels and rainfall patterns. Arid events during this time appear to have coincided with major breaks in cultural development. Wetter periods were marked by the enlargement of smaller settlements and growth of farming communities in desert regions, revealing a parallelism between climate and Near East cultural development. [41]

Archaeological evidence reveals recurrent periods of habitation and abandonment of many sites along the western shore of the Dead Sea. These have been dated through concurrent historical records, coins, pottery, and archaeological ruins. These sites were plotted according to their chronology and elevation and found to match various points on the historical hydrograph of water levels and rainfall. [42] In other words, higher population levels match with higher water levels and rainfall, and abandonment matches with lower water levels and minimal or absent rainfall.

The economic prosperity of this area during the Byzantine period came to a halt in the mid-sixth century. In the second half of the sixth century and continuing through the seventh century, a sharp decline in both urban and rural settlement is evident. For example, at Mampsis in the northeastern part of the Negev Desert, the north gate was destroyed by fire and the entire site was abandoned in the mid-sixth century. The entire village of En Gedi on the western shore of the Dead Sea was abandoned and destroyed around 600 A.D. A sharp urban deterioration also was found in cities of the Decapolis such as Gerasa. At Scythopolis (Bet Shean), excavations point to the mid-sixth century as the beginning of degeneration and decline in the life of the city. [43]

At this time also, numerous springs in this area dried up and were covered by sand dunes, leading to the abandonment of communities that had depended on them. For example, at ‘En Hatzeva, the spring which supplied abundant water to the nearby bathhouse in the Late Roman and Byzantine periods dried up completely; the bathhouse ceased to exist and the nearby village was abandoned. A monastic farm near ‘En ‘Aneva in the Judean Desert, founded during the early Byzantine period, was abandoned at the end of the period, again because of the drying up of the local spring. Near Yavneh-Yam in the Mediterranean coastal plain, a Byzantine well was abandoned in the mid-sixth century because it had entirely dried up and was blocked by sand. All of this accords with the testimony of Procopius of Gaza, who wrote Jerome of Elusa a letter describing how the roots of the vines had been exposed by a combination of drought and relentless winds [44].

8. THE RELIC CLOTHS OF GOLGOTHA

The Sudarium of Oviedo -- Pollen studies conducted by the late Dr. Max Frei [45,46] confirm the historical route of the Sudarium from Jerusalem and the Dead Sea area through North Africa and into Spain as well as the location of the Shroud in Jerusalem, the Dead Sea region, France and Italy. [47] While the presence of pollens can locate the cloth geographically, this evidence can contribute nothing to the problem of dates.

The fact is, we do not have a compelling timeline for the travels of the Sudarium. It generally is asserted that the cloth was removed from Palestine for safekeeping shortly before the city was conquered by the Persian Chosroes II in 614. [48,49] This tradition relies entirely on the twelfth-century *Liber Testamentorum,* a book commissioned by Pelayo (Pelagius), Bishop of Oviedo 1101–1129, to record ostensible donations made to the Cathedral of San Salvador. The documents comprising the *Liber Testamentorum,* however, are widely acknowledged as fabrications [50]. The fabulous claims of the book earned Pelayo the sobriquet "historiador-fabulador." [51]. Pelayo’s “manipulation, interpolation, and outright creation of documents” [52] are seen as an effort to commemorate Oviedo’s prestigious past, enhance the city’s recently diminished Episcopal status, and restore the city’s place of honor, which faded after King Ordono II transferred his residence to Leon in the early tenth century. [53] We may conclude that the connection of the cloth’s removal from Palestine to the arrival of Chosroes remains an unsubstantiated hypothesis.

The history of the Sudarium after it arrived in Spain, especially its odyssey north to Oviedo, is mentioned in a number of other documents and is not disputed here. Yet the date when it was taken from Palestine remains uncertain.

We suggest its removal may have been instigated by catastrophic events of the mid-sixth century.

The Shroud of Turin -- The “Image of Edessa,” which circumstantial evidence strongly suggests may be identified with the Shroud of Turin, came into the historical record at just the time we have been discussing – the mid-sixth century. Its earlier provenance remains a mystery. The earliest mention of an image is in the *Doctrine of Addai* where initially it is described as a painting by Abgar’s envoy, Hanan [54]. Eusebius’s tale of letters exchanged between Abgar V Ukkama and Jesus is not credited as historically valid. The account is not merely suspect: The *Catholic Encyclopedia* refers to the exchange, both as recounted by Eusebius and as found in the later *Addai*, (which professes to be of the apostolic age), as a “legend,” and as “imaginary,” and notes: that the “correspondence has long since ceased to be of any historical value. The text is borrowed in two places from that of the Gospel, which of itself is sufficient to disprove the authenticity of the letter” [55]. In a detailed examination of the material related to Abgar, the respected historian Walter Bauer concluded: “Thus we find the Abgar saga to be a pure fabrication, without any connection with reality.” Bauer “resolutely” rejects “any thought of a ‘historical kernel’" [56]. However, Professor Ilaria Ramelli of the Catholic University of Milan has undertaken an extremely thorough investigation of possible historicity of the *Doctrina Addai* and has found: “In conclusion, I suppose that the *Doctrina* might contain some historical traces, especially in the correspondence between Abgar and Tiberius, even though wrapped in a legendary dress” [57]. Nevertheless, she refers to the material as a whole as “absolutely unhistorical.” [58], and as “a fiction,” [59] particularly with regard to the supposed exchange of letters between Abgar and Jesus.

Ian Wilson’s identification of the folded “Image of Edessa,” aka the “*Acheiropoietos,*” with the cloth that arrived in Constantinople in 944 is fully credible, but the notion that this cloth might have been hidden for centuries, actually forgotten, in the damp city walls of Edessa, [60] is not.

In any case, we have no credible information pertaining to the removal of this cloth, the record of Jesus’s passion at Golgotha, prior to the sixth century.

9. CONCLUSION

The Roman world suffered significant crises during the sixth century, as a result of the cataclysmic changes we have described. In contrast to the age of Justinian, the later sixth century was characterized by political, economic, and military collapse. Just three years after Justinian's death in 568, the Lombards began their conquest of Italy. During the latter part of the reign of Justin II (d. 578) large numbers of Slavs, forced west and south by loss of agricultural fertility, began to cross the border of the Empire. Migrations of the Avars from central Asia followed during the last quarter of the sixth century. Moreover, the Arabian peninsula as well was progressively drying up during this period, forcing Arab populations to move into surrounding territories. The long wars between Persia and Byzantium, which exhausted both sides, also may have been exacerbated by social dislocations resulting from plague, famine, etc.

We suggest that the basis of social upheaval during this time may be found in the natural catastrophes dating from the mid-sixth century, and that these disasters may thus be considered among several possible factors in the appearance of the Shroud of Turin in Edessa as the "*Acheiropoietos*" and the appearance of the Sudarium of Oviedo in North Africa shortly thereafter.

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Edessan sources for the legend of the Holy Grail

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Abstract

Second-century Edessan King Abgar VIII is shown to be the originator of the account of the apostolic conversion of Abgar V. After Edessa's flood in 201, he built a new royal complex on high ground, thence known in Syriac as the Birtha*. Documents attest that* Birtha *became* Britium *in Latin. The Easter display of Edessa's Christ-image as changing its appearance from Child to Crucified became the secret of the Grail in its legends. Glastonbury later usurped the name Abgar as the fictitious king who brought the Faith to Britain, inventing Joseph of Arimathea as Britain's apostle.*

Keywords: Lucius Abgar VIII, *Birtha*, Eleutherus, *melismos*

1. INTRODUCTION

In Edessa, a cloth bearing a faint life-sized image made directly from the face of Jesus is reported in the sixth-century Greek apocryphon called the *Acts of Thaddaeus* (*AT)* [1] and with different details in the earlier fourth-century Syriac *Doctrine of Addai* (*DA*) [2]. Sculpted renderings of Jesus' bearded face began in the fourth century, and copies of Edessa's image exist from the sixth century on. So it seems to have been a real and impressive image. Its arrival in Edessa is contained in the legends surrounding the healing of Edessan King Abgar V Ukkama, a contemporary of Jesus who ruled from 4 BCE to 50 CE.

In 1978 Ian Wilson's brilliant research first drew our attention to Edessa and its Abgar V legend [3]. Wilson's Edessa insight continues to be the only plausible early historical venue—after the New Testament—of the elusive Shroud. This fact obviously precludes the Shroud's presence anywhere else during the years immediately after the Resurrection, especially since none of the claimed venues mentions a shroud or even an image of Jesus. The rule remains: history proceeds from documents.

The writer of the Syriac *DA* said he found the Abgar V story in the city's archives already in Syriac [4]. J. B. Segal, the major historian of Edessa [5], has already concluded that this archival original contained a reference to the correspondence between Abgar and Jesus as well as a reference to a remarkable image of Jesus, one which refused to be described simply as a Byzantine icon. He writes that the story must have arisen during the monarchy at Edessa, i.e., before its subordination by Rome in 242. Thus this record in Edessa's Syriac archives antedated and was indeed the direct source of the *DA* and other versions of Edessa's conversion.

I have turned up evidence that points directly to the late-second-century Edessan king Lucius Abgar VIII Megas (Abgar the Great, 177-212 CE) as the originator of the legend of Abgar V's apostolic conversion. It was he who inserted the Abgar V story—as we have it—in the royal archives. This king was concerned to provide his lands with a conversion by a direct disciple of Jesus. In fact, we now have evidence that Abgar VIII himself was converted to the orthodox Faith—and at a time when all manner of Christian teachings were competing for the minds and hearts of the people of Edessa.

The writer of the *DA* thus will have found in the archives that Abgar V, who suffered a crippling ailment, sent his agents on a mission to the Roman governor at Eleutheropolis. We know this information can only have come from Abgar VIII's time, since it was only about 200 that Roman emperor Lucius Septimius Severus renamed the town of Beth Gubrin as Eleutheropolis, to celebrate his granting of municipal status to its people.

There is more: significantly, according to Rome's sixth-century *Liber Pontificalis*, King Lucius Abgar VIII—who took his nomenclature to honor his Roman conqueror, the same Lucius Septimius Severus—sent a letter to Pope Eleutherus (175-189) asking for missionaries to come and preach the Faith in his city [6]. We also know from the important Roman historian Dio Cassius (150-235) [7] that this Abgar, now friend of the Roman Empire, paid a celebrated state visit to Rome in the time of Pope Eleutherus. The coincidence of Abgar's letter to the pope and his presence in Rome argue strongly for Abgar VIII's studied acceptance of orthodox Christianity. It speaks to the determined efforts of this king to combat paganism (as his contemporary Bardaisan wrote in his *Dialogus de Fato*).

In the pre-Nicene setting of Abgar VIII, still a time of multiple Christian sects, we may surmise that this Christian king wisely saw the value of his city's conversion by an immediate colleague of Jesus, one who would surely be in a position to teach the most orthodox form of Christian beliefs, as received from an intimacy with Jesus himself. Hence, we find the story of Abgar V's first-century conversion and the roles of Thomas and Thaddaeus/Addai inserted in the archives. There we read that on the return of Abgar V's delegation from Eleutheropolis, they reported seeing Jesus healing the sick in Jerusalem. This led to Abgar's letter to Jesus asking him to come and heal him. Jesus then appointed Thomas to bring or send a reply. Thomas sent Addai (Syriac for Thaddaeus) who, ironically and pointedly, spoke to Abgar the famous words of Jesus to Thomas drawn from John's Gospel (20:29): "Blessed are those who believe though they have not seen". Addai then adds Jesus' praise of Abgar: "Because you have believed in me, may the city in which you dwell be blessed and may the enemy never prevail over it" [8]. It was Abgar VIII who stood to gain by permitting the story of Jesus' epistolary promise to protect Edessa to be published in the city's archives. Under Abgar VIII, Edessa's defenses were in good hands.

This does not mean that Abgar V never became a Christian or that he never obtained the Shroud, but only that the famous legend of his conversion contained some key elements that could only have been written 150 years later, in the time of Abgar VIII. Besides the Eleutherus connections, let us notice that, in the name of orthodoxy, several other second-century figures populate the account of Abgar V's conversion in the first century: Palut, Edessa's bishop, next named in the existing account after the first-century Bishop Aggai, went to Antioch around 200 CE to receive ordination from Bishop Serapion (190-203), who had taken his own office at the hand of Zephyrinus, bishop of Rome (199-217) [9].

Segal, in his great book in 1970, has called the legend a successful "pious hoax"—as it stands—but he had no doubts about a first-century conversion of Edessa. I submit that by "hoax", Segal means to say that he has also noticed these anachronistic elements, i.e., so many second-century elements in a first-century setting [10].

We can, I think, all agree that there never was a Mandylion (meaning the image of Jesus' face on cloth associated with his ministry). We may also agree that Edessa's imaged cloth was always the Shroud, folded and framed to expose only the face.

I would argue that the writers of both the fourth-century *DA* and the sixth-century *AT* were eyewitnesses of Edessa's cloth image, for they actually try to describe it and their descriptions are plausible. The *DA* called it a face of Jesus made with "choice pigments", which may hint at the very faint dilute appearance of the image of the Turin Shroud [11]. Otherwise, "choice pigments" would be an entirely gratuitous and virtually meaningless expression. In the *AT*, Abgar's agent was unable to capture the appearance of Jesus when he tried to make the portrait which Abgar had requested. "Knowing this, Jesus asked for a towel, on which he wiped his face, leaving his image miraculously on the cloth". It was afterwards described as *acheiropoietos,* or image "not made by human hands". Describing the towel, this author called it a *sindon tetrádiplon* [12]. Given that these words can be translated as a "burial wrap folded in eight" and given the obvious faintness of an image formed by the mere wiping of Jesus' face, we may accept that our anonymous author had seen the folded Shroud in Edessa and has given us a version of the legend that virtually defines the faint image on the Turin Shroud.

2. ON ABGAR VIII

A short digression on the character and mind of Lucius Abgar VIII will reveal him as a man who truly deserves the epithet "the Great". The "Chronicle of Edessa", dated about 540, contains a chronological account of the city's history in 106 entries [13]. The entries are short, most of them needing only one or two lines. Entry 8, on the great flood of 201, is unique in its great length and in the clear signs that it was originally composed by Abgar VIII himself. Edessan scholar Andrew Palmer has noted: "This report, though it is one of the most famous texts in the Syriac language, has never been studied closely". I will paraphrase most of it, keeping with the general tone of Palmer's translation. The scribes have properly placed Abgar in the third person, but his reactions and motivations seem surely to have been dictated by the king himself**:**

"In the year 201, in the reigns of Severus and of King Abgar VIII, the water of the Daisan River spilled over the battlements, devastating the splendid palace of our Lord the King and all the city's fine buildings in its path. King Abgar retreated to the safety of the acropolis above his palace. The water also ruined the nave of the church of the Christians. This catastrophe cost more than two thousand people their lives, and the city was filled with the sound of screaming.

"When King Abgar saw what devastation had been caused, he commanded that the width of the river bed should be enlarged as determined by experts in land surveying. King Abgar commanded, moreover, that a winter palace be built in the high ground [*Birtha*] for the dwelling of his majesty.

"In order to restore the stability of the city, King Abgar commanded that the taxes of its citizens should be remitted for five years, to give the population time to recover its strength and to restore the buildings of the city.

"This event was recorded *according to the directions of King Abgar*. And it was received and entered into the archives by the Keepers of the Archive". (Italics added.)

We should note the entirely rational tone and modern "ring" of this text, without any expected religious nuance. Notice Abgar's (i.e., the government's) socio-economic "stimulus" solutions in the form of taxation relief for the citizens after that crippling disaster. This is the character of one of the truly great rulers of the ancient world.

3. EDESSA'S EASTER RITUAL [14]

My next and extremely important notice is the Easter ritual involving Edessa's famous *sindon*. Every Easter the cloth was exposed for the public in a most remarkable manner: at the first hour (6 a.m.) Jesus' image was displayed as an infant, at the third hour (9 a.m.) as a child, at the sixth hour (noon) as a youth, and at the ninth hour (3 p.m.) as the crucified Jesus. How this "polymorphic Jesus" display was achieved remains a matter of conjecture.

Sometime after the cloth was sent to Constantinople in 944, a new Eucharistic service called *melismos* (fraction of the bread) began to be practiced [15]. During the Byzantine liturgy (or Mass) the loaf of leavened bread was carried to the altar on a *kylix* (a shallow chalice) or on a *diskos* (paten) covered by a cloth image of the infant Jesus. The cloth was removed, and the bread was cut into communion morsels with a *longche* (miniature lance). As the bread was taken in communion, the child Jesus changed symbolically into the adult Jesus of the Last Supper and Crucifixion. One cannot easily guess why the Child should have a place in this commemoration of the Last Supper, unless it was inspired by the polymorphic or changing Jesus of the Shroud's Easter display celebrated for centuries in Edessa [16]. The *melismos* service would have been one of the experiences that crusader knights brought home in the very period when the Grail romances were being developed in the fertile minds of French poets.

My project is to show that Edessa's history and legends were fictitiously replayed in Britain. In this way, the Shroud helped to define the legend of the Holy Grail.

4. THE HOLY GRAIL

All of the above existed in the world centuries before the Holy Grail ever saw the light of day. Though the word *graal,* or its French variants, described an ordinary table dish or bowl [17], our object, the *Holy* Grail, was invented between 1180 and 1200 by a French poet named Chrétien de Troyes. Chrétien described it as a large platter holding only a single communion host. It was carried in procession to a crippled king (remember crippled Abgar V). The theme of his poem was the quest for the Holy Grail by Perceval, a knight of King Arthur. More importantly, soon after Chrétien, and certainly before 1191, another French writer, Robert de Boron, provided a *history* for the Holy Grail, which he said—for the first time in all literature—was the cup used by Jesus at the Last Supper. Strangely, then, two French poets set their magnificent story of the Holy Grail in Britain [18]. Fortunately, how and why this began can now be revealed.

In the eighth century, Venerable Bede, writing his *Ecclesiastical History of Britain* [19], tells us that his friend Nothelm, working in papal files in Rome, found a stunning item in the *Liber Pontificalis*, which contained the important events under each pope to that time. Under late-second-century Pope Eleutherus he read: "This pope received a letter from *Lucio Britannio rege* [which he interpreted to be a British King Lucius] asking for assistance in converting his lands to the Faith" [20].

This was welcome news to Bede. *Up until this moment nobody had ever heard of a King Lucius in Britain.* Here, he thought, was evidence that Britain had become Christian already in the second century. Of course, he was wrong. The problem is that there were no national kings in Britain in the second century, when it was still a province of Rome. Moreover, Adolph Harnack, the great German scholar of the Church, wrote in 1904 that there was only one King Lucius who converted to the Faith in the second century: Lucius Abgar VIII of Edessa—the same who visited Rome in the time of Pope Eleutherus. Rome was then, in a fashion, Eleutheropolis, the "city of Eleutherus" [21].

But every British historian and clergyman read Bede. His non-existent King Lucius of Britain thus became an important "reality" as the king who brought the Faith to Britain in the second century, as Lucius Abgar VIII had done in Edessa. In fact, the story of Edessa's conversion under Abgar V had long been available in Latin Europe for later British writers to exploit. The fourth-century pilgrim Egeria knew it [22], Pope Stephen III knew it in 769 [23], and medieval British writers Ordericus Vitalis ca. 1131-1141 [24] and Gervase of Tilbury ca. 1211 knew it. Gervase actually gives two versions of the faint image of Jesus' whole body on his burial sheet [25]. We will see that virtually everything in the conversion stories of Britain was drawn from the story of Abgar V in Edessa.

The plot is about to thicken. About 1136 British historian Geoffrey of Monmouth [26], unconcerned about Bede's British King Lucius, discovered a first-century British king named Arviragus in the pages of the Roman satirist Juvenal (fl. 98-128) [27]. Poking fun at a street-corner poet, Juvenal wrote: "Veiento blurts out flimsy sycophantic prophecies to an emperor: 'You will capture some king—perhaps Arviragus will tumble out of his British wagon'". Juvenal must have drawn the name of this king from Edessa's King Abgar VII (109-116), pronounced "Avgarus" and prominent in Rome, since he had then been causing trouble in the East.

Again, as in the case of "British King Lucius", there never was a King Arviragus in Britain. Juvenal's Arviragus was a satirical joke. Since the legendary letter of "British King Lucius" to Pope Eleutherus reflects a real second-century event, but in Edessa and not Britain [28], in another study [29] I asked if an earlier—apostolic—conversion of Britain might also have a parallel in Edessa.

I found that the name of Arviragus, placed by Geoffrey between 44 and 54 CE, may indeed be the mirror of Edessa's Abgar V of the same period [30]. The very names of these kings are virtual homophones for each other, especially when the Greek "Avgaros" and Latin

"Avgarus" are seen against the frequent scribal variant "Arvigarus" in Geoffrey's *History of the Kings of Britain*.

When Geoffrey resurrected the name of Arviragus from five lines in Juvenal's *Satire IV* after his 1000-year absence from all known records and embellished him in seven pages as a major enemy of the Romans in Britain, he did not know what he was hatching. On the subject of British religious history, Geoffrey knew only what Bede had provided about British King Lucius. And Bede himself knew no Arviragus.

A full two hundred years after Geoffrey, Glastonbury's monks, concerned to enhance their abbey as the birthplace of Christianity in Britain, adopted Arviragus as an enabler of British Christianity, as Bede had done with Lucius. But unlike Bede's rather innocent mistake, the reinvention of Arviragus in Glastonbury in the first century was a deliberate fabrication taken directly from Geoffrey.

Here is the evidence. About 1125 William of Malmesbury had written a definitive *History of the Church in Glastonbury* [31]. The name of Arviragus was absent. In 1342 John of Glastonbury updated William's book. In his *Chronicle,* taking a cue from Glastonbury monk Adam of Domerham (*fl.* 1290), John inserted Geoffrey's Arviragus into this history as the king who provided Glastonbury land for Jesus' disciple Joseph of Arimathea to build the first Christian church [32]. Why Joseph? Known in the New Testament mainly for providing Jesus' shroud, Joseph had entered Edessa's story quietly when, whether already in Edessa or later in Constantinople, their imaged cloth came to be recognized as Jesus' burial shroud.

The hypothesis that the history and legends of Edessa's conversion were transported to Britain continues to be reinforced. The role of both Arviragus in Britain and Abgar V in Edessa was to preempt their respective second-century counterparts (both named Lucius) by introducing Christianity into their lands at the hands of a direct disciple of Jesus (Joseph of Arimathea and Thaddaeus). In both accounts, the purpose of this was to elevate their kingdoms to leading places in the hierarchy of neighboring national churches.

We return now to the question as to why the two French creators of the Holy Grail legends located their stories not in France but in England. Recall that after the flood of 201 Abgar VIII built a new royal precinct on the high hill above the city and that their word for this was the *Birtha*. Both Thaddaeus and Thomas, the apostolic missionaries identified with Edessa, were buried with honor in the *Birtha*, among the graves of Edessa's kings.

The next point is very important: in the time of Abgar VIII, Clement of Alexandria, one of the Fathers of the early Church, wrote that "Thaddaeus and Thomas were buried in *Britium Edessenorum*", clearly signifying "in the *Birtha* of the Edessenes" [33]. So we may now urge with textual evidence that the word *Birtha* came over into Latin as "Britium" and that the "British King Lucius" found by Bede in the *Liber Pontificalis* was indeed Lucius Abgar VIII of Britium (Edessa)—as Harnack already attested—and not some non-existent King Lucius of Britannia.

The quest for the Holy Grail rarely found success. Only the best knight could achieve (comprehend) it. At least two Grail romances deal with the achievement of the Grail by the greatest knight. In the prose romance called the *Perlesvaus* (which followed and used Robert's proto-history of the Grail), Sir Gawain achieved the secret of the Grail [34]. What is the Grail's ultimate secret that only the greatest knight may experience? In the Grail, Gawain first sees the infant Jesus. Then the Grail is removed. When it next comes before Gawain, he sees in it the crucified Jesus. The Christ Child has changed mystically into the adult Christ. The secret of the Holy Grail was to experience Christ born and Christ crucified.

In the romance called the *Vulgate Queste*, constructed upon the themes of Robert de Boron, the hero is the perfect knight Galahad. He also sees in the Grail the same "polymorphic" (changing) Jesus. After that, he dies, having achieved all he had ever wished for in life. Here is the scene in which the best knight achieves the secret of the Holy Grail: [35]

"Next Josephus [invented son of Joseph of Arimathea, not found in Robert] entered upon the consecration of the Mass. He took from the vessel a host made in the likeness of bread. As he raised it aloft, there descended from above a figure like to a child, and he entered into the bread, which took on human form before the eyes of those assembled there. Then raising his eyes, he saw the figure of a man appear from out of the Holy Vessel, unclothed and bleeding from his hands and feet and side".

We have already seen how the Byzantine *melismos* Eucharistic practice strangely involved the Christ Child's image placed over the communion bread to then "become" the body of the adult Jesus of the Last Supper and Crucifixion. This was derived from Edessa's Easter exposition of its famous image, appearing to change from Child to Crucified throughout the day. The Shroud was not the Grail, but given the numerous Edessan parallels, we must accept that the romances surrounding the very secrets of the Grail have also been drawn from the legends and history of the Shroud in its Edessan period.

5. CONCLUSION

The links are too many to be simply coincidental: we meet with a confusion caused by similarity of lands (Britain; Britium), royal names (British kings Lucius and Arviragus/Arvigarus and Edessan kings Lucius Abgar VIII and Abgar V/Avgarus), dates (late second century), accidentals (Eleutherus; Eleutheropolis), and identical story functions (to invite missionaries and introduce Christianity to their respective lands). All of this, and the secret of the Grail too, may now be traced to Edessa.

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Unknown hideaway of the Holy Shroud?

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Abstract

Data suggest that the Shroud, after its arrival in Turin in 1578 and before the siege of 1706, was secretly removed from the Savoy capital at the beginning of the seventeenth century. A tradition exists in the town of Maddalene, not far from Turin, that the Holy Shroud found shelter in the town at the beginning of the seventeenth century when Turin was threatened by Spanish troops. One can assume that the Holy Shroud was hidden in this place, which was the property of the Savoy family, with the purpose of protecting It from hazards of war.

Keyword: Maddalene, seventeenth century, Princes of Acaja, Savoy, Brotherhood.

1. INTRODUCTION

It is commonly accepted that once it arrived in Turin, the Holy Shroud left the town only in two occasions: during the siege of Turin in 1706 and during the second world war in 1939 [1].

In the small town of Maddalene, near Fossano, 80 kilometers south of Turin, there is a time-honoured tradition according to which the Holy Shroud found shelter in the palace of the town's local lord at the beginning of seventeenth century [2].

2. MADDALENE AND ACAJA PRINCES

Maddalene is a small village of around 200 people belonging diocese of Fossano. The feudal territory of Fossano during the seventeenth centhury was the property of Acaja's Prince.

The title of Prince of Acaja, created in 1204 after the Fourth Crusade [3], went to the Savoy family, after dynastic unions, in the fourteenth century. In 1301 Isabelle, heiress of that principality, married again, this time to Philip I of Savoy, son of Thomas III. Through this marriage he became Prince of Acaja and started the Savoy-Acaja branch. In 1314 Fossano was added to the Savoy-Acaja territories, becoming the second capital city after Pinerolo.

The Acaja branch in Maddalene descended from Thomas, count of Flanders (1177-1233). Their power in the territory ended in 1418, the year in which, with Ludovic's death, the Savoy-Acajas died out and their properties were returned to the principal branch of the Savoy family [4]. Amadeus VIII became lord of the territories of Acaja in Piedmont.

Under Acaja control, Maddalene's palace was built with great rooms in medieval style. It was used primarily as a hunting manor. The rulers lived there in autumn, the season best suited for hunting [5]. During the rest of the year the family lived in Fossano's castle.

Figure 1. The Palace of Maddalene (Ph. © Alessandro Piana).

At the beginning of the seventeenth century, some families clustered not far from the palace. They built, besides their houses, also a small church. Santa Maria Maddalena Church was converted to a parish on the 13th of December 1604 and was committed to Our Lady of the Rosary [6].

Figure 2. The Church of Maddalene (Ph. © Alessandro Piana).

According to some researches of the 1990s, some signs lead us to presume that the Holy Shroud stayed in the Palace of Maddalene, which was the property of the Savoys in 1617 [7]. In that year a Spanish army, formed of 30,000 men led by Don Pedro of Toledo, entered Piedmont and besieged Vercelli, which fell on the 26th of July [8]. Charles Emmanuel I, Savoy's duke, who felt that Turin was being threatened, secured the family's treasures. This was a common custom in case of impending danger. Among the Savoy treasures was certainly the Shroud [9]. Displacements of the Shroud during periods of war are documented also during its stay in Chambéry [10].

One can assume that, as happened in 1706 and in 1939, the Holy Shroud had been hidden, this time in the Savoy palace in Maddalene, very close to French territories. Again, the purpose was to protect it from the hazards of war. Are there other data supporting this hypothesis?

In Maddalene in 1617 a chapter was founded of the "Brotherhood of the Holy Shroud", which was officially recognized two years later by local authorities and in 1668 by a papal bull of Clement IX [11]. A series of clues leads us to suppose that the Brotherhood was founded when the Shroud was in Maddalene [12].

3. THE BROTHERHOOD OF THE HOLY SHROUD

The first Brotherhood of the Holy Shroud was founded in Chambéry in 1506 when it was established that the Liturgy and Mass of May 4th would be the feast of the Holy Shroud. Charles III of Savoy and his wife subscribed to this Brotherhood [13]. In 1519 a plenary indulgence was granted to worshippers who, every year, on May 4th attended the Shroud exhibition. In 1530 it was announced that one could see the Shroud in the Ducal Chapel also on Holy Friday [14].

Other Brotherhoods were founded in subsequent years: in Ciriè in 1521 and in Rome in 1578. In Rome it was founded in the church where people from Savoy, Nice, and Piedmont assembled [15]. In 1598, twenty years after the arrival of the Shroud in Turin, the Brotherhood of the Holy Shroud and of Our Lady of Graces was created in the Savoys' capital city [16]. On April 17th during the 2010 exhibition of the Shroud, the Brotherhoods were in Turin for veneration.

Evidence of the link between the Brotherhood of Maddalene and those of other towns is a painting gifted at the end of the 1970s from the Brotherhood of the Holy Shroud of Turin to the local people. On this one can read: "To the Maddalene community, witness and soul of the memory of the Shroud, a Christian greeting from the Brotherhood of the Holy Shroud of Turin, in union of prayer and friendship, June 17th, 1979" (see Fig. 3).

The Brotherhood of Maddalene, as said before, was endorsed in 1668 by a papal bull of Clement IX. In 1668 this pope drew up a Summary of Perpetual Indulgences granted to the members of this Brotherhood and to the faithful [17] (see Fig. 4).

Figure 3. Painting gifted from the Holy Shroud Brotherhood of Turin to people of Maddalene (Ph. © Alessandro Piana).

SOMMARIO
DELLE INDULGENZE PERPETUE
CONCESSE ALLA CONFRATERNITA DEL SS.^mo SUDARIO
ERETTA NELLA CHIESA PARROCCHIALE DI S. MARIA MADDALENA, FINI DI FOSSANO
dalla Santità di N. S. Papa CLEMENTE IX, come appare per suo Breve:
Dat. in Roma li 15 dicembre 1668.

1. Concede a tutti i Fedeli Cristiani dell'uno e dell'altro sesso nel giorno, che entreranno in detta Compagnia, Indulgenza plenaria, essendo confessati e comunicati.

2. A tutti quelli, che sono e saranno in detta Compagnia, in articolo di morte confessati e comunicati, potendo ciò fare comodamente, o almeno contriti divotamente col cuore, non potendo colla bocca, invocheranno il nome di GESU', Indulgenza plenaria.

3. Inoltre ai detti Confratelli, quali similmente confessati e comunicati nella Domenica immediatamente seguente al giorno della Festa del SS. SUDARIO visiteranno la detta Chiesa dal primo vespro del sabato antecedente sino al tramontar del sole di detta Domenica, ed ivi pregheranno S. D. M. per l'esaltazione di S. Madre Chiesa, estirpazione dell'eresie, conversione degl'infedeli, concordia tra Principi Cristiani, e salute del Romano Pontefice, Indulgenza plenaria.

4. Ai medesimi Confratelli, che ancora confessati e comunicati visiteranno detta Chiesa, e pregheranno come sopra nei giorni di S. Giuseppe, secondo giorno di Pentecoste, quarta Domenica di settembre, e Festa di Tutti i Santi sette anni d'Indulgenza, ed altrettante quarantene la Solennità di Natale, secondo giorno di Pasqua, Purificazione, ed Assunzione di Maria Vergine.

5. Più ad essi Confratelli concede sessanta giorni d'Indulgenza per caduna volta, che interverranno alle Processioni prescritte dall'Ordinario, ed ai Divini Ufficj, Congregazioni pubbliche o secrete, quando accompagneranno il SS. Sacramento nel portarsi agl'infermi, oppure essendo impediti, al segno della campana diranno inginocchiati divotamente un *Pater noster* ed un'*Ave Maria* per l'infermo.

6. Concede la medesima Indulgenza di sessanta giorni ai detti Confratelli ogni volta, che accompagneranno i cadaveri de' Fedeli defunti alla sepoltura, se alloggieranno in casa poveri, pellegrini, o quelli consoleranno nelle loro avversità, ovvero comporranno la pace tra nemici, o ridurranno qualche traviato alla via della salute eterna, o gl'insegneranno i Comandamenti di Dio, e ciò che appartiene alla salute dell'anima, come anche se diranno cinque volte il *Pater noster* e l'*Ave Maria* per l'anime de' Fedeli defunti in grazia di Dio, che sono stati di detta Compagnia.

CLEMENTE Vescovo di Fossano.

[illegible] Segret.

In Cuneo 1669, ed in Savigliano nel 1833 dalla Stamperia di Giuseppe Daniele. Con permissione.

Figure 4. Summary of Perpetual Indulgences granted to the members of The Brotherhood of Maddalene. (Ph. © Alessandro Piana).

In fact, it was Clement IX who in 1669 founded a Congregation whose duty was to regulate indulgences. In 1908 this responsibility was shifted to the Holy Office and in 1918 to the Apostolic Penitentiary [18].

As in Turin, also in Maddalene every year on May 4th the Holy Shroud and the Brotherhood were honoured [19].

4. THE CHURCH OF MADDALENE

The inside of the church is enriched by symbols of veneration, either coeval or subsequent to the event; particularly interesting are the standards of the Brotherhood (see Figures. 5, 6, 7).

Besides these objects, there are two Shroud-related paintings, each representing a Shroud exhibition. Most interesting for our research is the painting located at the entry of the church, just opposite to the altar (see Fig. 8). This one, dating from the seventeenth century, represents three bishops holding the Shroud. The Shroud exhibition portrayed in this painting probably occurred during its sheltered presence in that small town.

Figure 5. Banner of the Brotherhood of the Holy Shroud (Ph. © Alessandro Piana).

Figure 6. Carved wooden stick used by the Brotherhood's guide during the processions. (Ph. © Alessandro Piana).

Figure 7. Another banner of the Brotherhood of the Holy Shroud (Ph. © Alessandro Piana).

Figure 8. Painting of a Shroud exhibition: entry of the church (Ph. © Alessandro Piana).

At the moment it is not possible to affirm whether the bishops holding the Shroud in the painting preserved in Maddalene are the same depicted in prints of that period. We need further research in this direction.

It is, in any case, very interesting to emphasize that in the period between 1614 and 1618, critical political years in Turin, there was no news regarding public exhibitions of the Holy Shroud in Turin [20].

The second painting is located in the apse to the left of the altar and depicts a Shroud exhibition in the presence of the Virgin Mary (see Fig. 9).

In the twentieth century, priests devoted to the Shroud and its assumed sojourn in this site have placed a set of Shroud references in Maddalene.

Figure 9. Painting of a Shroud exhibition: left of the altar (Ph. © Alessandro Piana).

Figure 10. Paint of the twentieth century: two angels hold the Shroud. (Ph. © Alessandro Piana).

5. TWO CURIOSITIES

Before concluding, I would like to relate two curiosities. First, it was one of the first bishops of Fossano [21] who wrote one of the first books about he Holy Shroud [22]. In 1621 Father Agostino Solaro [23], priest of Moretta in the Saluzzo surroundings and commander of the Maurician Order, was named as the fourth bishop of Fossano. He wrote an historical and theological treatise on the Shroud, published after his death by his nephew in Turin in 1627. We do not know if the book was written also in memory of the Shroud's stay in Maddalene.

Second, Severino Poletto, archbishop of Turin, was bishop in Fossano between 1980 and 1990.

6. CONCLUSIONS

In conclusion, though without absolute certainty, all these data suggest that the Shroud, after its arrival in Turin in 1578 and before the siege of 1706, was secretly removed from the Savoy capital at the beginning of the seventeenth century to stay in the town of Maddalene, part of the family's property.

ACKNOWLEDGMENTS

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3. First recipient is Guillaume de Champlitte.
4. Princes of Savoy-Acaja are: Philip I (1301-1334), James (1334-1367), Amadeus (1367-1402), Ludovic (1402-1418). For the link among families one can look at P.L. Datta, *Storia dei principi di Savoia del ramo d'Acaia*, Torino (1832).
5. AA. VV., *op. cit.*, p. 53 (2004). From 1870 to 1930 was used as state school. Today it is used as a housing project.
6. Parish archive of Maddalene.
7. C. Griseri, *Le immagini della Sindone nel Cuneese con notizie e curiosità storico ambientali*, Bollettino della Società per gli Studi Storici, Archeologici ed Artistici della Provincia di Cuneo, n. 106, p. 181 (1992). *Ibid.*, *La S. Sindone sostò a Maddalene di Fossano?* Bollettino della Società per gli Studi Storici, Archeologici ed Artistici della Provincia di Cuneo, n. 104, p. 101-102 (1991). *Ibid.*, *Iconografia della S.Sindone nel territorio del Cuneese e nell'esilio in Liguria del 1706* (VHS).
8. According to an agreement stipulated in Pavia on October 9th, Vercelli was to be given back to Charles Emmanuel by the end of the month, but was in the end given back in the summer of 1618.

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13. In the same period was founded a Brotherhood in Bourg-en-Bresse for weavers and fabric merchants. G. M. Zaccone, *Sindone, reliquie e immagini di Cristo. Pietà e devozione nel basso medioevo*, in *Guardare la Sindone. Cinquecento anni di liturgia sindonica*, Effatà Editrice, Cantalupa, p. 122 (2007).

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17. Parish archive of Maddalene. Also, Canonical Act in Rome, December 15th 1668.

18. Clement IX (Giulio Rospigliosi: born in Pistoia, January 28th 1600; died in Rome, December 9th 1669; reigned 1667-1669). Pope Paul V (1605-1621) prohibited exhibition of a copy of the Veronica, which had been stolen in Rome in 1527 and then, probably, had reappeared in Manoppello.

19. Parish archive of Maddalene. Document of June 20th 1890, relating the history of the Duty and Legacy of the Brotherhood.

20. L. Fossati, *op. cit.*, p. 139 (2000).

21. Fossano diocese was founded in 1592.

22. A. Solaro, *Sindone Evangelica, Historica e Theologica*, Torino (1627). Agostino Solaro was bishop of Fossano from 1621 to 1625; see Zaccone G.M., *Contributo allo studio delle fonti edite sulla Sindone nei secoli XVI e XVII*, in *La Sindone. Nuovi studi e ricerche, Atti del III Congresso Nazionale di studi sulla Sindone Trani 1985*, Edizioni Paoline, Rome, pp. 54-56 (1986).

23. Elected bishop under Pope Gregory XV on March 29th 1621, he governed his diocese from 1621 to 1625. See C. Morra, *La Diocesi di Fossano e i suoi Vescovi*, Edited by Archivio Vescovile di Fossano, Fossano (1995).

Two unpublished letters of Secondo Pia about the 1898 Shroud photography

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Abstract
After the first photograph of the Shroud of Turin made in 1898 the lawyer Secondo Pia had extensive correspondence with many personalities and scholars throughout Europe. In particular some letter, traced in this paper, refer to contacts with whom Filippo Crispolti disserts some technical details of unpublished and management Pia's archive. The study of this correspondence opens new avenues for research into the first photo of the Shroud.

Keywords: Shroud exposition, photographic negative, Pia

In 1842, to celebrate the wedding of Crown Prince Victor-Emmanuel with Arch-duchess Mary-Adelaide of Austria, the Shroud of Turin was publicly exhibited in Turin. It is well known that on this occasion there was an attempted photographing of the Shroud with the daguerreotype by Enrico Federico Jest [1].

The occasion was during the exposition from a balcony of the Royal Palace, but it is reported that, due to bad weather, it was impossible to take any photographs (see figure 1).

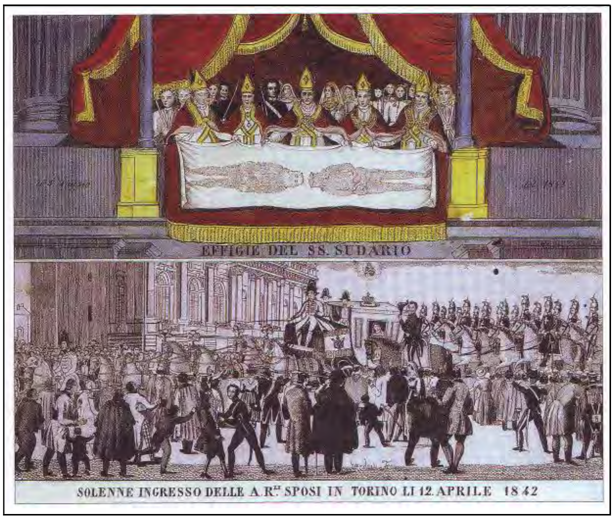


Figure 1. Commemorative print of 1842 Shroud's exhibition**.**

The opportunity would arise again in 1898. The 1898 Exhibition marks an important and decisive turning-point in the Shroud history and in the knowledge of the Shroud itself. Until then, the Shroud had been considered only on a devotional plane.

After the first photograph taken of the cloth had led to the discovery of the image negative properties, it became an object of examination on a scientific plane as well. The Exhibition was allowed by the House of Savoy to solemnize the wedding between Crown Prince Vittorio Emanuele III and Montenegrin Princess Elena Petrovich-Niegos and it was part of ampler civic and religious events celebrated in Italy and in Turin.

The event that went down in history was not the Exhibition unusual duration, from May 25 to June 2, 1898, but the taking of the first photograph of the Holy Cloth. The cloth was displayed in a large and artistic frame with the consequent discovery that the imprints that could be seen on it were a perfect negative [2].

We must remember the interest and the work of the Salesian Father Natale Noguier de Malijay (figure 2).

Don Noguier made the suggestion to photograph the Shroud. To his bitter surprise, his idea was rejected, as being too "dangerous" for the Shroud.

The proposition of Don Noguier was examined by a commission set up on April 18, directed by Baron Manno and others.

Figure 2. Father Natale Noguier de Malijay

In cooperation with Secondo Pia, Baron Manno proposed to photograph the Shroud and to use the photos to promote the "Arte Sacra." Finally, king Umberto gave his permission to show the Shroud in its full length, during the "Arte Sacra" in the Cathedral of St. John.

During the development of the glass plates Secondo Pia (figure 3) noticed that the image on the photographic negative appeared as a perfect positive of a man composed solemnly in death. (figure 4) He was very amazed at his discovery but arrived at the conclusion that the image on the plate appears as a perfect positive and that the actual object itself must likewise be a perfect negative [3].

Figure 3. Secondo Pia.

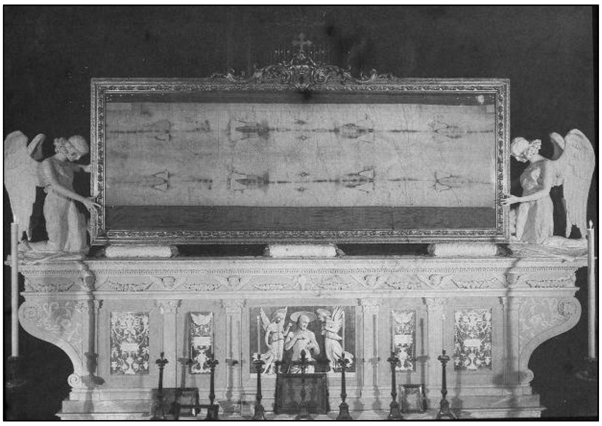


Figure 4. The Shroud in the 1898 frame.

A precise reconstruction of Pia's work was realized by his son, the lawyer Giuseppe, in an accurate article in the magazine "Sindon" (April 1961) [4] to which we refer people who want to have first-hand information.

The article quotes some documents in its appendix, among which the most important is one titled "Memory" that Pia wrote in French for Arthur Loth, who published it in the volume "*La Photographie du Saint Suaire de Turin*", printed in Paris in 1907.

Until today this is the only writing that Pia left about his work to offset skeptics and their criticisms that the photograph was not perfectly realized.

The confirmation of the results did come from photographs like the one by lieutenant Felice Fino and the one by Jesuit Father Giammaria Sanna Solaro, who published his photograph in the work "*La Santa Sindone di Torino che si venera a Torino illustrata e difesa"* (figure 5). It is also reported that Don Noguier took some successful photographs but unfortunately there is no trace of them.

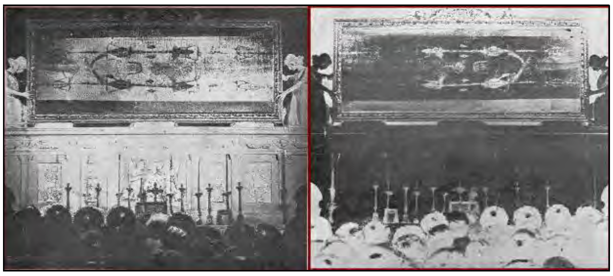


Figure 5. Negative and positive of the Sanna Solaro's photo.

The qualification of "amateur photographer" given to Pia in many subsequent writings was a distortion of reality, reestablished in its very rich objectivity through the numerous national and international recognitions given to him.

Father Antonio Tonelli, in an article published in "*Rivista dei giovani"* [5] remembering Pia's work, wrote: "*Pia told a friend of mine that once (he) placed the plate in the bath, he felt the need to jump because he was so filled with emotion and happiness"*.

The other detail is remembered by an assistant of Pia's nephew in an article published in "*Collegamento pro Sindone"* [6]: *"Pia was at the threshold of the dark room. In his hands he held the big plate still dripping fixative. Once close to him, my grandfather was struck by the strange expression of his face. He looked down at the plate and saw..."* (figure 6). Two really interesting and very important articles about Pia's various photographic sessions in 1898, with original photographic documentation, were published in "*Sindon"* in 1991 and 1995, signed by Gian Maria Zaccone [7] on the occasion of the donation by Pia's son, the lawyer Giuseppe, of his father's collection regarding the Shroud: writings, documents, original photographs and plates.

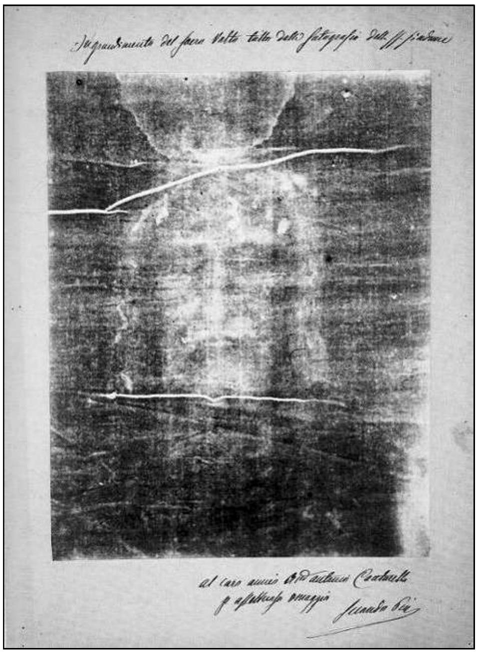


Figure 6. The detail of the face.

I present it here with the words of the author: *"It's a fund* [collection] *not of great dimensions, but of notable importance. It has been munificently given by Secondo Pia's children - Giuseppe and Chiara - in successive stages, from the 60's until today. It is composed of papers, particularly correspondence, that cover a period of time from 1898 to the 1930's, and naturally, of original photographic plates, prints and reproductions of the Shroud. It also includes the large camera, whose image has become familiar to every Shroud researcher and lover, used by the photographer of Asti for the Shroud photography in 1898. The Shroud photographic section is only a small part of Pia's marvellous photographic archives created during the many years he dedicated to this new art."*

During the exposition of 1998 in Turin Zaccone edited the exhibition "The image revealed. Secondo Pia photographed the Shroud", which showed for the first time a lot of material and photographs of 1898.

Recently I was so fortunate to receive notice about some unpublished letters (see figures 7, 8, 9, 10) written by Secondo Pia kept in the Archives of the Dominican Fathers' Convent of Santa Maria sopra Minerva in Rome [8]. This fund that, among other things, includes a section of a certain size related to correspondence, was donated by the heirs of Marquis Filippo Crispolti.

The Marquis Crispolti (figure 11) was a journalist and writer, politician, deputy and senator. He published one of the first articles about Pia's photography in a foreign magazine. An article which caused some talk. Correspondence with Pia is estimated at approximately 10 letters contained in an envelope, two of which are those that concern us more, because they deal with the photography of the Shroud.

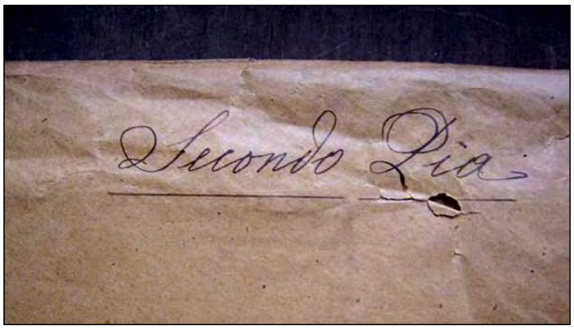
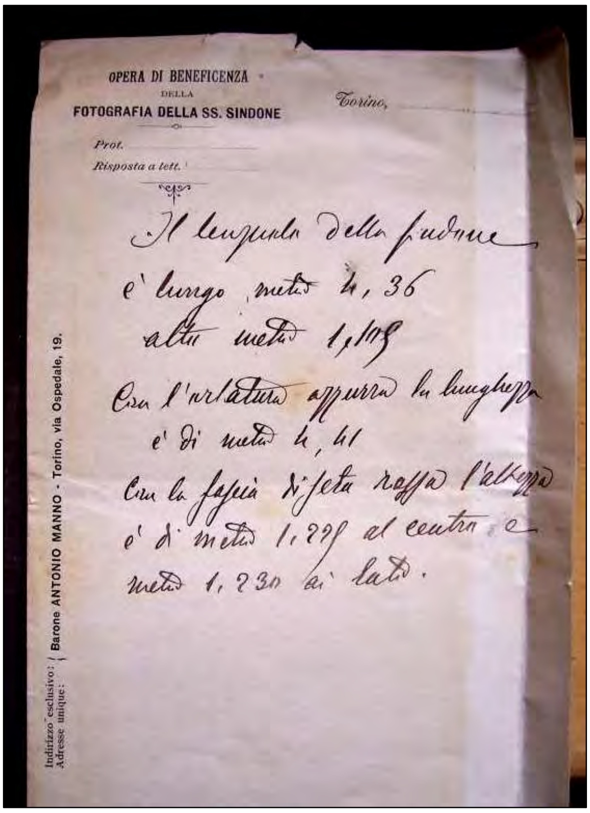


Figure 7. Detail of the envelope.

Figure 8. All the letters of Pia to Crispolti.



OPERA DI BENEFICENZA
DELLA
FOTOGRAFIA DELLA SS. SINDONE

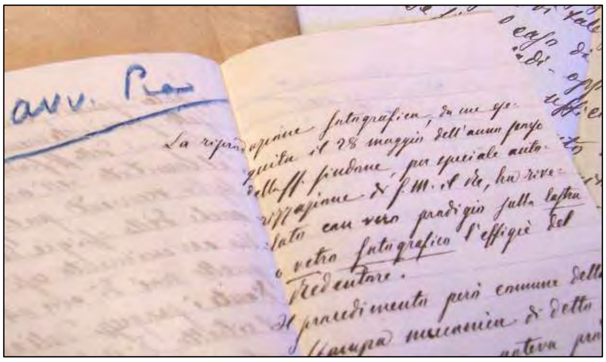
Torino,

Prot.
Risposta a lett.

Il lenzuolo della Sindone
è lungo metri 4,36
alto metri 1,10
Con l'orlatura appurai la lunghezza
è di metri 4,41
Con la fascia di seta rossa l'altezza
è di metri 1,225 al centro e
metri 1,230 ai lati.

Indirizzo esclusivo: / Adresse unique: Barone ANTONIO MANNO - Torino, via Ospedale, 19.

Figure 9. Pia's measurement of the Shroud size.


avv. Pia

La riproduzione fotografica, da me ese-
guita il 28 maggio dell'anno scorso
della SS. Sindone, per speciale auto-
rizzazione di S.M. il Re, ha rive-
lato con vero prodigio sulla lastra
di vetro fotografico l'effigie del
Redentore.
Il procedimento però comune della
stampa meccanica di detta

Figure 10. Detail of the first letter.

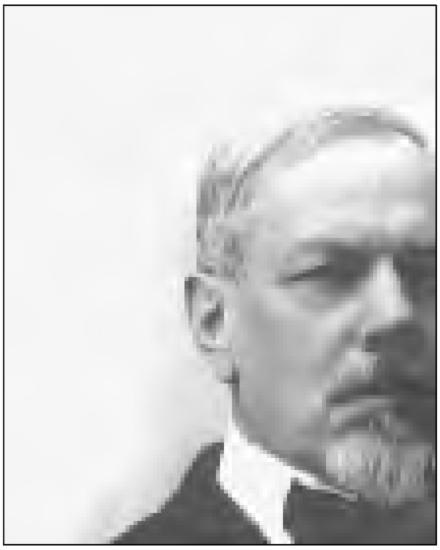


Figure 11. Marquis Filippo Crispolti.

They are not dated, but they clearly date back to 1899. In the first short letter Pia refers to a verbal interview, in which the recipient had apparently asked for precise data on the Shroud measurements, to prepare a second article. In this letter Pia mentions the request to continue a technical publication of the photos he had taken and, specifying that the administrative aspects were responsibility of another person, he recommends that the public be informed that he derives no financial profit from publication and that the only satisfaction given him by his work is moral. In the second instead Secondo Pia describes how he had obtained the enlargements of the only face, that were marketed together with those of the entire Shroud. The technical details contained in the letter are very important, because until now there has been no news of how they had been obtained. It is known in fact that Pia accomplished only the shooting of the total picture of the Shroud and nothing special.

Pia writes [9]: " *The photographic reproduction of the Holy Shroud I took on 28th May of last year under special authorization of the king has surprisingly revealed the image of the Redeemer on the photographic glass plate. However the common procedure of printing such glass mechanically on paper could not but produce the reproduction of the Holy Shroud, as it had been admired during its solemn exhibition. The importance of this event made me try to reproduce on paper not only the Holy Shroud, but also the rear side of it, that is of the holy face. I started this work with apprehension, as I had to submit the negative or original plate to a certain pressure because of the contact with another sensitized plate with consequent possible break. Fortunately the original plate had no damage, therefore, as I had already done with the print of the Holy Shroud, I could furnish the Committee of Sacred Art the plates necessary to print also the image of the Redeemer. Such an unexpected event, that is obtaining the portrait of Our Lord Jesus Christ thanks to the progress of photography, didn't allow the people who were not competent in the photographic chemical process to exactly understand how it could take place: it is therefore natural and comprehensible the confusion the most even now make between positive and negative copy.*

Once the photograph of the Holy Shroud, eagerly awaited by the faithful, was published, it was widely requested from every part of the Christian world: when later the photograph of the Redeemer's image was published, the requests were inferior because of the confusion I mentioned before.

It would be thus advisable that the public, in spite of the modest publications, was better informed about such new work that would complete the previous one and especially because this would spread the Holy Image in the world of the believers and the sales could go on, increasing the proceeds destined to charity by the King.

Considering the importance and the interest for history and religion of having finally found the portrait of Our Lord Jesus Christ after so many centuries, I thought I could enlarge it and after long and patient efforts (there's nothing like being modest) I succeeded.

This blow-up was carried out by me alone in my study exposing the original glass by transparency and then in larger and larger dimensions, paying attention that this enlargement didn't alter the features of the holy face in the least; and I didn't retouch anything in this delicate work as well as in the original glass, but I obtained only what my camera offered me with mathematical precision and accuracy.

The above-mentioned blow-up was executed in three different dimensions, the largest of the face only of cm 14 for a photograph of cm 21×27. The medium of cm 8 for a photograph of cm13×18 and the smallest of cm 5 for a photograph of cm 9×12.

As I had already done previously, I prepared the plate necessary for the printing and publication of this photograph and to this purpose the baron Manno founded an office called "Opera di beneficenza per la fotografia della SS. Sindone" situated in via Arsenale n. 15 until June and from 1st July in Via San Francesco di Paola n. 19."

Figure 11. The Shroud inside the Cathedral of Turin in 1898.

REFERENCES AND NOTES

1. Capello di Sanfranco, L., *Un cenno sulla SS Sindone*, in Museo Scientifico, Letterario e Artistico 24, (1842) pp. 189-190. See also: G.M. Zaccone, *Torino 1898, l'Ostensione della Sindone e l'Esposizione d'Arte Sacra,* Gribaudo, Paravia Torino (1998).

2. G. Sanna Solaro, *La S. Sindone che si venera a Torino*, V. Bona, Torino (1901).

3. A fundamental book about the work of Pia is: G.M. Zaccone, *L'immagine rivelata. Secondo Pia fotografa la Sindone*, Archivio di Stato, Torino (1998).

4. G. Pia, *La prima fotografia della SS Sindone,* Sindon, III. N.5, aprile 1961, pp. 51-53.

5. A. Tonelli, *La fotografia ha deciso*, Rivista dei Giovani, Torino, (November 1929).

6. L. Fossati, *Un oscuro promotore della ripresa fotografica della Sacra Sindone nel 1898: il salesiano Don Natale Noguier de Malijay,* Collegamento pro Sindone, July\August 1988, pp. 8-42. The name of Pia's assistant is Carlino.

7. G.M. Zaccone, *La fotografia della Sindone nel 1898: recenti scoperte e conferme nell'archivio Pia*, Sindon, nuova serie, II, n. 3, pp. 69-101 (1991). See also: G.M. Zaccone, *Alcune note sul riordino e la consistenza dell'archivio Pia*, Sindon, nuova serie, VII, n. 8, pp. 91-98 (1995).

8. Minerva Archivium: Pia H III,16, busta 39.

9. This is the full text of the letter. Translation of the author.

Did Jesus give his Shroud to "the servant of Peter"?

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Abstract
Jerome credits the Gospel of the Hebrews for the following statement: "And when the Lord had given the linen cloth to the servant of the priest, he went to James and appeared to him." Since it appears unlikely that Jesus would have presented his Shroud to the priest of the Jerusalem temple, various emendations to the text have been suggested to support a restoration to an alternate reading: "to the servant of Peter." This solution has been uncritically accepted in numerous papers relative to Biblical research and has served to support the claim that Peter had possession of the Shroud. The proposed restoration is shown conclusively to be untenable.

Keywords: Jerome, Gospel of Hebrews

1. INTRODUCTION

The origin of the *Gospel of the Hebrews* (*GH*) is obscure. It has come down to us in fragments quoted or paraphrased by various Church Fathers -- Jerome, Papias, Hegesippus (cited by Eusebius), Clement of Alexandria, Cyril of Jerusalem, Origen and possibly Ignatius [1]. It has been dated to the first half of the second century. It has proto-gnostic tendencies and a strong Jewish-Christian character, not only as may be seen in the title, but also in the emphasis on the figure of James.

Near the end, *GH* tells of an appearance of Christ to James. This appearance of the risen Christ is an independent legend, apparently a reflex of *I Corinthians* 15:5-7: "He [Christ] appeared to Cephas, then to the twelve. Then he appeared to more than five hundred brethren at one time. . . . Then he appeared to James. . ."

Jerome, in *De Viris Illustribus 2,* writes: "The gospel called *According to the Hebrews* which I recently translated into Greek and Latin, and which Origen often uses, recounts this after the Resurrection of the Savior: And when the Lord had given the linen cloth to the servant of the priest, he went to James and appeared to him."

This is a peculiar statement, presenting us with a conundrum. Why would Jesus have given his Shroud to the priest of the Jerusalem Temple, who, after all, had just headed the council that condemned him? Although the "linen cloth" is quite credibly understood to refer to the Shroud now in Turin, it seems most unlikely that Jesus would have presented his Shroud to the priest of the Temple, through his servant or otherwise. Moreover, if this were true, Peter and "the other disciple" would not have seen the Shroud when they entered the tomb, as recounted in *John* 20:5,6.

Figure 1. The scholar Saint Jerome, 337 – 420, with the faithful lion, from whose paw he had removed a thorn. (Albrecht Dürer)

Nevertheless, a number of emendations to the text have been suggested to support an alternate reading: "to the servant of Peter." On the basis of common sense, this does not appear plausible. Analysis of the arguments in favor of the emendation reveals that it is not only implausible, but impossible [2].

2. HEBREW CONSONANTS "SOLUTION"

Alfred O'Rahilly, writing in 1942, commented: "It is generally felt that there is something wrong with the [phrase] but it is difficult to conjecture what [it] should be. . . The Hebrew consonants for slave (*ebed*) and priest (*Cohen*) would not be very different from those for Peter (K*epha*) and John *Yochanan*)" [3]. O'Rahilly here appears to have conflated Jerome's text with a later tradition [4] that the grave cloths were taken away by "Simeon and John" (i.e., Simon Peter and the "other disciple" of the fourth gospel 20:2-8) because the text of Jerome does not mention "John."

Let us examine O'Rahilly's comparison of *ebed* with *Kepha* and *Cohen* with *Yochanan*:

servant / "*kepha*"
עבד / כיפא / כפא
ebed / *Keipha* / *Kepha*
(Heb.) (Ar.)

Figure 2. Saint James, extolled in *G H*
Sixth-century mosaic from Kankariá, Cyprus

כ י פ א *(Keipha)* is a Hebrew nickname, based on כ ף *(Keph)* "rock." *"Kephas"* is the English transliteration of the Greek transliteration of כ י פ א, *Keipha,* or in Palestinian Aramaic, which Jesus and his disciples would usually have spoken, כ פ א *(Kepha)***.** In Aramaic, *Kepha,* and the common noun, *kepha,* "rock," are spelled the same [5].

The consonants are *Ayin, Bet, Dalet* for servant/*ebed* and *Kaf, Yod, Fe, Alef* for *Keipha*. It takes no knowledge of Hebrew whatsoever to see that the consonants are not at all the same and would not easily be confused.

priest / John
כהן / יוחנן
(Cohen) / (Yochanan)

Consonants for the next pair are *Kaf, He, Nun-sophit* for "priest" (*cohen)* and *Yod, Vav, Chet, Nun, Nun-sophit* for "John" *(Yochanan)*. This pair shares only one consonant, the final *Nun* and again, would not easily be confused.

Clearly, the Hebrew and/or Aramaic consonants have nothing to do with any supposed confusion on the part of the scribe. Thus there can be no Hebrew or Aramaic basis for O'Rahilly's uninformed conjecture.

3. HEBREW VOWELS "SOLUTION"

The failure of this proposed solution on the basis of consonants led others to conclude that the confusion must have arisen from a (supposed) similarity of the vowels.

servant Keipha/Kepha
עֶבֶד כֵּיפָא כֵּפָא

עֶבֶד is a segolate noun and the vowels, if they had been written, would have been written as three dots (*segol*) beneath the first two letters, *Ayin* and *Bet*. The vowels for כֵּיפָא would have been two dots (*tsere*) beneath the first letter, *Kaf*, and a line with a dot under it *(qamatz)* beneath the third letter *(Fe)* for pronunciation of the final vowel.
The vowels for כֵּפָא would have been a line (*patach*) beneath the first letter, *Kaf*, and a line with a dot under it *(qamatz)* beneath the second letter *(Fe)*. These vowels are not the same as those for עֶבֶד.

In the next pair, the vowels for כֹּהֵן would have been a do t (*cholam*) just to the upper left of the first letter (*Kaf),*

כֹּהֵן יוֹחָנָן priest / John (*Yochanan)*

and two dots *(tsere)* below the second letter *(He)*.
For יוֹחָנָן the second letter, *Vav*, functions as the first vowel, with a dot (*cholam maleh)* written above it, and a line with a dot under it *(qamatz)* would have been written beneath the third and fourth letters *(Chet* and *Nun)*. The vowels of these two words do not correspond to one another.

But this system of "pointing" to indicate vowels was a later development of the Masoretes. Pointed texts with vowels represented by dots and lines came into existence in Tiberias in the sixth century. The various systems of pointing were not standardized until the eighth or ninth century by a consensus of Rabbinic scholars. So vowels were not indicated in Hebrew texts at the time of Jerome, or previously, and thus a supposed scribal "error" could not have arisen from a confusion of vowels, which would not have been similar, even if they had been indicated in the text, whether Hebrew or Aramaic, and they most certainly were not.

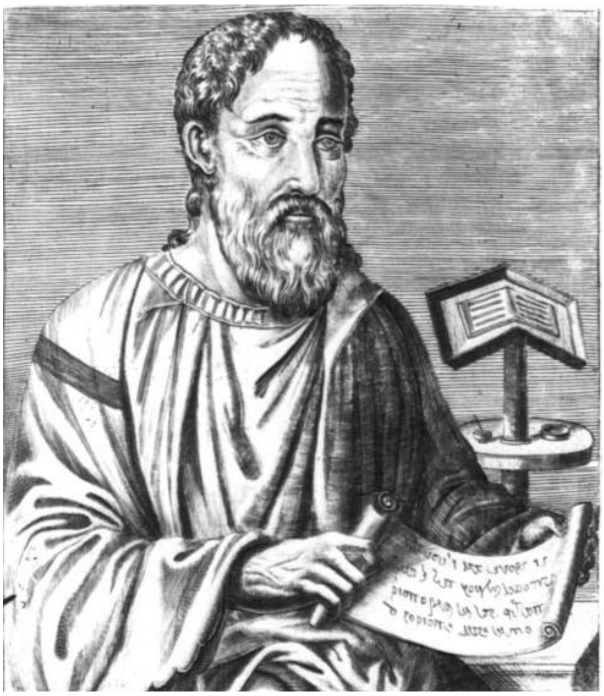

Figure 3. Eusebius of Caesarea
263 – 339
(André Thevet)

4. LATIN MISREADING "SOLUTION"

John Theodore Dodd, reputed scholar of Christ Church, England, suggested in 1931 [6] that the original text read *Petro* (dative of *Petrus,* "Peter") instead of *puero* (dative of *puer*, "child," "servant"). Dodd pointed to this same mistake, *puero* written for *Petro*, in the short ending of the *Gospel of Mark,* found, however, in only one Latin manuscript, and in an entirely different context [7].

The suggested emendation: *puero* was mistaken for *Petro*

Dodd further justified his conjecture by an appeal to *I Corinthians* 15:5-7: "It is more likely that the original did state that Jesus gave the burial Shroud to Peter, because Paul among the appearances of the risen Christ mentions the appearance to James but states he was first seen of Cephas,"

There are so many obvious problems with this spurious "solution" that it is difficult to understand why anyone would ever have taken it seriously, but it is still cited, after almost eighty years.

First, Dodd is trying to justify his emendation to a Latin translation of a Hebrew or Aramaic original (*GH*) by basing it on an erroneous Latin translation of a different Greek text (*Gospel of Mark*) which erroneous translation has been found in only one out of numerous manuscripts, and in a very different context. Moreover, although he was basing his emendation on Latin translations involving supposed Latin substitutions, the Latin words in question do not correspond to the Hebrew words the scribe is supposed to have miscopied or mistranslated.

dedisset sindonem "puero" sacerdotis. (he gave the Shroud to "the servant" of the priest.) *dedisset sindonem "Petro" sacerdotis.* (he gave the Shroud to "Peter" of the priest.)

"Servant" remains in Dodd's "restoration", which is a sort of translational oxymoron, for the scribe is said to have mistaken *ebed* for *Kepha*, substituting *puero,* "servant" for *Petro*, "Peter." Yet the new reading, "the servant of Peter" retains the word "servant." If the scribe had made the mistake Dodd ascribed to him, the amended text would necessarily read, "... to Peter of the Priest." Absolute nonsense.

Moreover, the proposed emendation is entirely the product of Dodd's imagination, because Jerome's text does not include the word *puero.* It reads, *Dominus autem cum dedisset sindonem* ***servo*** *sacerdotis, ivit ad Iacobum et apparuit ei.* We have no instance of another text where Jerome quotes *GH* with the word *puero* instead of *servo.*

This clearly untenable emendation to the text so that it reads that the Shroud was given to Peter is cited for support of the idea that Peter took the Shroud to Antioch and other attempts to connect Peter with the Shroud.

In any case, we should be cautious in using the Gospel of the Hebrews as a reliable historical source. It differs from the canonical gospels in important respects. For example, we are told in the fourth gospel that the burial cloths were found lying in the tomb, not that they had been given to Peter or to anyone else. The passage we have been considering, wherein we are told that the Lord gave the cloth to the servant, continues: "For James had sworn that he would not eat bread from that hour in which he had drunk the cup of the Lord until he should see him risen from among those that sleep."

GH suggests, contrary to *NT*, not only that the first appearance of Christ was to James, but also that James was among "the twelve" at the Last Supper [8].

5. CONCLUSION

Emendations to Jerome's text citing *GH* -- whether based on Hebrew letters, non-existent Hebrew vowels, Latin substitutions, or the passage in *I Corinthians* 15 -- are not credible. Jerome's text can provide no support for the idea that Jesus gave his Shroud to Peter. Are we left with a conundrum? I think not. *GH* is valuable for some theological ideas of early Jewish Christians, but its historicity is dubious and it may be discounted as far as historical authenticity is concerned, as Erbetta [9] concurs.

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1. The major primary sources for quotations from the *Gospel of the Hebrew*s include the following writers and their works: Cyril of Jerusalem (*Discourse on Mary Theotokos* 12a), Origen (*Commentary on John* 2.12.87), Clement of Alexandria (*Stromateis* 2.9.45.5, 5.14.96.3), and Jerome (*Commentary on Isaiah* 4, *Commentary on Ephesians* 3, *Commentary on Ezekiel* 6, *De viris illustribus* 2). The relationship of *GH* to *The Gospel of the Ebionites* and *The Gospel of the Nazoreans* is not clear. They may in some instances have overlapped with *GH*. The *Oxyrhynchus Sayings* were formerly thought to have originated in *GH*, but since the discovery of the Nag Hammadi manuscripts, they have been found to come from *The Gospel of Thomas.*

2. Professor Mario Erbetta has proposed an interesting interpretation. He suggests that the author of *GH* is recounting the transfer of the cloth to the servant of the Priest as a legend, not as historical fact, involving an elaboration of *Matthew* 27:65 – "Pilate said to them [the chief priests and Pharisees] You have a guard (κουστωδιαν)..." This implies that the guard would have included a servant of the priest. In Erbetta's opinion, *GH* was written with apologetic intent to Jewish Christians. See M. Erbetta, *Gli Apocrifi del Nuovo Testamento*, Marietti, Torino, p. 122 with note 4 (1975). I am indebted to the reviewer for this information.

3. O'Rahilly, Alfred. "The Burial of Christ: Peter and John at the Tomb," in *The Irish Ecclesiastical Record,* LIX, p. 169 with note 6 (1942).

4. Isho'dad of Merv, fl. *ca.* 850. See M. Gibson, Ed and Trans. *The Commentaries on the New Testament of Isho'dad of Merv*, p. 208 (1903). Reprinted by Kessinger Publishings Legacy Reprint Series, (2008.)

5. The apostle's Hebrew name was ש י מ ן (*Shimon)* but it appears that he was commonly known by his nickname. The English name "Peter" derives from English transliteration of the translation from Hebrew *Keph / Keipha*, "rock" into Greek *Petros,* "rock."

6. Dodd, J. T. "The Appearance of Jesus to 'The Priest's Servant,' as Recorded in the Gospel of the Hebrews, and 'The Holy Shroud,'" *The Commonwealth,* pp. 189-194 (October, 1931). Guscin's reference to C. H. Dodd is mistaken. M. Guscin, *The History of the Sudarium of Oviedo*, The Edwin Mellen Press, Lewiston, N.Y. p 18 (2004)

7. Codex *Bobbiensis*, the version of the Bible used by Cyprian. It survives in a fragmentary copy of Mark and Matthew, now in Turin and in other fragments elsewhere.

8. *Cf.* W. Schneelmelcher, R. McL. Wilson, trans. *New Testament Apocrypha.*: The Westminster Press, Philadelphia, p. 160 (1963).

9. M. Erbetta, *op. cit.*

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Figure 2. Courtesy Permanent Mission of Cyprus to the United Nations.

Figure 3. Public Domain

Did Jesus carry the Cross or the patibulum?

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Abstract
About forty years ago G. Ricci suggested that Jesus carried only the patibulum on his shoulders and not the entire cross. In support of this hypothesis, G. Ricci alleged the two roundish spots appearing on the back of the Man of the Shroud. Those spots were caused by the epidermis of the Man of the Shroud rubbing on scraggy wood of the patibulum. Nevertheless, this hypothesis does not seem realistic for two main reasons. The first is that Jesus wore a robe of honor and, more probably, an underwear put on his skin. These two garments acted as a pad between the skin and the rough wood of the patibulum. The other reason was the prohibition to keep permanently impure objects, because they were cause of contamination, according to the Jewish belief.

Keywords: Cross, patibulum, Shroud stains.

1. INTRODUCTION

Bibliographical tradition scarcely reports about the kind of cross Jesus carried from Lithostrotos to Golgotha. The four Gospels relate no more than He bore the weight of the Cross [1]. The verbal expression used is *bastazo* which, in a literal sense, means "to lift", "to put on", "to load with a burden". Nothing has been recorded about the cross Jesus actually carried.

First of all, we have to leave out the pictorial tradition or whatever illustration that represents Christ while dragging the Cross formed by stipes and patibulum [2]. Until the first half of last century it was generally accepted that Jesus had carried the Cross as a lot of images used to portray him.

At the end of the Fifties of the 20th century, Mons. Ricci, member of a small group of researchers deeply concerned with the Holy Shroud, suggested that Jesus had carried only the patibulum (i.e. the horizontal pole) and not the Cross [3]. In order to uphold such a supposition, Monsignor Ricci showed two large round blood stains, which can be seen close to the shoulder-blades on the dorsal image of the Holy Shroud, see figure 1.

2. DISCUSSION

At first this hypothesis was regarded with some skepticism, but it was gradually taken into account and accepted by most of the Shroud researchers. I have been thinking a lot about this hypothesis that, in some way, seemed to be quite inexplicable. How was it possible, I wondered, that abrasions with blood stains were close to the shoulder-blades and not to the rachis that is the most protruding part of the back? If Jesus was burdened only with the patibulum, this should weigh heavily on the backbone too and not only on His shoulder-blades. But even such a position of the patibulum seemed to me quite unrealistic. Therefore I loaded on my back a rounded piece of wood and so burdened I tried to walk up a gentle slope. The length and weight of the pole were, respectively, 2,3 m. and 8,2 Kg. (see figures 2, 3 and 4).

But I was not able to hold the piece of wood on my shoulder-blades. I tried also to put my arms under it, in the attempt to wrap it, but nevertheless it was impossible to hold it, see figures 2a, 3a and 4a.. I should have untied and longer arms, at least twice their length. I tried other positions, but the pole never stayed on my shoulder-blades. In such position it pushed me backwards and forced me to bend my back otherwise I could fall down!

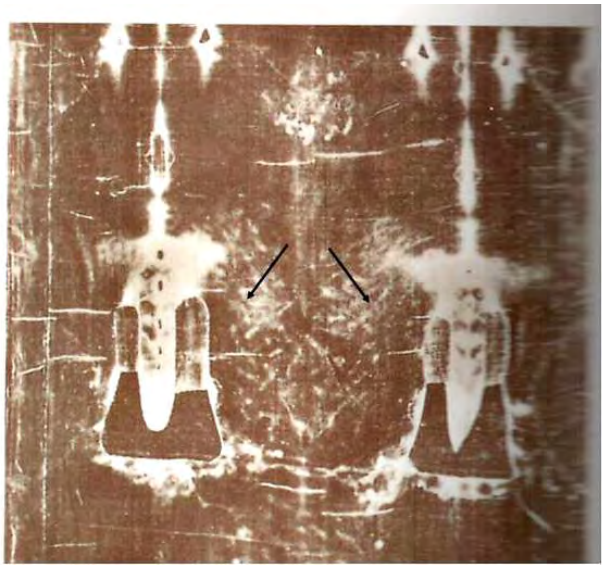

Figure 1. Detail of the dorsal image of the Shroud of Turin (negative). Arrows indicate two large round blood stains.

I have asked many friends to do the same attempt and when I was serving as an officer the Alpine Army I asked also many of my colleagues. The outcome was always the same: it was absolutely impossible to carry the pole on the shoulder-blades! The weight is carried on the shoulders, not along the back and so it burdens the shoulder-blades, see figures 2, 3 and 4. The blood stains, therefore, could not justify the weight and the rubbing of the patibulum on the shoulder-blades. Besides, there was the tunic Jesus was wearing, a garment made of a cloth without seams [4] that meant it was very precious.

If a rubbing had taken place, it would have torn the tunic of Jesus and so it would have lost its value.

Let us go back to the patibulum: even if the pole had been tied with ropes, fastened in some way to the forearms, the weight the forearms would have borne, should have borne down on the shoulders, not on the shoulder-blades. In this case (weight on the shoulder-blades) a blood stain was expected to be on the rachis and, I want to stress, not on the shoulder-blades because it was just there that the pole would have moved as a pivot. In order to leave the rachis without any marks, the pole should have had a kind of hollow exactly in its middle section, so to rest only on the shoulder-blades. However this is an absolutely improbable and inexplicable hypothesis.

Those round blood stains on the shoulder-blades were not a consequence of the rubbing caused by the patibulum along the way from Lithostrotos to Golgotha. In my opinion they have a different explanation, I will examine later.

At this point, let us place the torture of the Roman crucifixion in the Jewish (Hebrew) society. According to Monsignor Ricci, Jesus carried only the patibulum. His supposition was based on the fact that the Romans used to keep the stipes or the stipites in the appointed place of the crucifixion of the convicts.

This supposition is right, but not suitable for Palestine and for Jerusalem in particular, where the Temple and the presence of many priests who served in it involved that the observance of the Jewish rules was more strict and rigorous than elsewhere. According to the Jewish belief, people had to avoid any contamination with all that had touched the blood of a convict or a victim of a violent death. The rule stated that everything had to be burnt or removed.

Moreover, all that was touched by a corpse, was considered “impure”, so that anyone, who had to face such an event (because of love, work, or compassion), had to submit himself to purification according to strict rules.

The above mentioned rules are listed in Numbers (19:11-21; 31:18-24). The same rules, but much more detailed, have been quoted by the Jewish tradition in the Talmud, where they have been carefully codified.

It was impossible, therefore, that in the Jewish environment and above all in Jerusalem, the Romans could keep the stipites permanently in a place, in spite of the fact that they were polluted by the blood and the feces of the convicts. The Roman crucifixion was a spectacle, both enlightening and warning. The convicts were derided, insulted and scorned and even filthy and blunt objects were thrown against them [5].

The Romans used to give to the convicts to the crucifixion some drugged drinks that excited their reactions, without softening their consciousness. The behaviour of the people irritated the convicts, who reacted violently and their reaction, of course, incited the people to persist in their provocations. This performance could last for a long time, even for several days. Only a feast-day could stop both the spectacle and the tortures, so hastening the death of the convict. Once the convict’s corpse was buried in an unknown mass grave, the crosses had to be buried or burnt in a unconsecrated ground, far from any town or village.

Rufino of Aquileia (340-410 A.C.) priest, theologian, historian and particularly translator, in his Historia Ecclesiastica, wrote that the Cross of Jesus, together with those of His fellows of torture, was discovered by Makarios, bishop of Jerusalem inside a cistern under the temple of Artemis, built under the emperor Hadrian, just on the place of the Holy Sepulcher. The discovery of three crosses all together in the same place proves that crosses were actually buried. In this case, all of them were buried together with the *titulus crucis* [6] of Jesus. A significant fragment of it is preserved in Rome in the Basilica of Saint Cross in Jerusalem, together with a large piece of one of the two poles of the Cross.

The narrative is confirmed by Ambrose, bishop of Milan (De Obitu Theodosii) and by Cyril, bishop of Jerusalem. The latter informs that a lot of cross fragments were spread over all the Empire.

As I have already said, the Romans never left the stipes on the ground of the execution when it took place in Jewish towns or villages. Moreover, we have to deduce they did not help the local convicts by driving in those poles the very day of their crucifixion. Such a care towards men condemned to the slanderous torture of the crucifixion would have been quite unbelievable. The convicts had to carry their own cross to the appointed place of their execution. This is the reason why Jesus was so quickly set free from the burden of His cross which was given to the unfortunate Simon from Cyrene.

If Jesus had carried only the patibulum, this should have been tied to the arms and forearms with ropes that would have been untied in order to transfer the cross to Simon and this task would have requested a lot of time. The forearms of Jesus, besides, do not show any marks of knotted ropes (the question does not exist for the arms, since the image was burnt in the fire of Chambéry). The Shroud does not show any marks which may entitle us to think about ropes or other devices for tying the forearms to the patibulum. The patibulum had to be caught by the hands while the ropes had to wound round the wrists.

About this thesis, it might be objected that, since the crosses were very heavy, it was necessary to drive in advance the stipes in the ground where the execution had to take place and leave to the convicts just the burden of the patibulum. This hypothesis does not fit for Jesus, since He was condemned a long time after the third hour of Friday and there was not enough time to drive a pole just for Him on the Golgotha.

According to the Bible, Pilate did not mean to condemn Jesus and flogged him in the attempt to save His life and with the hope He could be preferred to Barabbas. The order of crucifying Jesus was given at the very last moment; this is the reason why He was obliged to carry also the stipes: in other words, the weight of the whole cross even supposing, of course, that in Palestine the convicts had to carry only the patibulum.

This is just one of many coincidences which made the execution of Jesus more terrible and unique than others.

What stated above consolidates the opinion that Jesus carried the complete cross, according to the tradition which dates back to almost two thousand years ago.

Even the falls of Jesus, as recorded by the tradition, imply He carried the whole cross. If He had carried only the patibulum and He had had His arms and forearms tied to it, the falls would have had such an impact of His face on the ground that His physiognomy could have been altered. On the contrary, the face of the Man on the Shroud reveals that it was thumped and slapped. Nothing compared to a fall on the ground that would have caused significant ravages to His features. It was the cross (the complete cross, I mean) that reached the ground first and so His face was protected, but this did not avoid many collateral consequences for His shoulders and especially for the right shoulder, on which Jesus carried the Cross.

Nevertheless, the Shroud reveals to us a dislocation of the right shoulder of Jesus, and this cannot be justified as a wound due to a fall, but to a strain manually caused by those who nailed the wrists of Jesus to the patibulum.

And now a brief comment on the blood stains on the shoulder-blades. Since those stains have nothing to do with the rubbing against the patibulum during the way from Lithostrotos to Golgotha, they have to go back to a rubbing that took place later on the cross.

The dislocation of the right shoulder means that the arms of Jesus were nailed to the patibulum in an almost horizontal position. The attempt to drive His wrist exactly to the hole made on the wood failed, and so His right arm was stretched until the humerus went out of its glenoid cavity [7]. In that position it was very painful to press on His wrists in the attempt to raise himself up. Only very slight movements could be done, because of the dislocation and the stiff position of the arms.

What Jesus could do to rise up just for breathing, was to lean against the patibulum which, certainly, was very thick. An attempt that could be done only rubbing the shoulder-blades on the wood of the patibulum which was supposed to be very rough.

This is the same movement made by a mountaineer while climbing along a narrow vertical crack in a rock-face, leaning and bending oneself on the rock wall in order to make climbing less difficult.

Jesus was obliged to bend His back on the patibulum, since the stretching of His arms and the sharp edges of the nails scratched the bones of His wrists preventing Him from leaning on His arms. Even the stretching of His arms prevented him pulling hard His biceps, since His forearms were not bended enough to allow him to strain those muscles.

I have thought a lot about the position Jesus had on the cross. I made an experiment where I was tied fast to a cross-shaped tree, with my arms as much stretched as I could in such a position. In that position what one can do, just to breathe in, is to rise up a little bit forcing on the shoulder-blades.

Concerning the remark that the weight of the two poles (that is to say of the whole cross) could be too heavy for the convicts, it may be worth calling back to our memory the numerous commemorations of the Passion that until few years ago used to take place in Italy and in Europe. In those occasions people often used to carry big and heavy crosses.

Jesus was in precarious conditions because of the cruel flogging and it was impossible for Him to carry His own cross. In fact, He carried it for no more than few meters and at the gate of Jerusalem He fell again and this meant He was not able to bear that burden. This was the reason why the unfortunate Simon from Cyrene, coming from the country with the aim to reach the town, was forced to perform this task.

REFERENCES

1. John 19:17. The Cross is an upright post with a horizontal bar on which Christ was crucified.
2. The Romans used two words to describe the two elements of a cross: stipes and patibulum. The stipes was the upright stake which was placed in the ground and the patibulum was the horizontal pole.
3. Giulio Ricci: *L'Uomo della Sindone è Gesù, diamo le prove*, Edizioni Carroccio, Vigodarzere (PD) – Italy (1989).
4. John 19:23-24.
5. Gino Zaninotto: *La tecnica della Crocifissione Romana*. Quaderni di Studi Sindonici, Emmaus Roma (1982).
6. The sign, or titulus, that indicated the crime the person had committed.
7. The cup-shaped structure in which the humerus articulates..

CORRECT WAY

This is the only way to carry a pole on a person's back.

WRONG WAY

This way of carrying a pole on the shoulders is wrong, because a man cannot grasp it with hands.

Figure 2

Figure 2a

Figure 3

Figure 3a

Figure 4

Figure 4a

PHILOSOPHY

The Promise (and Threat) of the Shroud of Turin

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Abstract: *Explanations for the image on the Shroud of Turin bring religion into science in controversial ways, with researchers divided on whether these are incommensurable domains. This paper shows how they are commensurable, and introduces the relevance from natural and social sciences of theories that postulate unobservable objects and processes.*

Keywords: Unobservable, resurrection, evidence, dematerialization

1. INTRODUCTION

In a paper published shortly before his death, Richard Rorty (with Gianni Vattimo) remarked that "empirical evidence is irrelevant to talk about God," and then observed that this viewpoint, advanced by both David Hume and Immanuel Kant, applies equally to theism and atheism [1]. Rorty speaks here for many people, if we interpret his remark as applying to all of religion, not simply God. Religious claims are widely said to be "matters of faith," and are implicitly considered to be devoid of evidence.

This tension between science and religion is also apparent in discussions of the Shroud of Turin (ST), where its evidential relevance to the Resurrection of Jesus is questioned, because the Resurrection is a religious dogma.

Western philosophy has had a vital interest in religion since its origin in pre-Socratic times (ca. 600 BCE), when it helped a critical form of thought to develop within Greek culture that came to be known as science. The rationality of religion has been a topic in Western civilization ever since, and philosophy has been plausibly understood as a discipline committed to the defense of naturalism, apart from an era in which Christianity dominated the academy (ca. 400 – 1700 CE) and philosophy itself acquiesced [2]. I will approach ST here as a philosopher of science and religion. Whereas many topics could be considered under this broad rubric, I will narrowly focus upon the recent conjecture that the image of the Man of the Shroud was produced when he became "mechanically transparent," or "dematerialized," or "disappeared in a shower of subatomic particles." The science and technology of the present time is not advanced enough to show us how to make another ST, but it is great enough to pose an intelligible question about a body's disappearance that was not possible in an earlier time, prior to the atomistic era.

2. SCIENCE, RELIGION, AND SHROUD OF TURIN LITERATURE

Ray Rogers illustrates the chagrin sometimes felt by scientists who must deal with both laboratory work as well as the conjectures of those having religious beliefs. In reviewing Mark Antonacci's book, *The Resurrection of the Shroud*, Rogers describes it as an attempt to "*prove* the resurrection through science," which he clearly considers futile [3]. In explicating the nature of scientific method several pages later, Rogers remarks that this method requires testing all hypotheses equally, and that "Hypotheses that involve miracles can not be rejected categorically, but they are impossible to test experimentally." A little later he remarks that claims about miracles cannot be proven or disproven, which parallels the view expressed by Rorty mentioned above. Further, Roger remarks that "all ethical scientists apply Occam's razor," i.e., the principle of "eliminating fictitious and unnecessary elements from explanations," and clearly considers Antonacci not to have employed Occam's principle. I will comment on Rogers later in this paper.

Another recent study that shows the tension between science and religion is a paper presented at the 3rd Dallas conference on ST in 2005, whose twenty-four authors attempt to offer a comprehensive account of accumulated evidence and classify these according to their evidential weight [4]. Unquestionable observations form 1st class items; confirmed observations form the 2nd; "facts that were evidenced by some researchers," but not by all, form the 3rd class; and the 4th class derive from biblical texts, provided that these are historic documents. Because the ST might be the burial cloth of Jesus Christ, the biblical documents are said to be appropriate to include, but "not on a theological level." What this clause is meant to include or to exclude is not clear, for the possibility that the Resurrection of Jesus is implicated in the ST image is not excluded later in the article. When this paper considers John Jackson's conjecture that the Man depicted on the ST "became mechanically transparent," [5] this conjecture is rejected as "not scientifically testable because it bases itself on a non-scientific fact" [4]. The assumption here is that scientific facts and non-scientific facts both exist, but how they differ is not explained. Neither is the inability of "non-scientific facts" to contribute to scientific testing explained. Again, the assumptions about science and religion could be questioned, along with views about the nature of evidence.

Perhaps the most curious item mentioned in the data derived from the New Testament (NT) (category 4) is the appearance of Christ to more than five hundred, which St Paul records. Accounts about appearances of Jesus after his death have generally been advanced by the Church as evidence for his Resurrection, but this reference is among the least impressive of the dozen or so reports found the NT. Nothing is said by Paul about the location or time of the appearance, or about the people who made up the five hundred; neither is any detail offered about what was actually observed, perceptually speaking. On the whole, this co-authored paper that includes many researchers in the natural sciences is ambiguous on the issue whether observational evidence is admissible for the Resurrection of Jesus, but I surmise that obtaining agreement among twenty-four authors on a topic in science and religion was difficult. Other authors on the ST are not cautious in letting theological and scientific concepts to be intermingled, such as physicist and historian of science, Thaddeus Trenn, who writes: "I should like to introduce weak *dematerialization* [which is a series of events at the level of microparticles] as perhaps a key feature of the resurrection event associated with the Shroud of Turin [6]" I will look more closely at Trenn's view below.

3. OBSERVATION

The value that Shroud scientists place upon observational evidence cannot be contested, but the nature of observation is no longer simple. According to Dudley Shapere, sophisticated kinds of equipment have expanded the concept from what it once was, so that physicists, for example, now routinely speak about observing neutrinos [7]. These subatomic particles that stream from the sun pass through the earth as though it were not an obstacle, and are "caught" in large vats of carbon tetrachloride placed in abandoned mines, triggering rare but detectible chemical changes. From the standpoint of common sense, neutrinos are not observable, but physicists tend to think otherwise, given their expanded understanding of observability. Observability enters discussion of the Shroud in another way.

The ST depicts a man who may have been dead when an image of his body was made, but death is not a matter of straightforward observation. The cessation of breathing, blood circulation, and brain activity have all been used to mark the distinction between being dead and alive, but none of them are exact, as a recent discussion by a neurologist about brain activity demonstrates. [8] Near-death experiences (NDEs) reported in the last thirty-five years also bring the imprecision of 'death' into focus [9], for opinions vary among experts concerning the status of those reporting NDEs.

Questions about whether the Man imaged on the ST was dead or alive when the image was made have never entirely disappeared [10], and this issue will never be clarified in any totally satisfactory way. If scientific studies introduce a precise standard for death resulting in an operational definition, the commonsense understandings of death will be transgressed, and people will baulk at changing their ways of speaking. In many technical fields of science precise operational definitions of terms are accepted as presented, but these definitions are about matters that are insignificant to us. With the concept of death, however, deepest human values and beliefs are implicated, and any proposed operational definition would be controversial and relentlessly contested.

4. UNOBSERVABLES IN SCIENCE AND RELIGION

Scientific development in the last two centuries would be unimaginable without theories that postulated unobservables. Dimitri Mendeleev's work on chemical elements, Gregor Mendel's conjecture concerning "inheritance factors" (genes), Charles Darwin's postulated mechanism in evolution, Ernst Rutherford's model of the atom, and Alfred Wegener's hypothesis concerning tectonic plates, all involve conjectures about the existence of unobservable objects or processes.

The experimental work that led to claims of existence concerning baryon-II particles is an instructive example of the value of this method. Subatomic particles were brought into collision in a cloud-chamber, and the photographic plate in the chamber records the sequence of events (Figure 1, read from left to right). The large dot denotes the collision, and the straight line indicates that the collision produced a charged particle. This particle quickly disintegrated, apparently producing a particle having no charge, which corresponds to the blank space (baryon-II); moreover, the V-shaped pair of tracks in the trajectory of the first straight line indicates that baryon-II also disintegrated. The V-shaped pair of tracks indicates that the two particles are repelling each other, and consequently have the same charge.

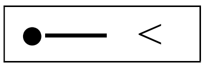

Figure 1

Meaning to the term 'baryon-II' is provided in this experiment by assigning a causal role to the postulated entity in relation to events just before and just after its hypothesized occurrence in the causal sequence. We might not be able to assert in some final sense that the baryon-II particle is unobservable, for some future technology might "observe" its presence. However, we can conjecture the existence of baryon-II in this sequence without understanding fully the causes of particle disintegration and without being able to describe the baryon-II particle in definitive terms. The method of reasoning described here was identified by the 19th century American philosopher of science, Charles Saunders Peirce, as retroduction (or abduction), in order to distinguish it from deduction and induction, whose structures are quite well known. This reasoning has unlocked so many fields of scientific inquiry that no reason exists for refusing to consider it concerning religion, provided that the conjectural nature of what is suggested is kept in mind. My claim here obviously conflicts with the certainty that is often (implausibly) claimed over matters of religion, and also conflicts with the claim that unobservable entities in religion cannot be supported or undermined by (observable) evidence.

Consider the strange event described in the synoptic Gospels in which Jesus is said to have performed an exorcism in which the "evil spirits" passed from men to swine [11]. All three gospels tell the story of two men (or maybe only one) in the area of the Gadarenes who were (was) so fierce that people did not go near. They accosted Jesus strangely, addressing him as the Son of God and asking him if he had come to torment them. When he commanded "the demons" to leave the men, "the demons" asked for permission to go into the swine feeding nearby, and Jesus gave "them" leave. The men immediately lost their ferociousness, but the swine rushed down a slope into the sea, as though "something" had been "transferred" – call it a 'spirit', in keeping with tradition – from the men to the swine. The relevant events here do not appear to be miracles, that is, breaches of established laws of nature, unlike levitation, say, which conflicts with Newton's law of gravitational attraction. This "transfer" *supplements* information about the conventional natural order, rather than conflicts with it, just as the discovery of baryon-II supplements existing knowledge of physical structures. Three existential realities are "observably" present in the event described in the New Testament: (a) "diseased" men who become normal as a result of the transfer; (b) a horrific form of (apparent) sentience that debilitates human life, is locally situated, and is forced to leave the men and allowed to enter pigs; and (c) something else – also described as Spirit – whose immense power is momentarily glimpsed and is then gone. An empiricist having no religious beliefs or practices, but having a background in modern atomism, could carry out the observation. Nothing in the reports requires construing spirit as non-material, and here I again part from tradition. Spirits can be defined contextually, primarily by the causal roles they are postulated to play, just as baryon-II is comparably defined.

5. RESURRECTION

The report of a resurrection is most extraordinary, so extraordinary in fact that such a report is generally dismissed without scrutiny. The *Los Angeles Times* reported an allegation from Nigeria in 2001 in which a minister seemingly killed in a car accident came back to life even after embalming had begun. His wife credited the presence of God in a building after a special service conducted by a German evangelist. This allegation has made no impression upon the academy, to my knowledge, presumably because of the inherent improbability of the claim that an indisputably dead man came back to life.

Professor John Hick, who has taught at the Universities of Cornell, Princeton, and Cambridge, and currently holds chairs in religion at Claremont Graduate University and in theology at the University of Birmingham, says that two examples of resurrections can be found in Hinduism from the last one hundred years [12]: Sri Yukteswar is said to have appeared after his death to Paramahans Yogananda, in a hotel bedroom in Bombay (Mumbai), and Yogananda also reports that Sri Yukteswar saw his own guru in 1895. However, Hick is simply wrong to view these as instances of *resurrection*, for we can legitimately ask if the bodies of the two gurus came back to life, leaving some causal effects in their graves or in jars where cremated remains are kept. These (mistaken) examples from Hick and the example from the *LA Times* indicate that claims to resurrection bring in several distinct matters for which evidence is relevant: (a) that some person is indisputably dead; (b) that the corpse no longer exists after its resurrection, and (c) that "someone" (*identical* to the dead person) is indisputably alive after having been dead.

The fact that some ST researchers claim that any report of a resurrection can be dismissed as devoid of evidence is curious, for it makes a pretension to omniscience about evidence, as though they had a full understanding of the subtle relationship between (successful) evidence claims and hypotheses to which such claims are relevant. Philosophy of science is not remotely close to outlining the full scope of evidence, which became graphically obvious in extensive discussions of confirming evidence for simple lawlike generalizations beginning in approximately 1965 [13]. The most significant epistemic fact about the Christian allegation of the Resurrection is that its earliest documents mention no eyewitnesses. Only an empty tomb was found, it seems, followed by alleged appearances, which biblical criticism has undermined by the following observations, among others:

1. Tradition has distinguished appearances of Jesus from visions of Jesus, with the Ascension serving as

the event at which the appearances (physical encounters) stopped and the visions (subjective experiences) began. However, *St. Matthew* puts the Ascension in Galilee, whereas *St. Luke* puts it in Bethany (near Jerusalem) forty days after the Resurrection. Then *St. John* implies that the Ascension occurred within the first eight days of the Resurrection..

2. Paul's list of witnesses in *I Corinthians* 15 is devoid of details, so that it is virtually without value as evidence. We who have become attuned to scientific demands clearly see its evidential paucity, for our collective epistemic sensibilities have been honed by several centuries of science and other forms of critical reflection.

3. The earliest gospel is *St. Mark*, the ending of which has been a matter of dispute. A widely accepted short ending has no accounts of appearances at all. A longer ending includes accounts of two appearances, one of which asserts that Jesus "appeared in a different form," although it does not elaborate. The Church has widely repudiated the claim that the form might vary, but its grounds for doing so are suspect.

4. No gospel includes a description of Jesus, and the only physical description of him in the NT is that found in *The Revelation*, which is widely viewed as symbolic of a transcendent reality, not as a portrayal of how he appeared to his followers. Inasmuch as the identification and re-identification of individuals usually depends exclusively on how they appear, the failure of the NT authors to adduce details about the appearance of Jesus before or after his Resurrection is mysterious.

5. Harmonizing the gospels with one another, and also with *I Corinthians* 15, appears to be impossible, for Paul identifies Peter as the first to whom Jesus appeared, and several gospels assert or suggest that Jesus first appeared to Mary Magdalene.

6. The gospels (including the long ending of *St. Mark*) mention something about doubts arising in those who saw Jesus, or that he was not recognized. For example, *St. Matthew's* account of the Ascension says that his disciples worshipped him, but some doubted. The nature of this doubt is not elaborated, however. The claim that he was not always recognized, or that doubts accompanied perceptions, is more understandable if his form varied.

7. The nature of the *seeing* involved, in reports that disciples had "seen the Lord," is in dispute [14]. Some consider Paul's own Damascus-road encounter to be a paradigm of all or most cases of the appearances, making them subjective visions [15]. The more life-like appearance accounts in *St. Luke, St. Matthew*, and *St. John* are then seen as redactions of the stories in ways that suppress docetism or enhance the divinity of Jesus.

8. The twenty to fifty years believed to have elapsed between reported events and the written accounts would generally be considered today as a serious flaw in any effort directed to maintaining the credibility of what was reported.

9. The "ordinary" historical claims on which the NT writers can be successfully evaluated, e.g., governors or rulers who are also mentioned in widely recognized historical documents, seemingly provide very little confirmatory value to the "extraordinary" events that they allege [16].

10. Academic study of the historical understandings of the origins of Christian faith has undermined confidence that the canonical biblical texts are the best place to begin. For example, only two canonical texts, viz., *St. Matthew* and *St. Luke*, assert the Virginal Birth; other early documents, which number something like fifty, offer very little or nothing by way of evidence for the Virginal Birth. Similarly, non-canonical texts that address the post-Resurrection phenomena do not endorse traditional views in obvious ways. To examine Christian origins from canonical texts is to undertake a *theological* inquiry; to examine Christian origins from all possibly relevant documents (and sources) is to undertake a *historical* inquiry. We might wonder why we should do theology when we can do history.

Other difficulties could be mentioned. What Christianity really needs in order to advance its unique position is evidence that the body of Jesus *disappeared* in the way that is necessary for a resurrection.

6. THE PROMISE (AND THREAT) OF THE SHROUD

The conjectures and allegations concerning the ST that have emerged in the last two decades offer just such a possibility, particularly the conjectures that the body of the Man on the Shroud became mechanically transparent [5], or that the body dematerialized [6], or that imaging below his body's surface has occurred [17]. Even if these suggestions offer little promise by way of testing, they raise a possibility that was seemingly never in clear view prior to the onset of the age of atomic physics. Who ever thought that evidence might be found for the disappearance of a body in a resurrection that no one witnessed directly? These conjectures bring into sharp relief a gap in the evidence that the Church now needs for its central doctrine, and now that this lacuna is in view, the future can never be like the past. The atomic age, combined with recent speculation about the source of the ST image, together have uncovered an evidential weakness in Christianity's central dogma. Since the NT accounts of post-death appearances of Jesus are not nearly as epistemically impressive as they need to be to support a resurrection, Christian faith must come up with more impressive evidence that the body of Jesus *disappeared* than the evidence from texts that merely report that his disciples could not find his body. The ST offers some promise on this point, but it is also a threat. A new idea has emerged whose significance will eventually change the way we all look at evidence for a resurrection. Let me return to Rogers's comments on Jackson.

Although Rogers says that Jackson's conjecture to account for known features of the ST image is beyond testing, he does make remarks about this conjecture that are test implications [18]. Rogers is treating Jackson's view in just the way that Karl Popper, widely regarded as one of the foremost philosophers of science in the 20th century [19], regards scientific claims, viz., they must be subject to falsification. Jackson considers the body of Jesus to have become "a body of light," the image of which was produced on the ST by irradiation. Rogers claims [18], among other things, that this radiation should have affected the blood on the ST in detectible ways; that greater differences should be observed between the structure of fibers in image areas than in non-image areas; and that the distinctive color found in fibers from image areas should also be found in the adjacent "pores" of the cloth. Jackson (with Keith Propp) rejected these arguments [20], which precipitated a response from Rogers (near the time of his death) reporting the minimal effects produced on flax fibers by radiation of various kinds, whether this is from photons, electrons, protons, alpha particles, or neutrons [21]. Rogers' objections have not ended the possibility that radiation in the form of coronal discharge might be implicated, however, as evidenced by the recent work of Giulio Fanti, Francesco Lattarulo, and Oswald Scheuermann [22]. These claims and counterclaims demonstrate that evidence continues to be considered relevant to religious claims.

Another conjecture about ST image formation has been offered by Thaddeus Trenn, who introduces the term *weak dematerialization* to describe it [6, 23]. He conjectures that the strong nuclear force binding the nuclei of the Man featured in the ST was overcome, thereby freeing the subatomic particles forming the atoms involved. Energy would need to *be supplied to* the body of the Man of the ST to accomplish this, according to Trenn, energy that would be sufficient to replace the binding energy found in an object weighing about eighty kilograms (the estimated weight of the Man). Trenn estimates that the amount of added energy would be roughly that found in twenty-nine atomic bombs. In Rogers' discussion of Jackson's conjecture, Rogers interprets Jackson as supposing that energy was *released* from the mass of the Man in the ST, but Trenn is envisaging something different – sufficient energy coming *from outside the body* to overcome the strong force binding the atomic nuclei forming his body. Various effects from such a conjectured dematerialization might be expected, he writes, including the production of pions (real, rather than virtual) that would quickly decay to produce x-rays, protons, and electrically charged muons [24]. Another effect would be the production of "Freed neutrons [that] would disperse with thermal velocity. But thermal neutrons impacting upon nitrogen, molecularly "fixed" in the linen cloth, would convert this *in situ* ^{14}N into ^{14}C thus augmenting the overall ^{14}C content of the Turin Shroud" [24]. The result, he says, would be variation in concentrations of radiocarbon, the highest being in the center of the cloth along its entire length, where the body earlier lay. Trenn makes some additional remarks about the "damage points" that collectively combine to create the subjective impression of a man on the ST, but even if Trenn cannot account for image formation, his conjecture about the fate of the Man of the ST is testable. It implies that *^{14}C distributions are not uniform* on the ST, which can be tested by placing photographic plates upon the ST, and encasing both in lead sheets in total darkness for some time [6]. This test could provide startling new evidence for the conjecture that the image was caused by a man who "broke apart at the subatomic level" – the promise of the Shroud. On the other hand, this test could falsify Trenn's conjecture, making us wonder again whether another conjecture might be found supporting the claim that a body disappeared in a way required by a resurrection that no one witnessed – the threat of the Shroud.

Trenn observes that to postulate the source of the extraneous energy in God would be to advance a conjecture he describes as "trans-scientific," and concedes that the Shroud might "elude the grasp of scientific methodology in virtue of the irreproducibility of the event complex that led to the evidence to hand," [24] as though to mark a difference between science and religion. However, the demand that science deal only with reproducible events only makes sense in those domains of exact study in which causal sequences can be controlled. In many domains we must wait to observe, as in cosmology, geology, meteorology, anthropology, and in other sciences. The concept of reproducibility does not completely define science any better than observability or falsifiability do, although these concepts are significant features of much of science. Whereas the ST itself is not an object that is reproducible, Trenn's suggested test is, for we can expect any test in Turin about concentrations of radiocarbon to be reproducible if the test were to be carried out on the ST in Rome or Paris. The irreproducibility of the ST does not render its study unscientific any more than does the irreproducibility of the Big Bang.

7. CONCLUSION

Religion shares a feature of science, for it is ultimately open to evidence for and against its claims. These claims cannot be tested in isolation, however. Like theories in science that postulate unobservables, the whole theory is subject to evidence that augurs in its favor or against. Rorty's claim that evidence is irrelevant to religion is mistaken, as is Rogers' view that religious claims are never susceptible to testing. The ST image might in fact be a causal consequence of an act of God, and to assert this is not nonsense, just as the claim that "A-Something-we-know-not-what" drove evil spirits out of men into pigs is not nonsense. Some religious claims are capable of having evidence adduced for and against them. This evidence will be incomplete, but that is the nature of science and other exact studies that have emerged out of more than several centuries of scientific practice.

The hegemony of science in Western culture, and its decision to arrogate to itself the delineation of rational belief has put religion on the defensive, especially those aspects of religion that speak to God acting in the world. Some have retreated in the face of this challenge, modifying Christianity sufficiently so that our scientific sensibilities are never embarrassed, with the consequence that the Faith that is presented often has "no teeth." Historic Christian faith has maintained, however, that God has acted in the world, if not in Abraham, Moses and the other patriarchs of Israel, at least in Jesus, who is called 'the Christ'. Whatever might be said by biblical critics about his acts and his teaching, and about how much authority we can accord the NT sources, the Church can affirm his Resurrection as something open to evidence. The ST is relevant to this claim, either by offering evidence for the claim that a body disappeared in just the way that we would expect if a man came back to life when no one witnessed it, or by showing us the kind of evidence the Christian Church needs to adduce for its startling claim, but does not have if the Man on the ST is not Jesus. This is the promise – and the threat – of the Shroud.

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The Brightest Light of All

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Abstract
There is a substantial body of evidence supporting the hypothesis that the Turin Shroud surface image was caused by a very brief burst of radiant energy. Our subject for discussion here is about how a dead body could produce the radiation. How did a corpse shine momentarily brighter than the sun? We postulate a dynamic interface between thought, light and matter which implies that the mind-matter duality resolves on the side of mind as the prime mover, that our physicality is a symptom of restriction of mind which when free transforms matter into light.

Keyword: Sentience, Radiance, Human Transfiguration

1. INTRODUCTION

The one hypothesis that has been found to be consistent with all the evidence regarding the Turin Shroud is that the primary image on the cloth of the crucified body of a man was the result of a momentary burst of radiant energy [1]. This would account for the distance coded information, the "photographic negative" characteristics, the confinement of the image to the surface fibres and the absence of pigment in the main body of the image.

But How?…and Why? How did a corpse shine momentarily brighter than the sun?

Did he leave us a photographic negative imprint of the very moment of resurrection?

We do not appeal to the concept of "miracle" nor to the platitudes of "mystery" but intend to demonstrate through reasoned argument and scientific evidence that the possibility of such a phenomenon is not merely plausible but is self-evident from the fundamental axioms which describe what we humans call reality such as it is.

For example: $E=MC^2$ suggests that mass can be seen as being like 'condensed' energy [2] (e.g. Hawking radiation, electron-positron pair production etc.)

As yet $E=MC^2$ has not been generally considered to have relation to the sentient observer. Quantum theory, at least according to Erwin Schrödinger (and he should know) needs the presence of consciousness to bring the equations to life.

Physicists and cosmologists believe that a "theory of everything" would need to unite quantum theory with relativity through gravity.

Schrödinger himself contended that quantum theory was consistent with the unitary nature of consciousness. This would imply that fundamentally we are all one. However, our thoughts and actions belie this by our divisiveness, self-centredness, ego and ignorance, which could take humanity to the brink of annihilation or "devolution" to become beasts.

If, as the equations, and our existence as incarnate sentient beings demonstrate matter is condensed "mind stuff" or "thought" then perhaps the man on the shroud conducted the greatest scientific experiment of all time by living a life that was an antidote to the qualities outlined above and therefore returned matter to the "light" from which it is derived.

2. BACKGROUND

There are three dichotomies, which we would like to address that would seem to be recurring themes when trying to understand the shroud image. We would like to suggest that these apparent dichotomies resolve into consistent explanations once the polarities involved can be seen as two sides of one coin.

The first is the dichotomy between rational explanation and miraculous explanation.

Secondly there is the question of whether the man on the shroud was a single exception in the history of humanity or an example of what is achievable by all human beings.

Thirdly there is the duality of mind and matter. We would like to discuss evidence that rather than mind being an emergent property of atoms, actually atoms are an emergent property of mind. We would also like to discuss evidence that rather than humankind being merely "inhabitants" of space and time we as sentient beings are actually their *raison d'être* and *sine qua non*.

When I (Silverman) was a medical student 20 years ago I attended an inaugural lecture by the first British Professor of Parapsychology Prof Morris. The subject of his talk was to discuss scientific evidence for the existence of "PSI" i.e. extrasensory perception and/or the direct influence of mind upon matter. During question time I raised my hand and said, "In raising my arm I have proved (at least to myself) that the mind can control matter".

It would seem that most people live their lives taking for granted every day that they are using free will to make choices. In fact it could be argued that even our systems of morality and law are based on the assumption that we are responsible for our actions.

It is an interesting exercise to consider what the ramifications would be to our scientific world view if free will were a fact.

The first step would surely be to define what we mean by free will.

Will, according to dictionary definition, implies determination by an act of choice.

The designation 'free' when applied to this suggests that there is no compulsion or 'force', which compels one to make a specific selection from available options.

This would mean that any sentient being that can exercise free will is able to harness what philosophers call a 'prime cause'.

Material structures such as planets, solar systems and galaxies or indeed an entire physical universe if it were devoid of sentient life would not in all its immensity have the power to perform this simple act of choice but would instead be continually following the dictates of force. To quote one of the founders of quantum theory Erwin Schrödinger:

"My body functions as a pure mechanism according to the laws of nature. Yet I know, by incontrovertible direct experience, that I am directing its motions, of which I foresee the effects, that may be fateful and all-important, in which case I feel and take full responsibility for them. The only possible inference from these two facts is, I think, that I –I in the widest meaning of the word, that is to say, every conscious mind that has ever said or felt 'I' am the person, if any, who controls the 'motion of the atoms' according to the laws of nature." [3].

Again as a medical student attending a public lecture in Dundee I heard Professor Sir Hermann Bondi speak about relativity. Bondi was an eminent theoretical physicist who was taught by Prof. Sir Arthur Eddington.

During question time I alluded to Einstein's time dilation Equation and asked Bondi whether he agreed that the equations implied that an observer travelling at the speed of light would be able to be everywhere instantly, 'all at once'.

He agreed that the equations allowed for the possibility but said that this was precluded because observers have mass and massive objects could not travel at the speed of light.

I then asked whether he agreed that nobody could weigh a thought and whether it was possible that consciousness could be manifested by a 'light' being if it could be manifested by a 'material' being. He replied that he had no theoretical objection but didn't believe this to be a fruitful line of enquiry.

I am sure many (if not most) readers will share his view but it is our contention that the shroud image provides material verifiable evidence of a phenomenon through which human beings are capable of transfiguration from matter into light.

That may sound a bold claim but some preliminary experiments suggest the possibility that the dead body of a man who many believe to have been the historical Jesus (Yeshua ben Yosef) arose from its resting place into a vertical position [8] and then momentarily shined brighter than the sun thereby forming the Shroud image [1].

3. DISCUSSION

Schrödinger made some interesting observations about the nature of mind. He wrote a book entitled "What is Life?" published by Cambridge University Press. Professor Paul Davies said of this book that Schrödinger in its pages *"..set down, clearly and concisely, most of the great conceptual issues that confront the scientist who would attempt to unravel the mysteries of life. This combined volume should be compulsory reading for all students"* [4].

In this book he made some fascinating observations about the nature of mind. One is that mind is of fundamentally the same nature in all of us and that separation in individuality is only an apparent property related to the fact that we are divided in space and time because of our physical bodies.

It could indeed be argued that the property of sentience is the same in all of us and all that differs are our points of view and individual memories.

It could also be argued that the property of free will is the same for all of us and again that we differ in the choices we make.

The Einsteinian 'block' universe suggests that everything that has ever happened and everything that will ever happen already all exists together but Schrödinger observed that consciousness generates a "present" tense and made a startling deduction from this:

"I venture to call (the mind) indestructible, since it has a peculiar time-table, namely Mind is always now"

and *"This means a liberation from the tyranny of old Chronos. What we in our minds construct ourselves cannot, so I feel, have dictatorial power over our mind, neither the power of bringing it to the fore nor the power of annihilating it"*[3].

If we consider the possibility that the natural status of all sentient being is to be eternal and to be one with all other sentient being then the obvious question which arises is of course 'what is the origin of separation? How do we come to exist as individuals?'

Perhaps a clue can be found in the concept of limitation.

To explain this it may be helpful to consider the origin of the physical universe.

It is thought by many that the Universe may have come into existence out of nothingness at the big bang via a singularity.

If this is true and if Schrödinger was right that consciousness has no beginning or end then that would imply that we exist within (or beyond?) that singularity as unified, limitless being [5].

What then would have propelled our separation from this all-encompassing state into a physical universe where we would encounter old age, suffering, sickness and death - A universe of 'moths, rust and thieves'- a universe constantly dividing and dismantling according to the second law of thermodynamics?

If logic and reason are to be our guide in answering this question then perhaps it makes sense to believe that we are free from within the state beyond limit to elect to take on limit through choice.

If everyone were all-knowing always and everywhere, then there would be nothing to divide us as individual identities. If we chose to experience existence away from this 'idyll' then that choice would create separation. Whereas a state of union could be independent of space, time and matter, separation would seem to be virtually synonymous with them. What is space but the separation of points? [5].

At the big bang it would seem that space and time began together. There was an initial short phase during which the universe was prevailingly made up of photons which we will take the liberty of referring to as 'light' but very quickly as the 'temperature' dropped energy began to be converted into mass and became 'frozen' in the form of atoms (initially hydrogen and helium).

I would now like to quote Stephen Hawking:

"There are something like ten million million million million million million million million million million million million million million (1 with eighty zeroes after it) particles in the region of the universe that we can observe. Where did they all come from? The answer is that, in quantum theory, particles can be created out of energy in the form of particle/antiparticle parts. But that just raises the question of where the energy came from. The answer is that the total energy of the universe is exactly zero. The matter in the universe is made out of positive energy. However, the matter is all attracting itself by gravity. Two pieces of matter that are close to each other have less energy than the same two pieces a long way apart, because you have to expend energy to separate them against the gravitational force that is pulling them together. Thus in a sense, the gravitational field has negative energy. In the case of a universe that is approximately uniform in space, one can show that this negative gravitational energy exactly cancels the positive energy represented by the matter. So the total energy of the universe is zero.

Now twice zero is also zero. Thus the universe can double the amount of positive matter energy and also double the negative gravitational energy without violation of the conservation of energy... 'It is said that there's no such thing as a free lunch but the Universe is the ultimate free lunch'" [6].

We have argued that free will is the capacity to make an unforced decision between available options and is thus more likely to be found where force is absent. Force in its four manifestations (the nuclear forces strong and weak, electromagnetism and gravity- although a good case can be made that gravity should not be considered as a force) can be seen as the driver, the instrument of cause and effect in a material scenario. Will can perhaps best be understood as primary, independent causation.

In taking on limit we become less free as our range of options and awareness diminish.

If separation in the physical universe is the result of the will to separate, then perhaps what we call physical force is just what will has become out of that separation.

If something is free, it has to have no force making it do what it does. So if we have free will then this implies that we are able to cause something without our choice being caused by anything.

So we can see that will is what happens in a state of what we might call 'peace', where there is no force and perhaps force is what happens when will is no longer free. The reason matter obeys physical force, may be just that matter is what thought has become after this separation and force is what will has become [5].

We as living beings are always an amalgam of the two: mind and matter, will and force, awareness and ignorance.

Given the evidence equating the man on the shroud with the historical person of Jesus and given the palpable uniqueness of his life and the impact it has had on the world and is still having even after two thousand years have elapsed it would seem sensible to expect that we might find some clues to what happened on the day in first century Judaea when the evidence suggests that the image was formed.

Perhaps he showed us a recipe of how to undo the limitations and restrictions that bind us as separate human beings.

We have already suggested that the initial 'pre'-'big bang' singularity or 'the whole' is logically greater than the sum of its 'parts' i.e. greater than the physical universe, space matter and time.

We have also postulated that if one of the founders of quantum theory is right and that the 'conscious observer' can logically have no beginning or end then as sentient beings we must have a place in that singularity.

We have suggested that if 'force' only began at the big bang then perhaps the choice to experience separation was the 'cause' of the big bang rather than physical force being the cause.

We have suggested that separation is the 'starter motor' which begins the 'engine of decay' we know as the second law of thermodynamics (please forgive the mixed metaphor!)

We have further inferred that the antidote to this is to lower the tension of separation between sentient beings through kindness and compassion such that matter can be released from the tension that separates us and in doing so begins to shine.

"Love thy neighbour as thyself" has great rational significance if Schrödinger was right when he wrote:

"It is impossible that this unity of knowledge, of feeling and of choice that you consider as YOURS was born a few years ago from nothingness. Actually, this knowledge this feeling and this choice are, in their essence, eternal, immutable and numerically ONE in all men and in all living beings (...). The life that you are living presently is not only a fragment of the whole existence; it is in a certain sense, the WHOLE" [7].

Perhaps then we have actually become separate beings, through our restrictions and limitations of mind, that stop us seeing the whole picture and that is what has made us become caught in a material physical universe and perhaps the life of the man on the shroud was showing a way to reverse that separation.

If mind is all one, but we make it separate through our restrictions and limitations, then it makes sense to love our neighbour as ourselves because our neighbour is our self. So actually we're all one and if we realise that, through how we live our lives, then we can undo the bonds of restriction that keep us separate and maybe then matter would begin to shine and the energy that is caught in atoms would be released.

Of course one could argue if that was the case then there would be the equivalent of many nuclear explosions worth of energy that would have been released. It would have completely destroyed everything around him, if all the mass was released as energy.

However, if the choice to separate was what made the universe happen in the first place, then perhaps reversing that might release that tension of separation and lower gravity.

There are many anecdotal reports from the time of Jesus that he was able to walk on water and was reported to have been witnessed rising above the ground.

If Hawking is right and the total energy of the universe is always zero then perhaps the reduction in mass-energy associated with human transfiguration is correlated with a reduction in universal gravitational energy so that energy is still conserved, as the summation of all energy is still zero.

Jesus himself always taught that all human beings had the potential to do what he did and it is reassuring that there are reports of other people for example the Buddha, Teresa of Avila, Peter (the apostle) who also are said to have been seen to show signs of not being bound by gravity.

It is important though not to place too much emphasis on the physical manifestations of 'enlightenment' as some of these could perhaps be replicated in an empty way by technology. However, as was explained very clearly by many speakers at IWSAI at Frascati, the Turin Shroud image still can not be replicated even with 21st century technology.

It would seem fair to say that anyone who has seriously considered the evidence regarding the Turin Shroud image will have seen that this is unique and has properties that nobody today can reproduce. One could therefore surmise that we have three options:

1. It is a forgery. Although modern technology can not replicate it, mediaeval technology was more advanced than ours and so what is not possible today was possible many centuries ago.
2. It is a supernatural miracle and is supposed to be a 'mystery', which we can not understand and perhaps we should not try to understand it.
3. It is the product of natural law but science has not discovered the laws, which are relevant for explaining it.

The first option is quite easy to dismiss as not only would the forger have had to somehow reproduce the surface effect of the image but they would have had to add in distance-coded information and holographic properties in fine detail and with a knowledge of anatomy, pathology and forensics which would not be available for centuries and they would have had to have designed it to such a specification that would allow for future technological developments many centuries later before their masterpiece could be appreciated e.g. photographic equipment, image intensifiers, modern computers.

If the second option were true then our attempts to explain it will always be unsuccessful but unless or until someone can give us a rational justification for giving up the attempt then I hope the reader will forgive us for trying.

It is at the very least a fascinating challenge and one that could help provide an illustration of the significance of human beings in the cosmos. This could perhaps help us to see that the potential contained inside each person is beyond our imaginings and that their value and preciousness are commensurate with this.

It may seem unusual to talk about natural law when discussing the direct influence on and transformation of matter through the action of mind but yet quantum theory has demonstrated the pivotal role of consciousness in 'making reality real'

It is interesting that our 'western' scientific culture and in particular the empirical method can sometimes stunt our thinking when we try to understand the mind. We all understand the phrase:

"Cogito ergo sum - I think therefore I am."

While considering those words we can observe the fact that we are thinking and logically deduce that there is 'something' or an 'entity' which is doing that thinking. We identify that thing or entity as 'I' and deduce that 'I' exists.

Is this a scientific approach?

As all scientists know, the word science literally translated means a subject, which is pertaining to knowledge. The scientific method is often described as an attempt to understand or derive knowledge about the world through developing theories, which can be informed by and tested by reproducible observation. However, many people equate the *scientific* method with the *empirical* method, which is actually subtly different.

The empirical method is specifically concerned with information gathered by the senses. This would mean that "I think therefore I am" could be scientifically tested but could not be empirically tested. As thoughts are invisible, silent, odourless, tasteless and intangible then is it the case that we can not know scientifically that we exist?

Many might say that this is not science but philosophy but if quantum theory (which is mathematically the most accurate and verifiable branch of science) depends on the existence of a conscious observer to collapse the wave equation then how can it be of no relevance to science whether or not we exist as conscious observers?

I would like to quote Schrödinger here one last time after all it is his wave equation we are discussing:

"We step with our own persons back into the part of an onlooker who does not belong to the world, which by this very procedure becomes an objective world".

"Colour and sound, heat and cold, are our immediate sensations. Small wonder that they are lacking in a world model from which we have removed our own mental person". "The objective world has only been constructed at the price of taking the self, that is, mind, out of it, remaking it mind is not part of it; obviously, therefore, it can neither act on it nor be acted on by any of its parts" [3].

Empirical research has actually been very beneficial to us in helping us to see the evidence that the shroud image was not 'made by human hands'.

It has also been very informative through the work of eminent scientists who have demonstrated the evidence that the image seems to have been caused by a short, intense burst of radiant energy [1].

Also, empirical research has shown that this radiance would need to have emanated from the body of the man to account for the unique distance-coded and holographic properties of the image and that the image was formed at some point after the man had died.

It has also indicated that at the moment the burst occurred it would seem that the body of the man was upright and possibly suspended above the ground [8].

It is worth mentioning at this point that clearly there is more to this phenomenon than the burst of radiant energy. Unique and astounding though this is. There is also the clear implication that there was something happening in that tomb which caused a dead body to become risen before or during this process. This may, of course have been a moment of resurrection.

This raises the question of what it is that enlivens a body. As living human beings we perhaps all have something of this in us in potential and perhaps this is a message we were intentionally left by the man on the cloth.

We do have some ideas about this process which we feel in a position to justify with the appropriate application of relativity, quantum theory and human biology. We hope to discuss these speculations further in a subsequent paper.

"What might cause a dead body to rise up into the air and shine brighter than the Sun?"

It is our contention that to address this question we need to consider the 'place' where subjectivity and objectivity 'meet'.

Could it really be coincidence that this event which is seemingly unique in human history would appear to have involved the one individual out of all the billions who have lived who has arguably had the most impact on humanity through his teachings and how he lived?

If it is not coincidence then does it not seem reasonable that as scientists we could try to speculate about the relation between mind and matter? Speculation that would consider whether a certain disposition of mind manifested by a certain way of living might have the power to transform our world and the atoms of our bodies.

This transformation would arguably be comprehensible through reason and be congruent with natural law. However, to do this, we might need to extend the subject matter of science beyond purely empirical observation. This is simply because within the empirically observed universe there is no such thing as mind. As Schrödinger pointed out the empirical model has been created by removing 'us' as conscious observers from the model as mind can not be observed by the senses. This is despite the fact that there are no senses without a mind to perceive them.

It is interesting that the science of psychology once made an attempt to understand the mind in an empirical sense, ignoring the subjectivity and seeing human beings as what physicists would understand as a 'black box' where only inputs and outputs are studied. This particular fad fell flat on its face for obvious reasons and thankfully has now gone out of fashion in psychology!

Is it possible that the man whose image is on the cloth was actually the greatest scientist who ever lived?

Is it possible that his life was a de facto experiment, which tested whether it is possible for the human mind and being to be transformed through uniting instead of separating? To be restored to what may have been its original status at the origin of the universe as omnipresent, omniscient 'being'.

Jesus himself always, of course, stressed that all his

achievements were reproducible and constantly referred to the untapped, limitless potential of all human beings for example when he drew people's attention to the 'old testament' scripture saying:
"Is it not written 'You are gods'?"

4. CONCLUSIONS

We have started from the experimental results that suggest the possibility that the shroud image may well have been caused by a short, intense burst of radiant energy [1] emitted from the body of a vertically 'risen' crucified man [8].

We have attempted to make some educated speculations about the mechanism that could give rise to this unique phenomenon.

To do so we have suggested that we need to use a working model of what is often referred to as the ''connection between mind and matter' but which we prefer to see as the 'mind-matter continuum'

We have suggested that the speed of light can be seen as an interface between temporal existence as identities with locations in space and time and an omnipresent, omniscient state of existence from which these identities may be derived.

Just as photons transformed into matter shortly after the 'big bang' of universal separation we have suggested that it would not be surprising if a putative reversal of the process which instigated this separation would be associated with the transformation of matter into 'light'. Bearing in mind that the initial formation of matter was offset according to Hawking by an increase in gravitational energy [6] we have considered the possibility that its reversal could accordingly reduce gravitational energy such that human transfiguration into light would not be associated with an explosion.

We have discussed the possible role of 'free will' in primary causation and the possibility that the manifestation of the property of sentience and free will implies that we as human beings could transcend time, space and matter as 'now' is 'now' through sentience [3].

We have considered that this could imply that all sentient being already existed in the 'pre' 'big bang' singularity and that perhaps it was the choice to experience separation that actually began the big bang [5].

We have seen that separation means that we are limited by our particular point of view and considered that qualities of mind and behaviour which enhance separation such as selfishness, racism, xenophobia and materialism actually cement our fixture in this universe of 'moths, rust and thieves' or, to use more modern terminology, a universe governed by the second law of thermodynamics where the 'arrow of time' is defined by increasing disorder.

We have considered that if, as we have argued, free will is an absolute in this universe of relativity then it is not pre-determined that we have to follow the momentums of separation.

We have suggested that 'love thy neighbour as thyself' is ultimately vindicated by a realisation that as the centre of our existence as sentient beings is logically beyond time and space actually we are all one and our neighbour is ourself.

Perhaps the man on the cloth realised this deeply enough through his actions and how he lived his life that he made it a reality rather than just a potential.

Unless an alleged mediaeval forger had technology way in advance of our 21st century technology then we would surmise that the unanswered questions concerning the shroud may give us a clue to a new understanding of the world and the potential of all human beings.

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ICONOGRAPHY

The copies of the Shroud

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Abstract

The existence of copies of the Shroud, at least about fifty, does not constitute a problem of "rivalry". Also the most beautiful ones are of modest making and clearly appear like drawings. Under analysis they reveal their composition: painting pigments. The aim of making a copy was not to cheat the simple-minded faithful, pretending it was the authentic funeral sheet of Jesus; so much so that it is often written on the copy itself when it had been made and that it had touched the original relic. The existence of the copies reveals, instead, only a devotional aim.

Keyword: Shroud image, blood stains, painting pigments.

1. INTRODUCTION

The Shroud body image, faint yellow, has characteristics [1] completely different from those of the copies [2]. The analyses prove that the Shroud image is not the result of an applied material, as a painting or a printing. Moreover it was not obtained projecting a manikin on a sensitized cloth, singeing a cloth by a hot bas-relief or pressing it on a model treated by acid substances [3]. The characteristics of the Shroud image suggest that the best explanation for its formation is a short and intense burst of directional ultraviolet radiation [4].

The reddish stains are human blood not transposed by a brush but by contact with a wounded body that was wrapped already dead. No image is present under the blood stains. The deduction is that the image formation followed the blood transposition on the cloth [5].

The existence of copies of the Shroud, at least about fifty, does not constitute a problem of "rivalry" like someone, hastily and superficially, wants to make us believe. Also the most beautiful ones are of modest making and clearly appear like drawings. Under analysis they reveal their composition: painting pigments.

Also the modern copies, realized by N.P.L. Allen [6], E.A. Craig [7], L. Garlaschelli [8], J. Nickell [9], V. Pesce Delfino [10], have characteristics completely different from those of the Shroud.

2. CHARACTERISTICS OF THE COPIES

At the beginning of the 16th century the custom to expose the Shroud to the veneration of the faithful spread. In that period also the tradition of reproducing the sacred sheet in full or reduced size began. The copies thus obtained, after touching the original, were considered relics by contact and exposed in permanence or in certain circumstances.

The 17th century was the period of the solemn exhibitions and also of the production of a great number of copies. The Dukes of Savoy, owners of the Shroud, had them made on request for those who wished to have a particular memory of the relic.

The copies that can boast an artistic value for their being of a refined workmanship are few, even if the good will and the devotion never lacked. Rarely was all the reality reproduced with perfect objectivity. The devotional value has a remarkable importance in reference to the historical and religious context that in some way produced them. The documentary value is what deserves most consideration, in relation to the people and the facts that fostered and favored them.

The copies hardly ever reproduce the exact dimensions of the original Shroud and their manual origin is patent. Never do they show a totally negative character, such as the Shroud displays; they are a mélange of positive and negative, in which the positive obviously predominates. One can see the difficulty that the artists encountered. In fact, in trying to reproduce a reality which was not exactly what they were accustomed to, they represented the figure in ways and means which did not correspond to that reality.

Not every copy has the burn marks and the darns. Trickles of blood are very rarely reproduced faithfully. In some copies the eyes are shut, in others they are open; in still other examples, it is difficult to determine whether the eyes are open, closed or half-closed. Most of the copies have the side wound in the correct position, that is, on the right, but in some of them it is reproduced on the left.

The lack of imprint in the pubic area was interpreted as a loincloth which is more or less evident in almost all the copies. The trickle of blood on the back is not always depicted. When it is, the interpretations vary widely, from a chain to a continuation of the loincloth.

Regarding the hands, in some copies the left hand is positioned over the right one, in others the right hand is over the left one, but there are also copies with the hands not crossed. In some of the copies the thumb is not visible, in others, instead, it is visible. The hand wound in some cases is in the wrist, in others it is in the palm, in others it is not depicted. The feet are depicted crossed, diverging or parallel.

A great Shroud scholar, don Luigi Fossati, compiled a list in chronological order of the copies with the date written on the cloth [11] and a list in alphabetical order of the localities where copies without the date and without any writing are kept [12], even if sometimes the relative pieces of information are found in covering documents or in other writings [13]. This paper is a summary of those sources.

3. COPIES WITH THE DATE WRITTEN ON THE CLOTH

1516 – St. Gommaire church, Lierre, Belgium.

This copy, attributed to Albrecht Dürer, measures 1.47m x 0.33m and carries the date, a Latin inscription in the center and an inscription in the Old Nuremberg dialect along the lower border. Four groups of red stains are clearly shown on this copy. The artist assumed they were bloodstains but they are, instead, burn holes.

Figure 1. Copy of St. Gommaire church, Lierre.

1568 – Monastery of the Virgin of Guadalupe, Guadalupe, Archdiocese of Toledo, province of Caceres, Extremadura, Spain.

This copy measures 4.40m x 1.00m and carries the date written at each end.

1568 – Parish church, Navarrete, Diocese of Calahorra-Calzada-Logroño, province of Logroño, Spain.

This copy measures 4.54m x 0.93m and carries the date written at each end.

1571 – Holy Sepulcher convent, Augustinian nuns, Alcoy, Archdiocese of Valencia, province of Alicante, Spain.

This copy measures 4.38m x 0.93m and carries the date written at each end. On the back of the reliquary, in which this copy has been kept since early in the 17th century, an inscription explains how the copy came to Spain: it was given to don Juan of Austria by pope Pius V. A document in the Municipal Archives gives a bit more detail, saying that this was one of two copies commissioned by Pius V and that when don Juan of Austria went to Rome for the Pope's blessing before leaving for Lepanto, Pius V gave him this copy. In 1574 don Juan of Austria sent the copy to the Holy Sepulchre Convent in Alcoy.

1594 – Cathedral, Puebla de Los Angeles, Mexico.

This copy measures 4.80m x 2.90m and is an oil painting on cloth.

1620 – Private property of José Falcao, Lisbon, Portugal.

This copy has approximately the size of the original. There are no documents concerning the provenance of this copy. Oral tradition relates that it was brought from Rome by an ancestor of the family, a friar, about 1634.

1620 – Parish church, Torres de la Alameda, Diocese of Madrid, Spain.

This copy measures 4.47m x 1.43m and has the inscription, along the lower border, which tells us that it touched the Shroud on May 3, 1620.

1623 – Cathedral St. Mary of Redonda, Logroño, Diocese of Calahorra-Calzada-Logroño, province of Logroño, Spain.

This copy measures 4.50m x 1.58m and is kept in a chest. The documents in the archives of the Cathedral of Logroño, written in Latin on May 4, 5 and 12, 1623, tell us that the prelates present at the exposition put the copy in contact with the original. Although the characters of the inscriptions on the Alameda and Logroño copies are quite different, other details common to them lead us to think that they could be the work of the same artist.

1624 – Monastery of Our Lady of the Rosary, Dominican nuns, Summit, New Jersey, USA.

This copy has approximately the size of the original and was given to the Monastery as a gift from the Dominican nuns of the Monastery of SS. Dominic and Sistus, Rome, on April 6, 1924.

1634 – Monastery of St. Joseph, Moncalieri, province of Turin, Italy.

This copy measures 4.36m x 0.98m and had been in contact with the Shroud during the exposition of 1931, as it appears from the inscription in Italian embroidered in azure on the red silk support and from an archival document written by Canon Michele Grasso, Chaplain of the Holy Shroud Chapel.

1640 – Church of the hospital, Castillo de Garcimuñoz, Diocese of Cuenca, Spain.

This copy measures 4.34m in length. The document of authentication was drawn up at Cuenca under the date of April 14, 1642.

1643 – Private collection, Countess Alessandra Ruà Lovera di Maria, Turin, Italy.

This copy measures 4.21m x 0.95m and after the date appears the Savoy Knot.

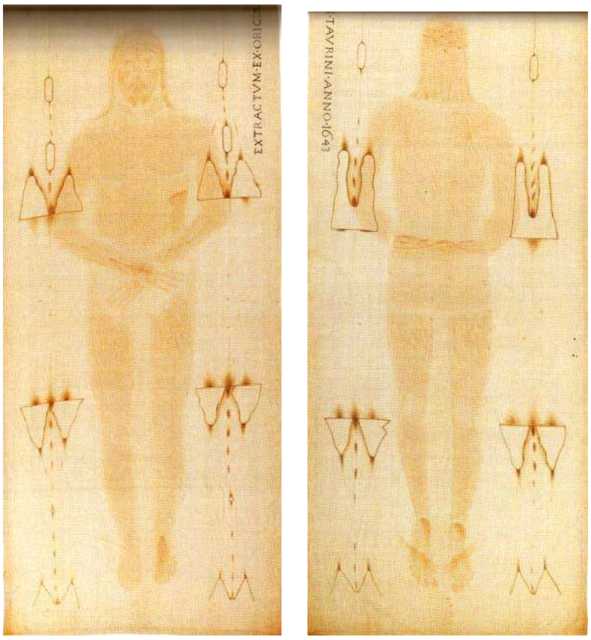

Figure 2. Copy of St. Hilary church, Casale Monferrato.

1643 – St. Hilary parish church, Casale Monferrato, province of Alessandria, Italy.
This copy measures 4.20m x 0.96m and was realized for the Irish faithful, but it was never sent to Ireland.

1644 – San Sebastian church, Acireale, province of Catania, Italy.
This copy measures 3.90m x 0.96m and very probably was given to the church by Fr. Innocenzo Marcinò of Caltagirone, General of the Capuchin fathers.

1644 – Monastery Our Lady of the Suffrage, Capuchin nuns, Turin, Italy.
This copy measures 4.47m x 1.05m and the date is followed by a little ornament. The Princesses Francesca Maria and Francesca Caterina of Savoy, Franciscan tertiaries, were frequent visitors to the convent. Without any doubt, the copy was a gift from them.

1646 – Cathedral of Bitonto, province of Bari, Italy.
This copy measures one third of the original. A document of the capitulary archives reads: "On May 25, 1659, the Illustrious Monsignor Alessandro Crescenzo, Bishop of Bitonto, gave to the Most Reverend Chapter the Holy Shroud. It touched the Original which is conserved in Turin, where he [Bishop Crescenzo] was Apostolic Nuncio for twelve years".

1646 – Cathedral of St. Peter, Bologna, Italy.
This copy measures 4.42m x 0.87m and the inscription is along the upper border. This copy, executed in tempera on a linen cloth, is attributed to the Princess Francesca Maria Apollonia of Savoy, daughter of Carlo Emanuele I.

1646 – St. Catherine church, Fabriano, province of Ancona, Italy.
This copy measures 3.97m x 0.83m and was given by brother Ippolito Righi. The drawing is very carefully done, however it is badly stained.

1646 – Monastery of the Ursuline nuns, Quebec, Canada.
This copy has approximately the size of the original and is in very precarious conditions.

1650 – Private collection, Countess Camilla Roggeri Mermet Gay di Quarti, Turin, Italy.
This copy measures 4.50m x 0.95m and in 1898 was photographed by Secondo Pia for Paul Vignon.

1652 – Monastery of SS. Joseph and Theresa, Mounts of Ponti Rossi, Naples, Italy.
This copy measures 4.37m x 0.95m and would seem to be by the same artist who made the copy of Caltagirone, of which we will speak later.

1653 – St. Mary parish church, Cuneo, Italy.
This copy measures 4.15m x 0.97m and the date is followed by a little ornament. The imprints are heavily outlined, resembling a rough charcoal sketch. On the back, a red silk lining prevents transparency. Entwined ribbons, red and white, run all around the border.

1653 – Oratory of SS. Peter and Catherine, Savona, Italy.
This copy measures 4.50m x 1.03m and is provided with an authentication by the Protonotary Apostolic Michele Beggiano, General Vicar of the Archdiocese of Turin.

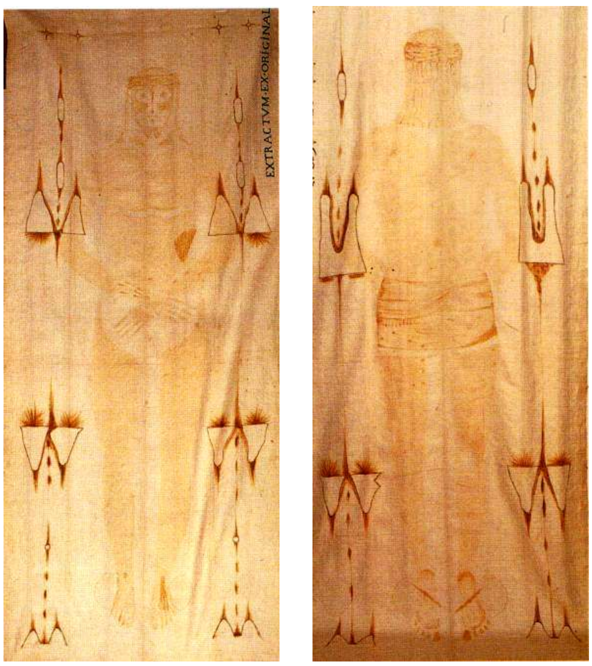

Figure 3. Copy of SS. Peter and Catherine Oratory, Savona.

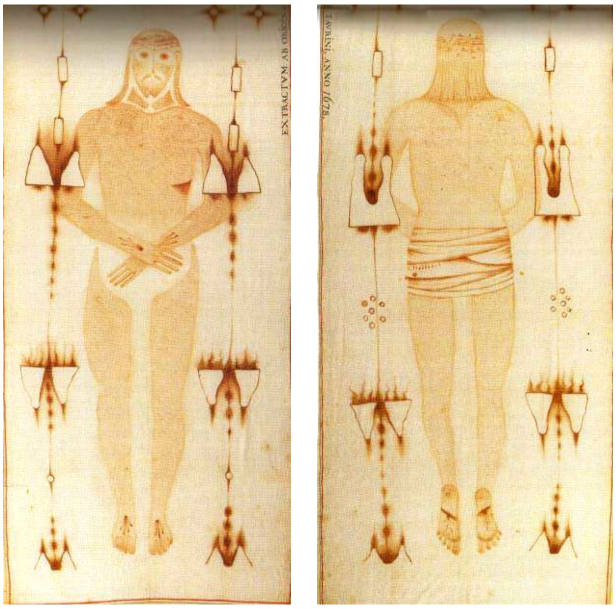

Figure 4. Copy of St. Maurice Basilica, Imperia.

1654 – Our Lady of Los Valles parish church, La Cuesta, Diocese of Osma-Soria, Spain.
This copy measures 4.16m x 0.93m and is provided with an authentication preserved in the parish archives.

1665 – Museum of the Cathedral, Salerno, Italy.
This copy measures 4.16m x 1.03m and comes from the Monastery of St. Michael Archangel of the Poor Clare nuns.

1678 – Basilica of St. Maurice, Imperia, Italy.
This copy measures 4.32m x 1.03m and is very well preserved. It is attributed to Giovanni Battista Fantino.

1697 – Monastery St. Therese, Carmelite nuns, Savona, Italy.
This copy measures 4.50m x 1.10m and is longer than others because the symbols of the Passion are represented at the ends. In the inscription is written that the author is Giovanni Battista Fantino.

1708 – St. Martha church, Agliè, province of Turin, Italy.
This copy measures 4.40m x 0.98m and was painted by Giovanni Battista Fantino.

1710 – St. Mary of the Assumption church, Gallarate, province of Varese, Italy.
This copy measures 4.47m x 1.09m and was painted by Giovanni Battista Fantino.

1933 – St. John the Baptist church, Verrua Savoia, province of Turin, Italy.
This copy measures 4.01m x 1.04m and was painted by Oreste Visone.

4. COPIES WITHOUT THE DATE WRITTEN ON THE CLOTH

Agliè, province of Turin, Italy, Sacristy of the Chapel of the Castle, 1822.
This copy measures 4.40m x 0.90m and is sewn onto a cloth of violet silk, which forms a border all around the sheet.

Arquata del Tronto, province of Ascoli Piceno, Italy, St. Francis church, 1653.
This copy has approximately the size of the original and touched it on May 4, 1653.

Badolatosa, province of Seville, Spain, parish church, 1674.
The exact measures of his copy are not known, but the size is less than the original. The copy is signed, like others, by the artist: Giovanni Battista Fantino.

Bologna, Italy, Monastery of Corpus Domini, 1645-1653.
This copy measures 1.41m x 0.42m and is an oil painting on linen attributed to the Princess Maria Apollonia of Savoy, who gave it to the Poor Clare nuns Monastery during one of her sojourns in Bologna.

Caltagirone, province of Catania, Italy, Sacristy of the Convent of the Capuchin Fathers, 1649.
This copy has approximately the size of the original and was given to the Convent by Fr. Innocenzo Marcinò of Caltagirone, General of the Capuchin fathers.

Dronero, province of Cuneo, Italy, Confraternity of the Cross.
This copy was given to the Confraternity by the Duke Carlo Emanuele of Savoy.

Campillo de Aragon, Diocese of Tarazona, province of Zaragoza, Spain, parish church, 1650.
This copy measures 4.38m x 1.03m and arrived to the parish church after various travels. It is the copy that Francisco Lucas Bueno, Bishop of Malta, received from the Duke of Savoy.

Escalona del Prado, province of Segovia, Spain, parish church, 1657.
This copy measures 4.50m x 0.96m and comes from Rome, were was property of Fr. Sebastiano da Gaeta, Commissary General of the Minor Observants and Reformed.

Escamilla, diocese of Cuenca, province of Guadalajara, Spain, parish church, 1640.
There are two copies. One measures only 0.53m x 0.32m while the other shows the frontal and dorsal imprints separately in natural size, 2.00m x 0.70m, that are mounted side by side on frames.

Figure 5. Copy of St. John the Baptist church, Finale Ligure.

Finale Ligure, province of Savona, Italy, St. John the Baptist parish church, 1728.
This copy measures 3.74m x 0.89m and was painted by Domenico Bocciardo.

Gallipoli, province of Lecce, Italy, Cathedral, 1585.
The somatic imprints on this copy measure 4.01m x 0.75m and it was taken to Gallipoli by the Bishop Quintero Ortis. Along one lengthwise side, another cloth has been sewn on for fixing it to a long staff.

Guadalupe, Archdiocese of Toledo, province of Caceres, Extremadura, Spain, Monastery of the Virgin of Guadalupe, 1588.
This copy measures 3.00m x 0.97m and has two figures of angels that hold up the Shroud. The manner of presentation, the noticeable stylistic differences from other copies of that period, and the delicacy of the work, induce one to think that the painting was retouched in later centuries.

Inzago, province of Milan, Italy, Provostship of St. Mary of the Assumption, 1581.
This copy measures 5.12m x 1.00m and was given by Carlo Francesco Bonomi, bishop of Vercelli, to St. Carlo Borromeo. It is in poor state of preservation. The fabric is rumpled and is it not possible to determine the artistic style. The frontal and dorsal imprints are not well defined.

Laguna de Cameros, Diocese of Calahorra-Calzada-Logroño, province of Logroño, Spain, St. Dominic church, 1790.
This copy measured 4.60m x 0.86m but it was cut in half so that now each half is 2.30m high and 1.72m wide. The two parts are set vertically side by side.

Lisbon, Portugal, National Museum, about 1500.
This copy has approximately the size of the original and comes from the Monastery of the Mother of God in Xabregas, Lisbon.

Madrid, Spain, Escorial Monastery.
There are two copies. One measures only 0.45m x 0.12m while the other one has approximately the size of the original.

Mondovì, province of Cuneo, Italy, Cathedral.
The preservation conditions of this copy let us argue that in the past it was often exhibited.

Naples, Basilica of St. Paul the Greater, Theatine fathers, 1608-1626.
This copy measures 4.10m x 0.85m but it was cut in half.

Rabat, Malta, St. Paul Collegiate church, about 1663.
This copy measures 2.93m x 1.01m and touched the Shroud on May 15, 1663.

Ripalimosani, province of Campobasso, Italy, Assumption parish church, 1595-1601.
This copy measures 3.86m x 0.79m and is associated with Giulio Cesare Riccardi, a prelate native of Ripalimosani.

Rome, Italy, St. Judas Thaddeus parish church, 1692.
This copy measures 4.30m x 1.04m and is in good state of preservation. In a letter it is written that it touched the Shroud twice.

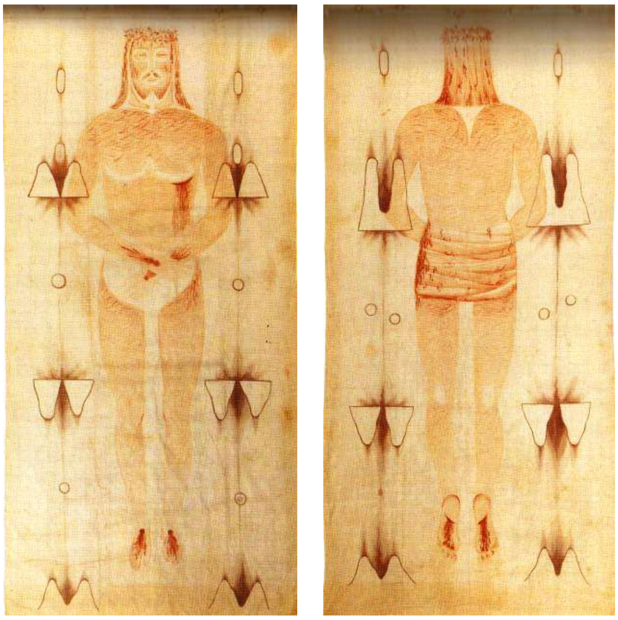

Figure 6. Copy of St. Judas Thaddeus church, Rome.

Rome, Italy, Holy Shroud church, 1605.
This copy has approximately the size of the original and was given by Clement VIII on the occasion of the consecration of the church. Some retouching was done in 1870-1871 when the church was reopened to the public after a period of abandon. On this copy the frontal image is at the right, whereas traditionally it appears at the left of the observer.

Salamanca, Spain, Monastery of Augustinian nuns, 1665.
This copy has approximately the size of the original and is well preserved.

Santiago del Estero, Argentina, Convent of St. Dominic, 1585
This copy folded in half measures 2.17m x 0.81m and is very faithful to the original, even in small details.

Silos, province of Burgos, Monastery of the Benedictine fathers, 1640.
In this copy the frontal imprint measures 1.59m, the dorsal imprint measures 1.63m and the figures are heavily delineated. The Monastery received this copy while father Nicolas Mélendez was abbot (1637-1641). Archival documents describe it as being entirely similar to the original.

Toledo, Spain, Monastery Mothers Commendadores de Santiago, 1587.
This copy measures 4.50m x 0.87m and is similar to that of Silos. Two other copies are mentioned in the document of donation, but of these there is no further information.

Turin, Italy, Piccola Casa della Divina Provvidenza (Cottolengo), 1750.
This copy touched the Shroud on May 27, 1898.

Turin, Italy, Monastery St. Mary Magdalen.
This copy measures 1.64m x 0.43m and is faithful to the original in the various colour shades.

Turin, Italy, Sacristy of the Holy Shroud Chapel, 1898.
There were two copies, one painted by Cav. Carlo Cussetti and another painted by Enrico Reffo.

Valladolid, Spain, Monastery of Our Lady of the Laura, Dominican nuns, 1567.
This copy measures 4.36m in length but it was cut in half and the two parts set vertically side by side.

5. CONCLUSIONS

The aim of making a copy was not to cheat the simple-minded faithful, pretending it was the authentic funeral sheet of Jesus; so much so that it is often written on the copy when it had been made and that it had touched the original relic.

The existence of the copies reveals, instead, only a devotional aim: the desire of being able to pray in front of that sacred image in an age in which the photography did not exist.

ACKNOWLEDGMENTS

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Crux Mensuralis of Grottaferrata and Shroud of Turin

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Abstract
In the Abbey of Grottaferrata there is a Crux Mensuralis (CM) made of cemented marble and fixed in a wall of a hidden corridor. The archival documents indicate that this unusual religious object was in the Abbey since the end of the 19th century, but another one was there since the 17th century and very likely well before that. Because the CM is credited to report the dimensions of Jesus Christ, its same existence in Grottaferrata, probably the only one existing in the world nowadays, provides important clues on the Shroud of Turin when it was not yet known in the West.

Keywords: Crux Mensuralis, Abbey of Grottaferrata, Hagia Sophia, Shroud of Turin, dimensions of Jesus Christ.

1. INTRODUCTION

In an inconspicuous corridor leading to the sacristy and to the medieval bell tower of the ancient church of Saint Mary in the Greek Abbey of Grottaferrata, a small town on the slopes of the Alban Hills south of Rome, there is a cross embedded in a plastered wall at man height. The cross is rather unusual because it is very different from the well-known Greek and Latin shapes, and at a first visual and hand examination seems to be made of the rare red porphyry. Moreover, it is so well hidden that the common citizens of Grottaferrata do not know its existence and, still more, several recent books describing the ancient and historical Abbey totally ignore it [1 - 3]. However, when the monks still servicing the Abbey were asked about this cross, they answered unanimously that it is a Crux Mensuralis (CM), but they do not know when, how and why it was brought there, although the oldest one among them remembers having seen it, in the very same place where and how it is today, since the thirties when he arrived as a novice at the Abbey [4]. Figure 1 shows a photo of the CM taken in its context just entering the corridor from a chapel of the church and looking at the right side. Although the CM of Grottaferrata (CMG from now on) is not known to the public at large in Grottaferrata and in Italy, this is not the case for some Italian scholars [5 - 8]. They do not say very much about the CMG, but what little they say is interesting enough for the present work to be reported here.

Zaninotto [5], who saw the cross, writes at pages 22-23: *I would like here to remind, for the venerable antiquity of the place and for the Greek community, the cross of granite in the Abbey of Saint Nile in Grottaferrata, near Rome. It has been moved to the corridor near the bell tower since the beginning of the century: nobody knows from where. The popular tradition believes that the cross displays the dimensions of the venerable body of Christ, but up to now there is not any substantiating documentation about. Moreover, its story is unknown. The cross is 178 cm high and 48.5 cm large. The relatively short width could recall a Greek origin rather than Latin.*

Ricci [6], who saw the cross, writes at pages 381-382: *The transversal dimension of the CM of Justinian corresponds to the width of the shoulders, as in the body image of the Shroud: exactly like the CM that "ab immemorabili" is worshipped in the byzantine Church of Grottaferrata (179 cm x 48.8 cm), certainly a faithful copy in red granite, inspired to that of Constantinople, which displays the same two characteristic measurements: 179x50.*

Coppini and Cavazzuti [7] writes at page 54: *The CM made by Justinian does not exist anymore, very likely disappeared during the sack of Constantinople in 1204. The Greek Abbey of Grottaferrata keeps one copy of it in a reduced form. The western tradition kept the memory of the CM until the French revolution* (1789). *Nowadays, it has been completely forgotten, together with its effects on the formation of the image of Christ.*

Volterri [8], who saw the cross, says: *Here, in the Abbey* (of Grottaferrata)*, in a room adjacent to a small chapel* (the Farnesian chapel) *where evocative marriages are often celebrated with the byzantine rite, it is possible to observe a strange cross, exactly 1.80 m tall, with the patibulus very narrow. Let's say like the width at the shoulders of a tall adult man. It is the "poor" copy of the precious CM of the emperor Justinian and lost in 1204. It is made of red porphyry and sits in a relatively hidden place.*

Figure 1. The Crux Mensuralis of Grottaferrata fixed on a wall of a secluded corridor called "Il Salvatorello" below a renaissance fresco depicting the Saviour and Saints, and at its side the old roman wall of the "crypta ferrata". A window with iron bars is prominent on the wall. The photo has been taken on December 29, 2009.

The previous scholars give us much conflicting information. The CMG, made of red granite or porphyry [9], is a poor copy or a reduced form of the precious CM created at the time of the emperor Justinian according to the dimensions of the body of Christ, taken very likely from the body image of the Shroud. Moreover, there are not historical documents available and so the origins of the CMG are unknown, but it has been worshipped since immemorial time in the Greek Abbey of Grottaferrata. Although this last information on the worship does not correspond to the reality, at least in recent times when, according to the monks of the same Abbey, not only the memory but also its use in the Byzantine liturgy has been completely lost, there were enough references to the CM, the emperor Justinian, the Byzantine world, the body of Christ, and the Shroud, which raised many questions and stimulated our interest to find out the whole story of the CM, by resorting as much as possible to reliable documentation. So, on one side we started to put together a credible story of the CM from the beginnings in the Eastern Roman Empire, later on also known in western Europe as byzantine empire, and on the other side we started to search systematically in the rich archives of the Abbey of Grottaferrata, which nowadays is the last monastery in Italy still using the old Byzantine rite attributed to St. John Chrysostom.

2. CRUX MENSURALIS

According to an anonymous monk of the 12th century, *"The venerable cross, which today is in the Skeuophylakion* (of Hagia Sophia in Constantinople), *reports the height of our Lord Jesus Christ which has been accurately measured in Jerusalem by faithful and trustworthy men. They made it of silver, decorated with precious stones and covered with gold. Up to nowadays it takes care of diseases, chases away illness and devils"* [10]. According to a broad literature, the measurement of Christ took place under the reign of Justinian I, 527-565, who sent the above mentioned faithful and trustworthy men to Jerusalem where, very likely, they measured the height and width at the shoulders of Christ from the Holy Shroud itself which was still in Jerusalem [6].

In this regard, it is also necessary to remember here that there is not any reference to this precious CM in the many and detailed works of Procopius of Cesarea (500-565), who was the historian *par excellence* of the Justinian period. It is very strange that an object like the precious CM could have escaped such a careful scholar. This singular lack of documentation together with other similar ones regarding religious subjects, the Mandylion for instance, casts some doubts on the story told by the anonymous monk, who, as has been suggested, may have been citing a late and unreliable Latin source [11].

However, it is also possible that Procopius considered the episode of the CM as a minor religious one not worthy to be reported in its Histories, taking in consideration that other important relics and sacred objects were already in Constantinople, among them many precious crosses. Moreover, there are other sources which witness the existence of the CM as an historical object.

In the context of the Passion ritual in Constantinople around 950, there is a reference to the famous cross, once in the Skeuophylakion of Hagia Sophia and used in the liturgy, which was exactly the size of Christ's body and contained the true relics of the Passion [12].

The measurements of the precious CM are reported in a parchment containing three lines of Latin words *"Haec linea bis sexties ducta mensuram dominici corporis monstrat. Sumpta est autem de Costantinopoli ex aurea cruce facta ad formam corporis Christi"* [13]. In the same parchment there is the figure of Christ holding a stylized cross in his left hand and standing on an elaborated pedestal 15 cm long. The short Latin text says "*This line* (pedestal) *multiplied by two times six indicates the measurement of the body of Christ. Moreover, it has been taken in Constantinople from the gold cross shaped in the form of the body of Christ*". In conclusion, the length of the precious CM is 15x2x6=180 cm! The above mentioned document is a folio of a richly decorated Book of Hours dated 1293. Because similar devotional books were very popular in the Middle Ages, it is logical to deduce that the folio itself or the information contained in the same were very much known at that time, and so their origin could have be well before the 13th century, and the tradition continued at least up to the 15th century [14].

A CM was erected in the 10th century outside Hagia Sophia, and it was still there in 1202 when Antony, bishop of Novgorod, visited Constantinople and wrote *"Extra sanctuarium minus, erecta est Crux Mensuralis, quae, scilicet staturam Christi secundum carnem indicat",* i.e. "*Outside the minor sanctuary there is a Crux Mensuralis which without doubt indicates the height of Christ according to his body*" [15]. There is more information about the CM, also concerning the connections with famous relics like the Image of Edessa and the Shroud, which can be found with some details elsewhere [5, 6, 16], but here we are interested to stress its liturgical aspects which started in the 10th century in Constantinople and spread widely in the Byzantine world. Indeed, since then the Orthodox Church developed a keen passion for the physical characteristics of Christ and, as far as the CM was concerned, special liturgies were developed especially for the Passion [12, 17] and celebrations for the dead [16]. Moreover, the Nartex occupied a special place in important ceremonies, for instance as the starting point of solemn processions who took hours to reach the final destination, usually the altar, iconostasis and bema, of the same church or more rarely another church or place of the city.

In conclusion, in the 12th century there were in Constantinople at least two CMs, the precious one of Justinian inside Hagia Sophia, and the other one of unknown material just outside it. They both disappeared after the sack of Constantinople in 1204, and they are not mentioned anymore since then. Very likely, there were copies of the CM utilized in other churches in Constantinople and in other religious buildings of the empire for the same functions, especially in the regions under the direct jurisdiction of the Patriarchate of Constantinople, but there is not any historical record about them.

About the two historical crosses in Constantinople, their looks are not known but, as far as the precious one in concerned, an educated guess can be made. Indeed, at the same time there were other precious crosses which were used in Haghia Sophia during various ceremonies, and often these crosses were also depicted on the walls of churches as paintings and mosaics, as the famous ones of Ravenna, Italy, at that time territory of the Eastern Roman Empire. Figure 2 shows the photo of a typical Byzantine jeweled cross of the same time as the precious CM. This magnificent cross, made of gold and precious stones, is only a glimpse of what could have been the precious CM of Justinian, who did not limit the richness of the empire when the religion and its image were at stake.

3. CRUX MENSURALIS OF GROTTAFERRATA

As stated in the introduction, after our rediscovery of the CMG in December 2009 a systematic search was started in the archives of the Abbey, and up to now relevant documentation has been found as described in the following.

Figure 2. This jeweled cross, 40 cm x 30 cm without the base, was given to pope John III by the emperor Justin II in the 6th century. A piece of the true cross is contained at its very center. It still stands in the treasure of the Vatican in Rome and it is known as *Cross of Justin II* or *Crux Vaticana*.

On January 22, 1890, the Abbot wrote to the Cardinal of Turin asking him the dimensions of the body image in the Shroud of Turin. The request was justified because in the sacristy there was a Cross embedded in a wall which, as written in an epigraph (now lost), reproduced the height of Christ as taken by the Sacred Shroud, and there was concern that its dimensions could have been modified during some restoring works. This Cross is said to be black (Black Cross) by the hieromonk Antonio Rocchi [18].

On January 30, 1890, the Cardinal sent an artistic print, made in 1876, of the Shroud of Turin reporting in the margin the length of the body image, 178 cm, and the dimensions of the Shroud, 410x140 cm. Nothing is said about how the body image was measured, and the dimensions of the Shroud very likely contained a typographical error, since indeed its true dimensions are 440x110 cm. On February 7, 1890, the Abbot thanked the Cardinal and told him that a new CM was being planned in accordance with the Sacred Shroud. Indeed, a new cross made of cemented marble was commissioned to an artisan of Frascati, and fixed in the wall on July 28 of the same year. On August 2, the rev. prof. (Ermete) Binzecher, in the Abbey for a spiritual retreat, returned to Rome bringing with him a petition for 100 days indulgence to anyone kissing the cross.

The new cross was made of a special material mixing looking like a porphyry/granite, a lost technique since then, and no mention on the fate of the old Black Cross is reported in the available documents [18]. The complete dimensions of the CMG are reported in Figure 3 for sake of completeness.

Up to this moment, there is no other information referring directly and clearly to the CM, but there are interesting traces worthwhile to be reported here.

In 1877, an inventory of the property of the Abbey reported in the corridor of "Il Salvatorello", among other objects, a "*Crocefisso a muro*", i.e. a crucifix in the wall, most probably the already mentioned Black Cross, although in plain Italian language a crocifisso means a cross with the body of Christ nailed to it [19].

In 1823, Queen Maria Cristina of the House of Savoy visited the Abbey. She was a very religious woman, and the owner of the mount Tuscolo overlooking Frascati and Grottaferrata, where once there had been the very old town of Tusculum connected during the 11th century with the founding of the Abbey of Grottaferrata.

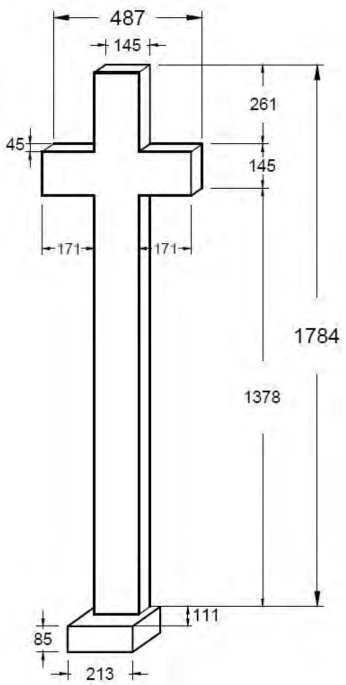

Figure 3. A perspective design of the Crux Mensuralis of Grottaferrata. The dimensions are in mm with an error of a few mm. The cross has been made of cemented marble with sharp angles and polished with care, a technique known and utilized in the 19th century.

There is a map copied by the abbot Giuseppe Cozza-Luzi (1881-82) from an original one (mappa Barberini) dated before the 17th century, which reports the existence of a *"crocetta"* (literally small/nice cross) overlooking an open space utilized in the past as a cemetery. The *"crocetta"* was on the external wall of a room containing funeral accessories, and adjacent to the then Chapel/Narthex of the Basilica [20].

In 1661, the Latin bishop Antonio Severoli, on a Apostolic Visit to the Abbey, ordered to place crosses as soon as possible in the high places of the corridor of "Il Salvatorello", because it was adjacent to the old cemetery of the Abbey. The original phrase is in Latin *"Dominus mandavit opponi cruces in parte superiori quam primum"* [21]. Very likely, the Black Cross was made at that time or, already existing in other places, was moved there for the occasion.

An old Typicon of the Abbey [22] reports about various religious objects, and in particular a *"cross"*, probably of big dimensions, nearby the main door of the Narthex in the medieval time, 12th century, that was related to several liturgies, and most probably also to the ceremonies for the dead [23].

The information presented up to now is important because it sheds some light on the CMG and other special crosses which exist and have existed in the Basilica of Grottaferrata since old times. But it does not tell us a logical story of why they were in the Basilica in the first place, when they were placed there, and why they were forgotten for such a long time, even up to the present. In order to answer appropriately these questions, it is necessary to put together the stories of the CM in Constantinople, of the Byzantine empire and its liturgies, of the connections between Latin and Greek Churches, and finally of the Basilica of Grottaferrata.

4. DISCUSSION

The Abbey of Grottaferrata was founded in 1004 by monks led by Nilo di Rossano, soon after his death a Saint, on a property where the remains of an old Roman villa were still prominent and donated by the Count of Tuscolo. At the end of 1024 a monastic church was dedicated to the Mother of God, Theotokos, better known since then as Saint Mary of Grottaferrata. Very likely, the original church was built following necessarily the layout of the Roman villa, up to the point of incorporating a still existing *"crypta ferrata"* (literally, "iron grotto" or in Italian "grotta ferrata": hence the name of the town, Grottaferrata). During the following centuries, the Abbey underwent several additions and modifications up to the actual medieval-renaissance aspect, but the primeval plan of the church remained substantially the same, although several adjacent pertinent buildings were added, destroyed, modified, and changed altogether with their use. These modifications will be dealt with when needed for the story of the CMG, but in order to understand why, when and how the church was built, it is necessary to go back in time to when Nilo was still a simple monk and hermit in Calabria, a Theme (province) of the Byzantine empire.

At that time all southern Italy, with the exception of Sicily, belonged to the Byzantine empire, and the religious activities were under the direct supervision of the Patriarchate of Constantinople, and so the liturgy was essentially Byzantine. In addition, Nilo was a cultured member of the Greek community, and as a monk became also an expert amanuensis, especially of religious texts. Because of the advancing Arab menace, he and his fellow monks abandoned Calabria and, after moving to various Abbeys during a period of 51 years enriched with several noticeable events, finally were in sight of Grottaferrata, when he died. His mission was continued by the other monks, and especially his best pupil Bartholomew, also a Saint later on [24], who among several appreciated personal qualities was also a reputed scholar, and wrote the first Typikon [25] of the Abbey and a life of St. Nilo [26].

With the above mentioned background, the monks founded near the very center of the Latin Church, i.e., Rome, a real Greek-Byzantine Abbey where the liturgical ceremonies required also well suitable premises. As a matter of fact, the church of St. Mary of Grottaferrata was built with the altar (bema plus iconostasis) almost towards the east, as much as possible with the existing constraints of the Roman remains, the Nartex perpendicular to the naves, and the imperial door, also beautiful door, leading to the naves and the altar from the Nartex. In short, they built a church complex which was, as much as possible for the medieval time, the rather peripheral location and the limited means, similar to Haghia Sophia in Constantinople [16]. The Byzantine reality in Grottaferrata was so evident that, after the Great Schism of 1054 between Rome and Constantinople, in 1089 the Pope sent the Abbot of Grottaferrata to Constantinople with a diplomatic delegation aimed at re-establishing the unity of the two Churches. To understand the whole story, it is necessary to add that after the Schism the monks of the Abbey remained faithful to the Pope but retained their Greek-Byzantine rites, and the said Abbot, Nicola I, was very likely a Greek from Constantinople [1, p. 30].

Notwithstanding such initial strong bonds between the Abbey of Grottaferrata and the Byzantine world, at least as far as language, culture and rite were concerned, during the late Middle Ages, a process of partial Latinization started to creep and continued beyond 1462, when the religious and temporal government of the Abbey was assigned to a high Latin prelate, usually a Cardinal. This status remained in practice up to 1881, when the Byzantine rite was fully re-established with the nomination of an Abbot, later on Archimandrite, who answered for it directly to the Pope. However, the process of Latinization was also influenced by the decadence of the Byzantine empire in Italy and its ultimate destruction in 1453 when the city of Constantinople, the second Rome, was taken by the Ottoman Turks. Since that fateful day, not only the Eastern Roman Empire ended at once but also the Byzantine Church ceased to be a reference point for the whole Christianity.

The above mentioned short chronicle is a much needed piece of information for the following discussion where two different hypotheses on the origin of the CMG will be presented in some details.

The first one, H1 from now on, simply derives from considering literally the documentation at disposal. In sect. 3 of this article an epigraph is mentioned telling *"In a small chamber adjacent to the chapel of St. Nilo there is the following cross with this inscription: measure of the height of our Lord Jesus Christ taken from the Sacred Shroud"*. The content of the epigraph (now lost) was fortunately written down together with the sketch of a cross in 1879-83, and referred to a Black Cross embedded in the wall in the preceding century*(?)*. The question mark is original in the Cronache Monastiche [18], because the monk did not know when the Black Cross was fixed in the wall. But today it is known from other documents that the wall where the cross was embedded has been erected in 1627 and slightly restored in 1819. So, the original Black Cross could have be embedded in the wall any time since the 17th century, as it is also suggested by the Apostolic Visit of the bishop Severoli. In addition, the old inscription says that the height of Christ was taken from the "S*acred Shroud"*, and at a first choice it is logical to think that it referred to the Shroud of Turin. When and how this measurement was taken is not known, but it is likely to have happened after 1578 when the Shroud was brought to Turin, a city much more convenient than Chambéry or Lirey in Savoy, now France, where the same Shroud first appeared in 1353. The only distant connection with this hypothesis found in the documentation was the visit paid by the queen Maria Cristina to the Abbey in 1823, but there is no mention of any reference to the Shroud. The Queen knew of the Shroud very well, because it was a property of her House of Savoy since the Middle Ages.

The second hypothesis, H2 from now on, derives from the same history of the Abbey and is much more appealing than the previous one from the historical perspective. However, it requires to move back in time to a few centuries before. The said Black Cross was surely fixed in the corridor of "Il Salvatorello" after the beginning of the 17th and before the middle of the 19th century, but nowhere is told that it was also manufactured at the same time. A fair hypothesis might be that it was already in the original wall and it was removed from there when a new wall was added. Moreover, we cannot avoid the question of why a similar singular cross was in that place. The answer is very simple if the origin of the place is taken in due consideration. Indeed, it was the first burial site of the Abbey. At the beginning the whole area south of the church was dedicated as a cemetery of the monks, and a cross in the external wall of the church in front of the tombs was a much used symbol, as it is customary still nowadays all over the Christian cemeteries. But the cross in the Abbey could have been a special one, because the monks were Greek-Byzantine, and so they used a cross in the form of the CMs of Constantinople as they culture and liturgy suggested. The CM remained there in the following centuries, also when the old cemetery was very much reduced until it disappeared completely and finally closed and covered by a roof in 1777. That is why now the CM is in a corner with no connection whatsoever to any previous religious function. Moreover, also the memory in the monk community faded away because of the advancing Latinization.

In the Abbey there is also another interesting connection between special crosses, liturgical ceremonies and the architecture of a few premises, which changed accordingly to the need of the times. As we have already said in a previous paragraph, the Narthex has been since the foundation of the church one of its main features, because it was the place reserved for the celebration of practical and symbolic religious functions (akoluthia). Originally it was the place where catechumens and penitents were required to stand while the divine liturgy was going on inside the church, but it also became the very place where solemn processions started from, and where the rites of the Passion and funerals were celebrated. So, it is not a case that a *"*(probably big) *cross"* was in the narthex near the beautiful door in medieval times, and the simple fact that it is mentioned in the Typicon, contrary to the lack of mention of the many other crosses existing in the church, testifies that it was a special cross with a specific function. Later on, a small room was opened in the Nartex, which was used to store vestments and vessels for funerals, and a *"crocetta"* was fixed in the external wall of it. Later on, when the memory of the *"crocetta"* and its function were completely lost, the presence of this particular cross convinced the monks to excavate the ground in front of it, and tombs were found everywhere, i.e. it was a cemetery. Very likely all these addictions, the small room and the *"crocetta"* outside it, were made after the old cemetery was no longer in use, well before the 17th century, and a new cemetery was needed. Finally in the first half of the 19th century all these additions were completely destroyed and other structures were built having in mind the Latin liturgy. At this moment, without more documentation about it is not possible to identify the two above mentioned special crosses with a CM, but very likely its knowledge and functions were very much alive in the first medieval community of monks.

5. CONCLUSIONS

As of now, the following information have been found to possess solid historical grounds.

- The present CMG has been made of cemented marble in 1890 and fixed in the same year on the wall of "Il Salvatorello", as it is today.
- Before that, in the same place there was a Black Cross with an epigraph telling that it reproduced *"the height of our Lord Jesus Christ taken from the Sacred Shroud"*.
- The wall where the CMG is fixed, and where the Black Cross was before, was added as a second wall in 1627 to avoid seepages of water on the adjacent frescoes of Domenichino.

So, as far as archival documentation is concerned, a CM may have existed in the Abbey since the 17th century, or even before on the first wall erected anytime between 1088 and 1608. Moreover, other special crosses existed in the Abbey since its foundation, which could have been either CMs themselves or closely related to them at least for their liturgical functions. This last statement is strongly supported by historical events which took place since the 11th century, as in the following.

- 910: Birth of Nicola at Rossano in Calabria, then a province of the Byzantine empire.
- 940-1003: Nicola becomes an hermit and soon after a monk, with the new name Nilo, at Mercourion, San Demetrio Corone, Valleluce and Serperi.
- 1004: Nilo di Rossano dies while approaching Grottaferrata, where he is buried, and his companion monks found the Abbey.
- 1024: Building and consecration of the church to the Mother of God.
- 1054: Great Schism between the Latin and Byzantine Churches.
- 1089: The Abbot of the Abbey Nicola I is sent to Constantinople as an envoy to try to lift the Schism.
- 1163-1191: Escape of the monks to the Benedictine monastery of Subiaco and their return.
- 1453: Fall of Constantinople.
- 1462-1869: A high Latin prelate is appointed by the Pope as head of the Abbey.
- 1870-1878: The new Italian state takes control of the Abbey, which becomes a national monument in 1874 with the monks as its keepers.
- 1879: Nomination of the first full-power Abbot, Giuseppe Cozza-Luzi, and restoration of the Byzantine rite, that is still in use today.

At the times of Nilo, the CM was a well known religious object in Hagia Sophia. Also the Patriarch of Constantinople was well known in southern Italy. Moreover, the abbot Nicola I was a Greek very likely native of Constantinople, and as such he knew the CM and its use in the Byzantine liturgy in Hagia Sophia, for instance in the ceremonies of the Passion and the dead. So, because these initial tight cultural and religious connections, the CM was very likely known in the Abbey, and most probably it had been there since the beginning in places where it was needed for the ceremonies, i.e.

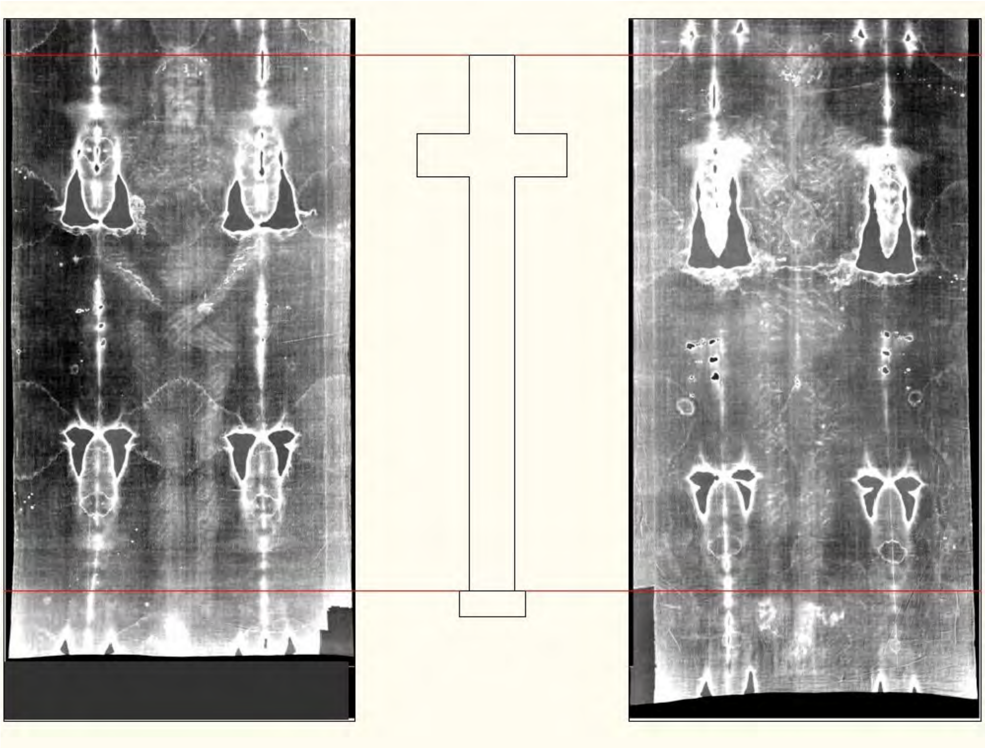

Figure 4. The CMG, center, and the negative photo of the body image front, left, and back, right, of the Shroud of Turin are reported in the same scale. The picture has been taken after the intervention on the Shroud in 2002, when its length was 441,5 cm [28, 29].

Narthex and cemetery. Its ascertained presence since the 19th and, very likely, 17th century in the wall of "Il Salvatorello", is a further proof of its use, because formerly in that place there had been the old cemetery of the Abbey reduced in time and finally moved elsewhere, but not the CM which is still there as a forgotten memory.

Anyway, the simple fact that a CM exists today in the Abbey of Grottaferrata is a proof that it was a well known religious object, which on the contrary was and is practically unknown in the Latin tradition. At this point it is worthwhile to remind that the Abbey of Grottaferrata was and still is a Byzantine island in a Latin sea. It is the opinion of the authors that the first modern Abbot, Giuseppe Cozza-Luzi, may have played an important role in realizing this brief recall of the CM at the end of the 19th century, which also concerned the Shroud of Turin. Indeed, the two hypotheses, H1 and H2, are both pregnant with consequences for the Shroud, as in the following.

According to H1, the CMG has been introduced in the Abbey in the 17th century by a monk of the Abbey or by an eminent visitor, who had an easy access to the Shroud of Turin and the dimensions of the body image of Christ. This fact could have happened only after 1353, or better after 1578.

According to H2, the CMG has been introduced in various forms (for specific functions) since the foundation of the Abbey or soon after in the Middle Ages, and it was moved to different premises following the many renovations performed during the centuries, until it landed in the 17th century where it is now.

In both hypotheses, the CMG and its liturgical functions have been completely forgotten in the Abbey soon after its inception up to nowadays, with the sole exception of a short revival at the end of the 19th century, when the Byzantine liturgy was revived.

So, as far as the Shroud of Turin is concerned, let us compare it with the CMG. Figure 4 shows an assembly of a high contrast picture of the said Shroud with the CMG. As expected, the body image is longer than the CMG but not that longer, because it should be taken in consideration that the length of the Shroud increased by several cm during his long history, especially after the intervention of 2002 [27,28,29].

Anyway, going back to the previous hypotheses, if H1 holds, it follows that the CMG is 178.4 cm tall as measured from the Shroud of Turin. On the other hand, the precious CM of Justinian was 180 cm tall. But Justinian measured the height of Christ from the Shroud, or a copy of it or other figurative document in Jerusalem in the 6th century, and therefore his measurement should equal that taken more recently from the Shroud of Turin.

If H2 holds, it follows that the CMG possesses the same height as the precious CM of Justinian which was modeled from the Shroud, or a copy of it or other figurative document in Jerusalem in the 6th century. But both have the same height as the body image in the Shroud of Turin today.

In conclusion, it results that the body image of the Shroud of Turin possesses the same dimension as that of the Shroud of Jerusalem, so that they may also be the same historical object. Moreover, the CMG gives also the width of the shoulders of Christ which is not reported in any other document existing today. Finally, the CMG may be the only surviving CM still existing in the world, which makes it a very precious historical object, although the material itself is not so precious.

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THE SUDARIUM OF OVIEDO

The Sudarium of Oviedo and the Shroud of Turin. A question of authenticity

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Abstract
The authenticity of the Sudarium of Oviedo and the Shroud of Turin is a complex issue that should be supported by a combination of medical and scientific analysis, and the evidence from anthropology, archeology and history. This paper describes how past research, and particularly the research related to the Sudarium of Oviedo, may contribute to give some answers related to the authenticity problem, but the results are still inconclusive. The use of new digital image processing techniques, quantitative color analysis and stains images matching methods can contribute to compare both cloths and solve some pending issues related to their authenticity.

Keywords: History, Forensic studies, Digital image processing and Image matching techniques.

1. INTRODUCTION

The Shroud of Turin is among the most known, controversial and enigmatic of the archeological artifacts. It shows the image of a tortured man. Various marks resembling wounds are visible on the body image. Areas having the characteristics of scorch marks and water marks are also identified.

Scientific research of the Shroud of Turin began in 1900 at the Sorbonne University under the direction of Yves Delage, professor of comparative anatomy. Additional tests have been performed on the Shroud by diverse scientific teams from Italy, USA and other countries. During the 1978 test program, members of Shroud of Turin Research Project (STURP) performed photographic imaging; visible, ultraviolet, and infrared (IR) spectroscopy; IR termography; x-ray fluorescence analysis; and x-radiographic imaging. They also collected microscopic samples for chemical testing. Details of these tests with results can be found in [9].

The Sudarium of Oviedo, kept in the Cathedral of Oviedo, north of Spain, is less known. The Sudarium is a small bloodstained piece of linen (84 x 53 cm), but no image appears on it. Scientific research of the Sudarium began in the mid 1960´s by Monsignor Giulio Ricci.

The Investigation Team from the Spanish Centre for Sindonology studied the Sudarium in Oviedo for the first time in November 1989 and several times in the nineties. Apart from studying the cloth as it appears to the naked eye, photographs were taken from various angles and distances, and with normal light as well as ultraviolet and infrared light. Samples of dust and pollen were taken, as well as small samples of the cloth itself.

Results of these studies and tests can be found in [7, 11]. The Sudarium of Oviedo is also as controversial and enigmatic as the Shroud of Turin because many people believe both cloths are relics related to Jesus of Nazareth passion and death.

The approach for the question of authenticity is a complex issue that should be supported by a combination of medical and scientific analysis, and the evidence from anthropology, archeology and history. This approach may be divided into three stages:

1. Establish that each cloth is a genuine cloth removed from a corpse.
2. Determine both cloths as belonging to a particular corpse.
3. Establish an association of both cloths with the historical person of Jesus of Nazareth.

The scope of this paper is to describe how past research of both cloths, and particularly the research related to the Sudarium of Oviedo, may contribute to give answers related to the problems issued in stage 1, and partially in stage 2 of the approach proposed above, but are inconclusive for establishing the association of both cloths with the historical person of Jesus, that is stage 3.

The comparative study of both cloths is a precondition for obtaining conclusive results. Particularly, the use of new digital image processing techniques, quantitative color analysis and stains images matching methods can contribute to establish the two cloths contacted the same body.

2. THE SUDARIUM OF OVIEDO

The Sudarium of Oviedo is kept at the Cathedral of Oviedo, north of Spain. The Sudarium is a small bloodstained piece of linen (84 x 53 cm), but no image appears on it.

Figure 1. The Sudarium of Oviedo.

The Sudarium's existence and presence in Oviedo is well attested since the eighth century and in Spain since the seventh century. Before these dates the location of the cloth is less certain.

The history of how this cloth reached Oviedo is well described by Mark Guscin [6]. He describes that most of the information comes from the twelfth century bishop of Oviedo, Pelagius (or Pelayo), whose historical works are the Book of the Testaments of Oviedo, and the Chronicon Regum Legionensium. According to this history, the Sudarium was in Palestine until shortly before the year 614, when Jerusalem was attacked and conquered by Chosroes II. It was taken away to avoid destruction in the invasion, first to Alexandria by the presbyter Philip, then across the north of Africa when Chosroes conquered Alexandria in 616. The Sudarium entered Spain through Cartagena, along with people who were fleeing from the Persians. The bishop of Ecija, Fulgentius, welcomed the refugees and the relics, and surrendered the chest, or ark, to Leandro, bishop of Seville. He took it to Seville, where it was for some years.The Sudarium was then taken further North to avoid destruction at the hands of the forces of Muslim Arabs and Berbers, who conquered the majority of the Iberian peninsula at the beginning of the eighth century. This possible itinerary is shown in Figure 2.

The Sudarium was first kept in a cave that is now called Monsacro, near Oviedo. King Alfonso II had a special chapel, called the "Cámara Santa” (Holy Chamber), that later was incorporated into the Oviedo cathedral.

The key date in the history of the Sudarium is the 14th March 1075, when the chest containing it was officially opened in the presence of King Alfonso VI. A list was made of the relics that were in the chest, and which included the Sudarium. In the year 1113, the chest was covered with silver plating, on which there is an inscription inviting all Christians to venerate this relic which contains the holy blood.

Figure 2. A proposed Sudarium itinerary.

The sudarium has been kept in the “Cámara Santa” where other important objects are hold. Amongst these are two crosses of immeasurable value. The first is the cross of Angels; a gift from King Alfonso II and the emblem of the city and the second is the cross of Victory, the symbol of the region with a deep story to its origin.

Figure 3. The “Cámara Santa”.

The Sudarium is mounted in a wooden frame sheathed in silver. The Sudarium is displayed to the public three times a year: Good Friday, the Feast of the Triumph of the Cross on 14 September, and Saint Matthew festivity, on the 21 of September.

3. SCIENTIFIC STUDIES ON THE SUDARIUM

Monsignor Giulio Ricci is considered to be the main contributor to the earlier studies of the Sudarium. In 1965 he compared for the first time the blood stains of the Sudarium and the Shroud of Turin. He published his results in the book: "L´Uomo della Sindone è Gesù", in 1969.

Max Frei took pollen samples of the cloth in 1979. He noted some coincidences and differences in the pollens found in the Sudarium and the Shroud of Turin [11].

Balma Bollone did the first blood studies of the Sudarium. Similar studies were later performed by Carlo Goldoni [11].

The author examined the Sudarium in 1984. He had a meeting in Danbury (CT), with Alan Adler in May 1986 for the identification of the most feasible sampling and testing techniques. After he sent some Sudarium photos to them. Unfortunately, we did not have the necessary financial support to continue the studies.

The Investigation Team from the Spanish Centre for Sindonology, named EDICES in Spanish, studied the Sudarium in Oviedo for the first time in November 1989 and several times later. Apart from studying the cloth as it appears to the naked eye, photographs were taken from various angles and distances, and with normal light as well as ultraviolet and infrared. Samples of dust, pollen and blood were taken, as well of minute samples of the cloth itself. The details of these studies are published in [7, 11]. For the sake of brevity, here we summarize some of the EDICES findings:

- They named the two sides of the cloth as Observe and Reverse, and the groups of stains as Observe Left and Right and Reverse Left and Right.
- The Oviedo Sudarium cloth is made of poor quality linen compare to the Shroud. The weave pattern called taffeta is perpendicular in wrap and weft (See Figure 4).

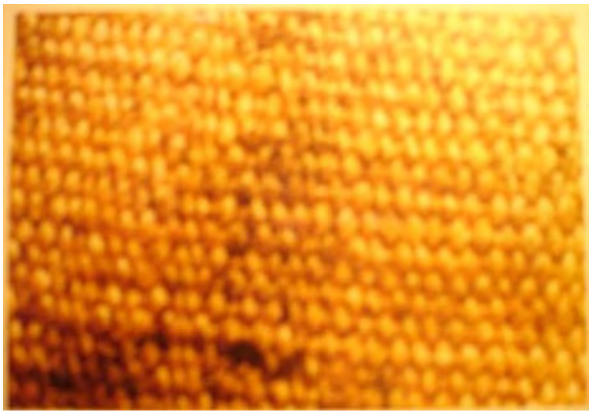

Figure 4. Weave pattern of the Sudarium.

- 30 types of pollen were found. Carmen Gomez from Complutense University in Madrid continued Max Frei´s work. She confirmed that there is pollen from Palestine present on the cloth (Quercus, Pistacia Palestina and Tamarix) [11]. But Maria Jose Iriarte own conclusions, presented at the 2st International Congress on the Sudarium of Oviedo, were quite different, stating that she was not able to identify pollen that could pin the Sudarium down to any given geographical location.
- The Sudarium is dirty and burnt in parts, stained and highly contaminated. According to EDICES microscopic observation there is no doubt which area of the cloth was in direct contact with the face of the corpse. This area is called by them the "Reverse Left" side. There is much more haematic substance in this cloth side than any other.
- The main Sudarium stains consist of one part of blood and six parts of pulmonary edema fluid. The central group of stains are superimposed on each other (See Figure 1).
- Professor of Forensic Medicine at the University of Valencia, José D. Villalain and EDICES member, was able to simulate the fluid coming out the corpse and to estimate the time elapsed between the formation of each superimposed stain by reproducing the mixture of blood and the fluid from the edema, and having a specially modeled head to recreate the flow of this fluid (See Figure 5).

Figure 5. Specially modeled head for fluid flow simulation.

- The Sudarium wrapped the head of a dead and tortured man. The cloth was placed over the head starting from the back, held to the hair by sharp objects.
- Once the man had died, he stayed in a vertical position for around one hour. His body was then placed on the ground on its right side. The forehead was placed on a hard surface and the body left in this position from approximately one more hour.
- His body was then moved, while some of the persons transporting the corpse, left his hand in various positions trying to stem the flood of liquid from the corpse's nose and mouth. The corpse movement could have taken about 5 minutes.

- Finally, on reaching the destination, for unknown reasons, the cloth was taken off the head.
- The man's death is compatible with crucifixion and the wounds inflicted before death as they are observed on the Shroud of Turin.

4. COMPARISON STUDIES

Since blood stains are the main feature of the Sudarium (See Figure 1), the comparison studies to relate it to the Shroud are mainly focused in the blood stains comparison based on the identification of forensic, chemical and geometrical correspondences.

The blood is human and of the AB group on both cloths.

The size of the stains is geometrically compatible considering their relative position in each cloth (see Figure 6).

Figure 6. Blood stains correspondence (from Centro Español de Sindonología).

Considering forensic studies of how stains are produced in both cloths, it is necessary to mention that stains do not necessarily have to match on a flat surface.

The stains formed by blood shed in life seem the same on each cloth. The stains occupy the positions predictable from the image formation of the Shroud.

There are coincidences between anatomical elements of the Sudarium and the man of the Shroud as presented in Table 1.

TABLE 1. Anatomical correspondences

Element	Sudarium	Shroud
Total area of the	2280,00 mm^2	2000,00 mm^2
Swelling on the right side of the nose	100 mm^2	90,00 mm^2

Possibly myrrh and aloes were sprinkled over both cloths [11].

It seems a sample from the Sudarium was carbon-dated around 700 AD [6]. As it is well known, the Shroud samples were carbon-dated 1260-1390 AD. These are controversial results that need additional research.

Attempts to identify nuclear DNA on the Sudarium were unsuccessful. However the Antonio Alonso team from the National Institute of Toxicology and Forensic Sciences, located in Madrid (Spain), was able to identify a human mitochondrial DNA.

A Whanger and M. Whanger applied the polarized image overlay technique as a comparison method for stains in the Shroud and the Sudarium. They applied this technique some years ago to compare the Shroud with old icons of Jesus [14].

They applied this technique to the Sudarium, comparing it to the blood stains on the Shroud of Turin. It seems they found seventy points of coincidence for frontal stains and fifty for the rear side [6]. The validation of these results is needed to consider them firm. The image matching methods proposed below may contribute to the validation of these results.

Nello Balossino photographically scanned the Sudarium in November 2006. He presented some results at The Second International Conference on the Sudarium of Oviedo [3]. They scanned images directly from the Sudarium in A3 format with different resolution: 300, 600 and 1200 dpi, and 16 bit color depth for either channel Red, Green and Blue. They obtained the components HSL (Hue, Saturation and Luminance) from the Sudarium. They showed an example of 2D superimposition (with different kind of pseudocolor) giving evidence that there is some mapping area belonging to the Sudarium and the Shroud.

The testing and analysis of the last few years, summarized here for the Sudarium and elsewhere for the Shroud [9], goes further in demonstrating that both cloths are genuine burial cloths from antiquity rather than the result of a medieval forger. But further studies should be conducted by coordinated and multidisciplinary international teams. Those studies would be directed towards comparing quantitatively blood stains features, forensic studies, chemical properties, pollen, historical documents and other research issues of interest.

5. A PROPOSAL OF NEW COMPARISON STUDIES

The comparative study of both cloths is a precondition for establishing an association of both cloths with the same person. Particularly, the use of some non-intrusive digital image processing techniques, quantitative color analysis and stains images matching methods can contribute to the realization of the authenticity approach described in the introduction.

Digital image processing, that is the manipulation of images by computer, has been applied in practically every type of imagery [4]. Digital image processing basically requires a computer upon which to process images. In addition, as seen in Figure 7, the system must have two pieces of special input/output equipment, an image digitizer, currently a scanner, and an image display device.

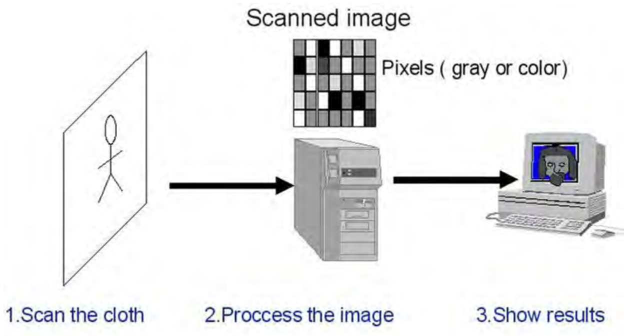

Figure 7. A digital image processing system.

Here in figure 7, we realize that a cloth can be scanned directly since it has been done nowadays for the Shroud and the Sudarium as mentioned above. This approach avoids the use of photographs with the particularities of the photographic film that are particularly evident in the tonal distortion of the image of the Enrie photographs taken in 1931. In the late seventies, Shroud photographs were scanned using a microdensitometer [8], a precision instrument able to read minute changes in image intensity, doing this by measuring the amount of light able to be transmitted through the image from point to point. The density value of each checkerboard square is known as a pixel (picture element). Currently, we use scanners that may be hand-held, flatbed or drum. Scanners are devices that optically scan images or text and convert it to a digital image, see step 1 of Figure 7. Modern scanners typically use a charge-coupled device (CCD) or a Contact Image Sensor (CIS) as the image sensor.

Processing an image, as seen in Figure 7, starts with one image, here the scanned image, and produces a modified version of that image, that may be presented in a display. The term digital image analysis is taken to mean a process that transforms a digital image into something other than an image, such as a set of measurement data or a decision [4]. The term digital image processing is loosely used to cover both processing and analysis.

Since the earlier work by Avis et al [1] and Tamburelli [13], diverse digital image processing techniques have been used and proposed for the Shroud. Some are mentioned here: simple contrast enhancements, spatial and spectral filters, geometric transformations, color enhancements, false color representation, simulations, image classification, quantitative comparison of images and quantitative color analysis.

A very promising and recent work regarding quantitative analysis of the Shroud image has been presented at the Ohio Conference by R.J. Schneider [12]. He used images taken by Barry Schwortz in 1978 and Durante in 2000, and known software tools such as Adobe Photoshop Elements, Python PIL, Matlab Image Processing Toolbox, CVI Ptools and Image J. He compared the same regions of different Shroud images. The problem to be solved was related to what is called image segmentation, involving the partitioning of image into regions and distinguishing from one another different elements in the Shroud that area cloth banding, image, blood, scorch and others. He converted a full range Shroud image to an indexed image with far fewer colors and applied contrast stretching of the separated color unit vectors. This processing seems to give a good segmentation of the main categories of interest. Considering the results, he proposes to explore the application of statistics taken from different image categories and seek to create a pixel classification algorithm that would automatically assign pixels to categories (blood, cloth, image) by their relation to the criteria [12].

Considering the similarities in the blood stains present in the Sudarium and in the Shroud but taking into account that the same face can produce different stains, especially in different cloths, and different faces can produce similar stains, the comparison of blood stains in both cloths is still an open issue.

Quantitative approaches for image segmentation such as the Schneider approach mentioned above, can give more objective results for blood stains comparison of the Shroud and the Sudarium than some subjective comparisons applied in earlier studies. Subjective comparisons may be biased by our visual perception system and brain interpretation. Some images of Mars, as the one presented in Figure 8 are illustrative of how subjective interpretation of images can produce misleading results.

Figure 8. A face on Mars surface?

Images matching methods can be classified as area based, feature based or symbolic. Area based methods use numerical comparison of digital numbers in subarrays from each of the images to perform the matching.

Feature-based methods involve the features extraction with subsequent comparison based on feature characteristic. Symbolic methods are hybrid solutions that involve some combination of area based and feature based approaches [2].

Feature-based methods of images comparison consist of the following three steps: feature extraction, feature matching and transform model estimation [15]. Identifying image features that are invariant to image scaling, rotation and partially invariant to changes in illumination is an important issue for the comparison of the Shroud and Sudarium blood stains. It would seem that a set of parameters that gave nearly the same scaling, orientation and translation for multiple features, which be a very confirming issue that the two cloths had derived their markings by, contact with the same body and configuration of blood stains. Also it is important to realize that cloths have different weave patterns, the Shroud has a herringbone pattern and the Sudarium as mentioned above has a taffeta pattern.

Conventional image features are broadly classified into three types: salient points, lines and regions in the image. Corners may be used as features in some images. Line features can be the representation of general line segments in given images and object contours. Region features can be used to detect the projection of high contrast closed-boundary regions and patterns [15].

The approaches described above, lead the author to propose the quantitative comparison of Sudarium and Shroud blood stains using digital image processing techniques and following these steps:

1. Propose the candidate features to extract from the blood stains images.
2. Extract the features from Sudarium, Shroud and blood stained control cloths.
3. Feature matching.
4. Make a firm connection between the two cloths to show that they covered the same body.

Another interesting technology that combines digital imaging techniques with common spectroscopic methods is called hyperspectral imaging technology, currently limited to 100 × 100 mm^2 maximum field of view [5].

Hyperspectral image technology was used to analyze some of the stained bills, which had been recovered from the suspects, as well as bills collected from the victims' home with similar stains. Hyperspectral images and associated spectra determined that the stains on the currency from the victims' home appeared to have the same optical properties under these specific lighting conditions in comparison to the stains on the currency seized from the suspects. Based on this information, the expert witness testified that there was no discernable difference in appearance and behavior between any of the stained bills obtained as evidence, which was consistent with the possibility that the bills originated from a common source. This information was included in the report that was admitted as evidence submitted and accepted in the trial [5].

6. CONCLUSIONS

As mentioned by the archeologist professor W. Meacham's: *Current opinion in Shroud authenticity ranges generally from "probable" to "proven" for stage 1 and from "possible" to "probable" for stage 2* (stage 3 in the approach presented here). *For a variety of reasons, not the least of which the fact the object is a religious relic, these opinions seem to err on the side of the cautious place, undue emphasis on negative evidence and are based on an assumption that the identity of the Shroud man is "unprovable"* [10].

Quantitative comparative analysis of blood stains for both cloths can be a contributing input for the answer to stages 2 and 3 of the authenticity question. Scanned files of both cloths are already available. It is out of the scope of this paper to describe the protocol to be used for the quantitative comparative analysis of the blood stains but to give some recommendations from the point of view of digital image processing techniques.

Most computer science methods of determining a matching between two images consist of feature extraction and feature matching. It is important to identify qualitative and quantitative features valid for the blood stains on both cloths. Features invariant to rotation, translation or scaling should be an important comparison issue.

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FORENSIC MEDICINE

Medical and forensic aspects of the Man depicted on the Turin Shroud

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Abstract

Selected medical problems of the crucified Turin Shroud Man are endeavored solved by help of disciplines within traumatology and forensic medicine. Traumata of nose, knee and chest are pointed out in order to describe the injuries from an empirical background. The possible sequelae of flogging the thorax are investigated. Additionally, the red color of blood and the formation of the specific "ε"-shaped blood flow are described by experiments.

Keywords: Shroud, nose displacement, hemarthrosis, flogging, blood color.

1. INTRODUCTION

Several medical specialists have described the injuries of the Turin Shroud Man (TSM) depicted on The Turin Shroud (TS) since it was first photographed in 1898.

The specialties count forensic medicine, pathology, hematology and several other disciplines. Additionally, the blood has been analyzed by chemists.

Direct observation on the cloth, blood sample analyses, Shroud photo scrutinizing, experiments with bodies and living persons fixed on crosses have let to important physiological results relating to the sufferings and cause of death of the man on the Shroud. However, the interpretation of results and subsequent conclusions in some cases point in different directions.

The author has as a general practitioner treated many acute human body injuries. The experience obtained from these cases has special interest for some areas of TSM research, i.e. nose, knee, chest injuries and blood flow from wounds.

Relating to the bright red blood color the claimed cause of redness of the TSM blood has been tested.

In the following there will be dealt with nose, knee, chest and blood of the TSM.

2. EXPERIMENTAL

NOSE. At the distal part of the TSM nose an irregular, black cross line can be observed, often diagnosed as a nose bone fracture.

However, the underlying tissue of this area is cartilage and out of proximal area of the nose bone. If a line is drawn following the bridge of the nose - starting from the horizontal level of the eyebrows and downwards - a slight displacement to the right of the distal third part is observed, beginning at the cross line (fig. 1).

For a physician this indicates a dislocation of individual nose cartilage pieces, most prominent the septal cartilage (fig. 2).

A blow hitting the nose or a bump against a hard surface causes this kind of injury and often makes the nose wry.

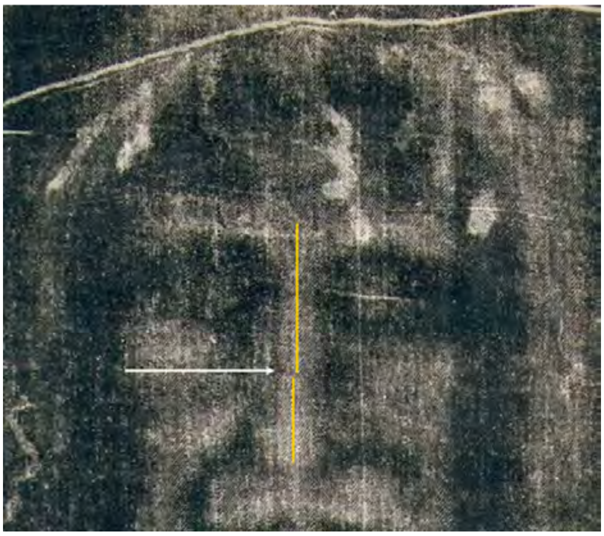

Figure 1. Displacement of distal part of the nose to the right. Arrow indicates outline jump at the distal cross line. © Niels Svensson.

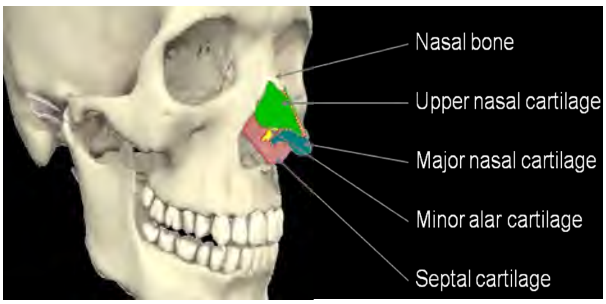

Figure 2. Nose cartilage pieces. © Niels Svensson.

KNEE. Proximal to the knee cap of the anatomically right knee of the TSM a swelling seems to show up (fig. 3). If such a swelling comes up shortly after a bump of the knee cap against a hard surface, an x-ray photo often reveals a knee cap fracture. The bleeding fills the articular capsule of the knee joint and causes a well known swelling around and proximal to the cap, hemarthrosis (see fig. 4). Therefore the TSM has most likely got a knee cap fracture simply by knocking his right knee against a hard surface.

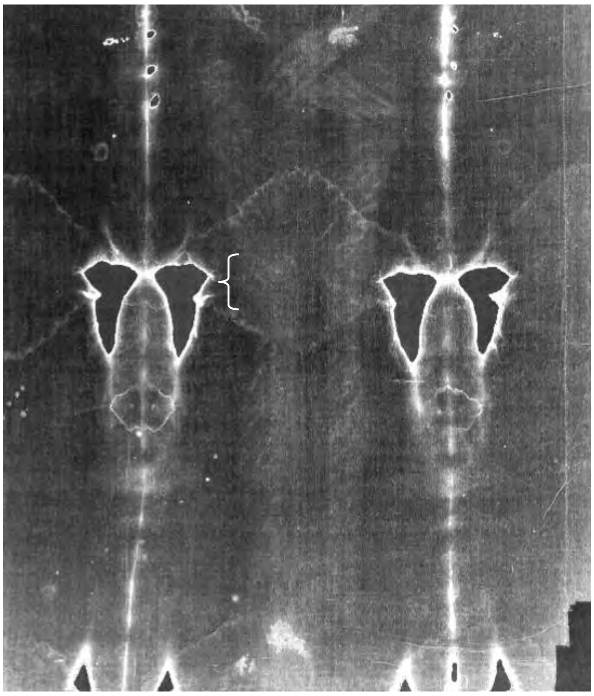

Figure 3. Swelling of the right knee region possibly due to hemarthrosis, the region indicated by " { ".

Figure 4. Fresh right knee cap fracture. Dotted white line indicates the knee cap outline; dotted black, hemarthrosis. © Niels Svensson.

CHEST. In an article from Journal of the American Medical Association (JAMA) [1] the draughtsman has on the TSM shown violent bleeding from lacerations, which means torn skin and tissue with massive bleeding (see fig. 5a). But apparently, this is not what happens by scourging with a Roman flagrum with two or more leather straps ending in dumb bell formed, heavy lead objects. Instead it might cause excoriations on the skin surface with punctual bleeding (fig. 5b) confirmed by the main wound imprints on the back of the TSM (fig. 6a and 6b).

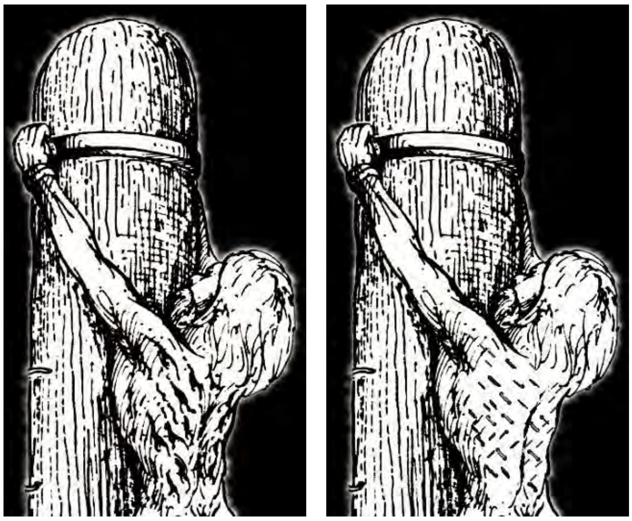

Figure 5a and 5b. Left: part of the original JAMA drawing with wound lacerations. © MAYO 1985. Right: same drawing, but changed to excoriations by the author as reflected on the TS.

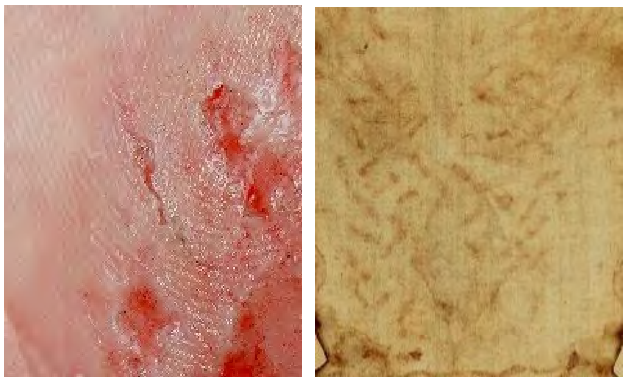

Figure 6a and 6b. Left: excoriations of skin. Right: the excoriations of the TSM back (inversed). © ODPF.

The impact of the heavy lead objects concerns structures under the skin such as hematoma (bruise) in connective and muscle tissue, rib fracture and lung injury [2]. The considerable power of the lead object left on a rib is dependent on the speed and angle of the object relative to the rib and can as a consequence cause rib fracture (fig. 7a). The sharp ends of a fractured rib are able to damage intercostal veins and arteries during respiration followed

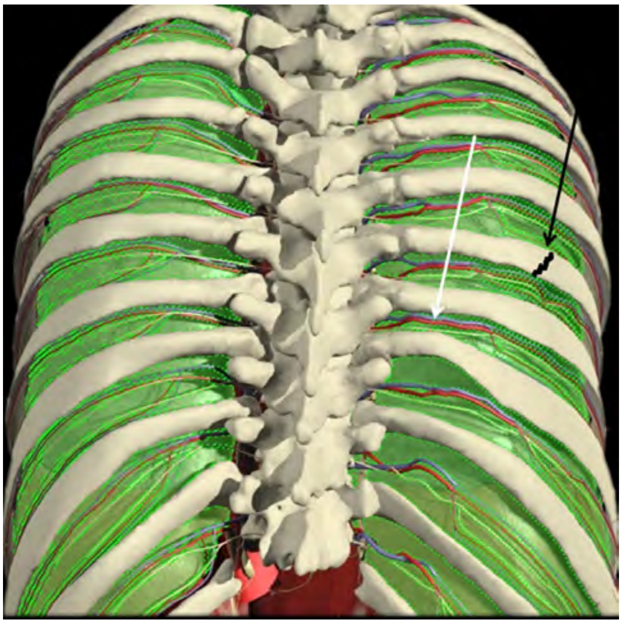

Figure 7a. Back view of the thorax. White arrow points to the intercostal vein and artery, the black to a rib fracture. The lung sac (green) covers the inside of the thorax. © Niels Svensson.

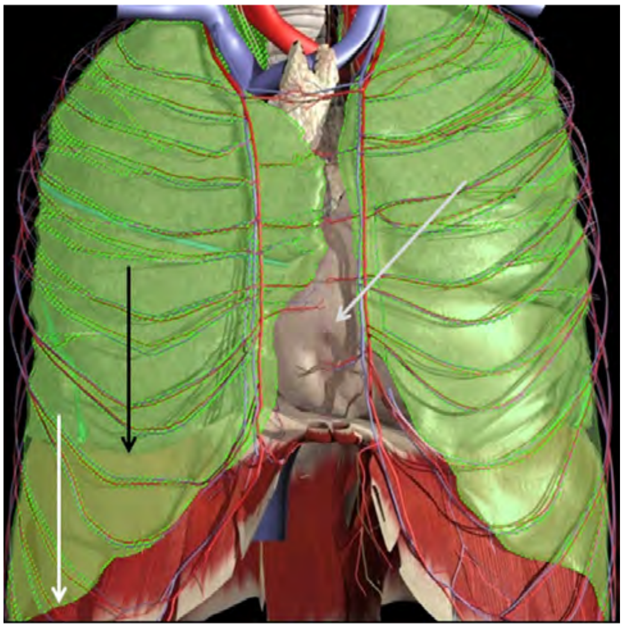

Figure 7b. Front view of the thorax (ribs removed). White arrow marks lower border of the right lung sac, black the lower border of the lung and grey arrow the heart sac. © Niels Svensson.

by bleeding into a damaged lung sac (fig. 7b), a common condition in emergency practice known as hemothorax (figures 8a and 8b). One part of the lung sac is widely outstretched behind the chest ribs, the other covers the lungs. In between is vacuum. The sharp fractured ribs may partly cause insufflation of air and bleeding into the sac. Both conditions may cause full or partly lung collapse.

If the individual dies, the postmortem blood in the lung sac will during approximately half to one hour - due to gravity - separate into two layers, i.e. the serum layer and the underlying dense blood corpuscle layer. This sequence can be demonstrated by fresh taken blood in a test tube, where the blood separates into two layers (fig. 8a). Apparently, this was what happened to Jesus after his death on the cross as the Gospel of John underlines by eyewitness (John 20.34). When a lance is thrusted into the lower area of the lung sac (fig. 8b), it is expected that the blood and serum pour out of the wound like "blood and water" - and in this succession running downwards. The large side wound of the TSM with blood running out in cascades to the right side of the chest and to the small of the back points to the lung sac as its origin.

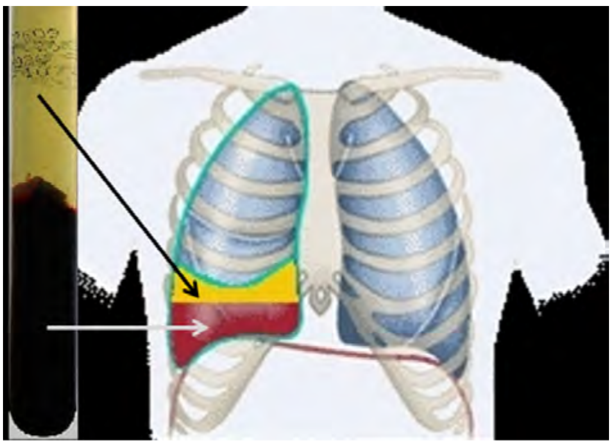

Figure 8a. Left: a test tube with blood one hour after sampling. The blood has separated into serum and blood corpuscle layers. This separation of whole blood also takes place after death in the lung sac, if the body is placed upright (right). © Niels Svensson.

Figure 8b. The side wound of the TSM (inversed) has been superimposed figure 8a in order to show the anatomic place of the wound. A lancea shows the place and direction of the thrust. The blood will pour out in cascades. © Niels Svensson.

BLOOD. It is well known, that blood darkens from red to black in few days due to oxidation processes. Shroud researchers have long wondered why the TSM blood is still red bearing in mind the TS assumed age of 2000 years (fig. 9). The image forming mechanism has been put forward as a possible conservation factor [4]. Also chemical action on blood has been tested. Diane Soran tested in 1977 the hemolytic effect on red blood cells by a soap weed (Saponaria Officinalis) washed cloth. The blood was still red after 26 years in 2003 [5]. Alan Adler suggested that it was the high concentration of bilirubin in the TSM blood that was responsible for preserving the red color of the blood [6]. This hypothesis has been tested by Goldoni et al. [7]. Bilirubin (conjugated or non-conjugated) is the yellow breakdown product of heme in hemoglobin, a principal component of red blood cells.

The author has tested the Adler statement by comparing an individual with four times the upper normal level concentration of serum bilirubin (A) to an individual with normal values (B). The high bilirubin concentration makes the skin and the white in the eyes yellow-brown, icterus (jaundice). The reference interval of bilirubin in normal human individuals is 5-25 μmol/l and that of hemoglobin 7,1-9,3 mmol/l.

Test person A: 45 years. Bilirubin: 98 μmol/l. Hemoglobin: 7,4 mmol/l. Jaundice for several months, toxic liver failure.

Test person B: 67 years. Bilirubin: 6 μmol/l. Hemoglobin: 7,9 mmol/l.

The two test persons differ slightly in hemoglobin concentration 7,4 versus 7,9 mmol/l, an insignificant difference, whereas the A bilirubin concentration is more than 16 times the B, a huge significant difference (fig. 10). Blood samples were taken at the same time, dripped on a piece of linen and compared over time by sense of sight and photography color test: day zero (fig. 11), one day, one week (fig. 12), two weeks, one month and four months (fig. 13). During this time the stains have been exposed partially to sunlight, partially overcast, but most of the time hidden away from light in a dark drawer at room temperature and a rather dry atmosphere.

Figure 9. Microphoto of blood stain from the small of the back. Note the red color. © 1978 Mark Evans Collection, STERA, Inc.

Figure 10. Two test tubes showing separated blood. Left: test person A, high bilirubin concentration causes yellow/brown serum. Right: test person B, normal bilirubin concentration causes pale yellow serum. © Niels Svensson.

Figure 11. Two blood stains photographed immediately after sampling and dripping on linen cloth. Left: test person A, right: test person B. © Niels Svensson.

Figure 12. Same as figure 11, after one week. A considerable color change has taken place. © Niels Svensson.

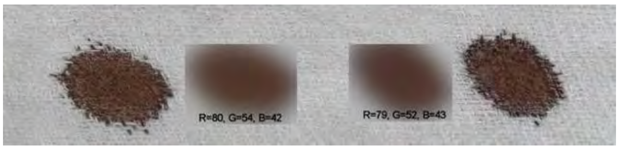

Figure 13. Same as figure 11, after four months. The stains have been blurred (middle section) in order to measure the average RGB values at the center of the blurred stains. © Niels Svensson.

After four months no significant color difference of A and B was observed. The red/green/blue (RGB) values of the photos of the blood were measured by blurring the stains and afterwards measuring in the center of the stains (fig. 13 and table 1).

TABLE 1.

	Red	Green	Blue
Person A	80	54	42
Person B	79	52	43

From the interpretation of the figures it follows that in the short run (months) high bilirubin concentration has no significant influence on the color of human blood on linen cloth, and therefore, presumably, neither in the long run (years).

It must be added, that the high level of bilirubin (test person A) is mainly composed of conjugated bilirubin while in Adler's hypothesis the main part of the bilirubin might be non-conjugated or free bilirubin. It is certainly very difficult to find blood samples with high levels of free bilirubin. If possible, future experiments should be done with free bilirubin to detect potential differences.

THE "ε"-SHAPED BLOOD TRICKLE. The TSM has a characteristic blood trickle above the anatomical left eyebrow (fig. 14), the so called epsilon, "ε" (the photographical positive image) or figure "3" (the photographical negative image). Shroud literature often claims that the curved (meandering) run of this rivulet is caused by wrinkles/furrows of the forehead. The furrows come up because the man is in agony. The author tested this hypothesis by dripping some drops of his own blood on his furrowed forehead - the head in vertical position - and found by several repetitions that the blood ran straight down to the bony projection of the eyebrow without curving (fig. 15).

Figure 14. The characteristic figure "3" above the left eyebrow of the TSM (white arrow).

Figure 15. Fresh blood dripped above the left eyebrow, the head still. The blood runs down in a straight line. © Niels Svensson.

Figure 16. By tilting the head slowly to the right and left the blood takes a curved, meandering run. © Niels Svensson.

If the head instead is tilted to the left and right during the blood run, the curved, meandering blood rivulet shows up (fig. 16). Once the rivulet is first formed then the outpouring blood continues to follow the path. Of course the individual furrow pattern influences the flow pattern, but surprisingly the head movement seems to be an additional and substantial curving factor.

3. CONCLUSIONS

From experience of emergency medicine and performed experiments the following can be concluded concerning selected injuries on the Turin Shroud Man:

NOSE. The nose is slightly displaced to the right due to nose cartilage displacement.

KNEE. The swelling of the right knee is most likely due to a knee cap fracture.

CHEST. The cascades of blood from the right side wound emerge from postmortem, separated blood in the lung sac.

BLOOD. The red color of the TSM blood seems not due to high bilirubin concentration.

THE "ε"-SHAPED BLOOD TRICKLE. The "ε" or figure "3" blood rivulet formation seems, apart from forehead furrows, due to different positions of the head.

ACKNOWLEDGMENTS

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Turin Shroud: a medical forensic study of its blood marks and image

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Abstract
From extensive analytical studies of the Shroud of Turin we know that the image is not man-made, and from medical forensic studies of the blood marks we know that a crucified man was laid out on his back and wrapped in this cloth. But the question still remains as to what caused the shroud image. A forensic evaluation of the blood marks and a study of the effect of gravity on surface anatomy suggest that a natural event is not the most probable cause of shroud image formation.

Keyword: forensic, blood, image, gravity.

1. INTRODUCTION

The Shroud of Turin, a cloth made of flax, is approximately 14.7 feet long by 3.7 feet wide and contains the blood marks of a crucified man that correspond anatomically to frontal and dorsal negative images of a naked man seen on this cloth [1, 2]. What caused the shroud image has been the subject of much discussion.

The objective of this paper is to decide experimentally if the cause of the image - the image forming event - was a man-made, a natural, or a supernatural event. It is through science, an organized body of knowledge, that we study cause and effect. Many theories (man-made, natural, and supernatural) of image formation have been postulated since the 1350's. At this point, the three categories of cause being investigated should be made clear. (1) A man-made event defines itself. (2) A natural event is one that can be understood or defined through our ordinary understanding of space and time. (3) A supernatural event (one that is not attributable to natural forces [3]) is one that cannot be understood nor defined through our ordinary understanding of space and time.

Shroud scientific literature, medical forensic evaluation of the blood marks, and effect of gravity on surface anatomy are presented in order to better understand the available data and resolve the question of image formation.

2. METHODOLOGY

Method I. Shroud scientific literature was reviewed. **Method II.** Medical forensic evaluation of physical findings related to the trauma contributing to the death of the victim, and medical evaluation of gravity's effect on body form were made. The data collected from these medical studies was organized under the following headings: ***(A) Medical forensic evaluation of two blood mark studies*** *and* ***(B) Medical evaluation of gravity's effect on the surface anatomy of the body.***

3. RESULTS

I. Shroud Literature Review

From chemical and medical forensic studies of the blood marks, we know that a scourged, crucified man with head wounds and a wound to the chest was laid out supine (on his back) and wrapped in this cloth. Blood mark formation occurred when moist blood clots and post-mortem blood simply soaked into the cloth. The transfer of blood from the body to cloth was a contact process and was a natural event [4, 5, 6]. Under the blood marks there is no image. This information tells us that the blood came first and prevented image formation wherever it was on the cloth. Therefore, the **first event** was the formation of the blood marks and the **second event** was image formation [7].

From extensive analytical studies of the image, we know that the image is not caused by paint, stains or dyes [8, 9], and it falls into no known artistic category [10]. It is the yellowed linen fibers (~15 microns in diameter) composed of cellulose that produce the image [11]. Heat, light, and acid can produce this yellowing of linen fibers; the image is the result of a chemical change in the cellulose itself. Most important, the image producing fibers penetrate the fabric only one fiber deep [12]. No one as yet has been able to reproduce the image at this microscopic level. It is unique in the world.

From the information presently available it is evident that the image is not man-made. With regard to the questions, was image formation a natural event or a supernatural event, there are many theories available in the literature, including those that postulate that this is the burial cloth of Jesus. However, no study adequately resolves the issue. The following medical studies address these questions.

II. Medical Evaluations

Please note: for the sake of orientation, the body of a crucified man was placed in the supine position (on his back) on one end of this long cloth and the other end covered the front of the body.

(A) Medical forensic evaluation of two blood mark studies.

Studies of the blood marks demonstrate how an end of this long cloth was draped over the front of the supine body of a crucified man. The cloth was sufficiently wrapped to allow it to absorb the moist blood clots that were on the body. The following two blood mark studies illustrate the cloth-to-body drape and the complexity of frontal image formation.

Blood mark study 1. Blood off the elbow.

Figure 1 shows the off-image blood mark at the left elbow of the image.

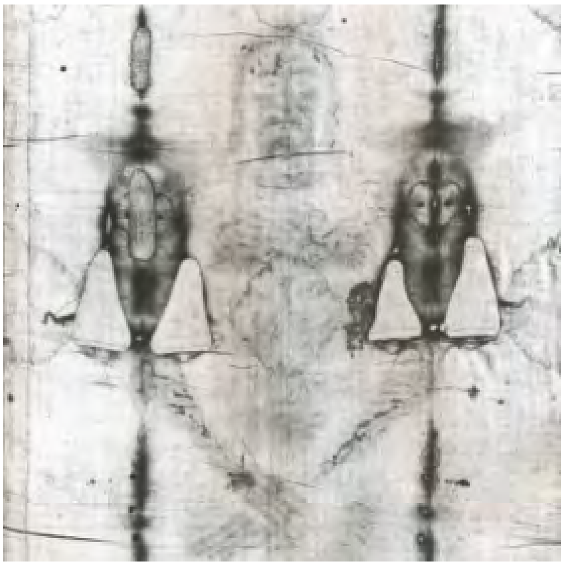

Figure 1. Off-image blood mark.

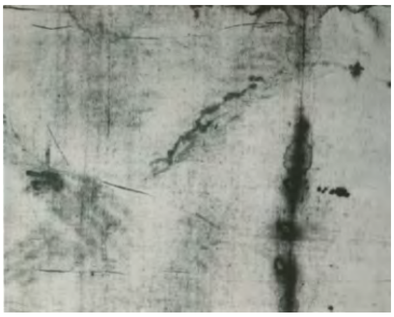

Figure 2. Close up of the off-image blood mark.

Figure 2 is a close up of the same. Note that there is no image here. Figure 3 shows that tracing paper was placed over the image, and the blood mark was traced onto the paper. Figure 4 highlights a person draped by the tracing paper from a frontal view. From this view the off-image blood mark cannot be seen.

Figure 3. Blood flow on tracing paper.

Figure 4. Frontal view drape.

Figure 5. Side view drape.

Figure 6. Shows how the blood flowed.

Figure 5 shows the tracing paper draping to the side of the volunteer's body. The shroud cloth was sufficiently tucked at the side of the body to soak up the moist blood clot that was at the back of the upper arm. Figure 6 shows that the blood flowed from the wrist, down the arm and around the elbow, and pooled at the back of the upper arm, and then dripped to the ground [13, 14].

What is the significance of the off-image blood mark?

(a) The blood mark is a contact process that occurred when the cloth came in contact with the moist blood clot at the back of the upper arm. (b) All the other blood marks tell us something about the first two dimensions, that of height and width. But this blood mark gives us the third dimension: that of depth. It tells us that this cloth draped around a three-dimensional man who was crucified. (c) The image is not a contact process because we know that the cloth came in contact with the back of the upper arm, but there is no image present. (d) Any proposed natural form of energy or organic substance emanating from a body would come from the whole body, and not just from its anterior and posterior surfaces. We know, because of the off-image blood mark, that the cloth was in intimate contact with the back of the upper arm – a lateral surface. In a natural event we would expect to see the image of the back of the upper arm, which would of course distort the frontal view. But no image was formed here which indicates that image formation was probably not a natural event, and suggests that it was intentionally driven.

Blood mark study 2. Blood on the Face.

Figure 7 shows the positive facial image of the shroud, showing that the blood marks are in the hair.

Figure 7. Blood marks in the hair.

Figure 8 is a cutout of the blood marks from the shroud face.

Figure 8. Cutout of the blood marks.

Figure 9 shows the face of the supine volunteer. Figure 10 shows the cutout draped over the volunteer. The cutouts were then filled in with paint. Figure 11 shows that the blood marks originated from the face and not the hair. Figure 12 shows that the blood marks were originally on the temples and cheeks of the man draped by the cloth; however, in image formation the blood marks ended up in the hair (See Figure 7) [15, 16].

Figure 9. Face of supine volunteer.

Figure 10. Cutout draped and filled with paint.

Figure 11. Blood marks originated from the face and not the hair.

Figure 12. In image formation the blood marks ended up in the hair.

What is the significance of the blood originating from the face and not the hair? (a) As with the off-image blood mark at the elbow, the shroud cloth draped over a three-dimensional body. The blood soaked into the cloth from the moist clots on the temples and cheeks. Once the image was formed, the blood marks that originated from the temples and cheeks are now seen in the hair that falls along the sides of the facial image. (b) The only way to understand how the blood marks on the face (temples and cheeks) moved out into the hair is to imagine that the cloth moved into a flattened position during image transfer. (c) There is no known natural event that can explain image formation of the face.

(B) ***Medical evaluation of gravity's effect on the surface anatomy of the body.***

Before we begin the **Gravity study** it is important to understand that when we are looking at the shroud image, we are looking at two separate events: the **first event**, the blood marks and the **second event**, the image. We will start by attempting to understand what we see when we look at the image. Why do we see this 3-dimensional figure on a 2-dimensional (flat) surface? From an artistic or photographic perspective, an image's form is dependent on variation of value. Variation of value is the variation of shading that causes the eye to decipher form. Figure 13 shows the figures of a rectangle and a cylinder. On the right we have a rectangle that has no form because it contains only one shade of grey. On the left we have a cylinder that has form because it has many shades of grey from white to black. More specifically, the rectangle on the right is flat. It is two dimensional with no depth. It has no form because the entire surface has the same shading. The cylinder on the left looks like a three-dimensional cylinder because it has variation of shading.

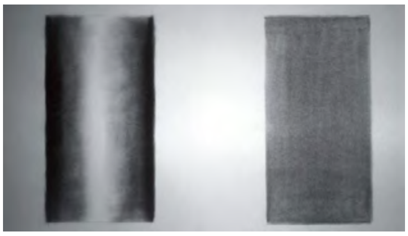

Figure 13. A cylinder and a rectangle.

Next, we need to better understand what we see when we look at the **first event**, the blood marks. Moist blood clots and their accompanying serum exudates soaked into the cloth by contact. The blood marks are simply flat areas as is seen in the flat rectangle. We also know that blood prevented image formation [7]. The more blood on the cloth, the less the image is seen on the cloth, gradually moving on a scale from full image (little to no blood) to some image (more blood) to no image (much blood). In this paper we will use the term masking which means that the image is prevented from forming depending on the amount of blood on the cloth. With this background we can better understand the shroud image that we are viewing.

Now we will study the effect of gravity on the human body in relation to body position and then compare it to the shroud image.

Gravity study. Upright man.

By studying the effect of gravity at the surface contact points of a body lying in the supine position (on his back), we understand how body weight affects anatomic form. From the following study we can appreciate the complexity of dorsal image formation.

Figure 14 is a drawing of a male volunteer who has the anatomic form that we would expect to see of someone in the upright position.

Figure 14. Volunteer in upright position.

Figure 15. Lying on his back on glass.

Figure 15 is this same man now lying on his back on a large plate of glass and we are looking at him from below. The weight of his body has flattened his backside and there are areas of the back and buttocks and calves that have lost their roundness from when he was standing. The flat areas are similar to the flat rectangle that has no form. You would see this same loss of body form if you were to examine bodies in an autopsy room. Note the change of hair position from the upright position to the supine position. In the supine position the weight of the body against the hair caused it to flatten. The hair will be further discussed below.

Figure 16. Positive dorsal shroud image (back lighting).

Figure 16 is the back of the shroud image. When looking at this image we will consider it from the point of view of two events. The blood marks **(first event)** are consistent with that of a man who was laid out in the supine position of burial. More than simply documenting the wounds and the blood flows of postmortem blood, the blood marks document body flattening. The blood marks at the area of the buttocks best demonstrate the expected flattening that is seen in Figure 15. Areas of blood at the calves of the legs and parts of the upper back suggest the same. Now the body image (**second event**) is best visualized by back lighting the full size photograph which helps to elucidate the form of the back image. Parts of the back image have been masked by the blood marks (**first event**). As mentioned earlier, the more blood on the cloth, the less image is seen on the cloth. Prime examples of this masking are the right foot and top of the head which show almost no image. With careful observation one can also make out areas where the blood subtlety masks the image and no form is observed; for example, see the partial masking of both calves and the buttocks, more on the right than on the left. Where there is less blood, the image (**second event**) is visible and reveals its form. The image of Figure 16 does not have the flattening that is seen in Figure 15. Rather, the form of the shroud image resembles the form that is seen on the upright volunteer of Figure 14.

Figure 17 now considers the hair, showing a long-haired young woman lying supine. The hair falls to the ground. What if the hair were mixed with blood, oil, or sweat? This may stiffen hair but the added *weight combined with the length* of the hair would simply react to the force of gravity and cause the hair to fall. Moreover, regardless of possible stiffening of the hair, in the supine position the weight of the body against the hair would cause it to flatten. See Figure 15. But as seen in the shroud image, the hair falls downward, front and back, as one would see in an upright person with long hair. See Figures 18-21.

Figure 17. Supine position, hair falls to the ground.

Figure 18 shows the same woman in the upright position; note that her hair falls along the sides of her face down to her shoulders.

Figure 18. Upright position, hair falls along sides of the face down to the shoulders.

Figure 19 shows the hair of the man of the shroud. His hair falls along the sides of the face down to the shoulders, just like that of the young woman.

Figure 19. Frontal image, hair falls along sides of the face down to the shoulders.

Figure 20. Upright, hair falls down the back.

Figure 20 shows that the hair falls down the back as one would expect when a person is upright. Figure 21 shows the hair of the dorsal shroud image falling down to his back, just like that of the upright woman.

Figure 21. Dorsal image, hair falls down the back.

Figure 22 is a summary of the Gravity study. In the shroud image, both front and back, the hair falls to the shoulders and down the back. We see that the form of the backside is consistent with that of the upright volunteer (see Figure 14). We see that the feet do not touch the ground. The images of the shroud, both front and back, are consistent with an upright man [17, 18]. With the Gravity study which includes the understanding of masking, we can now better see that the back image has some of the very same three-dimensional qualities as does the frontal image.

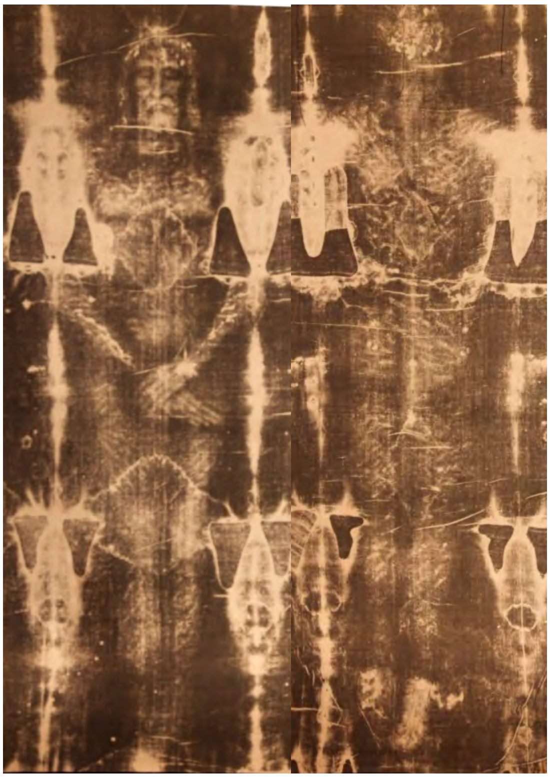

Figure 22. Summary of the gravity study: the shroud image is consistent with that of a man who is upright (back lighting).

What does the effect of gravity on the surface anatomy of the volunteers tell us about the shroud image? (a) We have seen what gravity does to the male volunteer lying on his back. Body weight flattens the backside including the long hair. From the frontal view of the young woman lying supine, we see that the hair falls to the ground. The above outcomes are what we would expect the shroud image to be, considering that the blood marks tell us that a crucified man was laid out on his back. (b) In stark contrast however, the image of the man of the shroud has hair that falls to his shoulders and down his back. The form of the image (excluding the areas masked by blood marks) is consistent with that of an upright man. (c) There is no known natural explanation for the image of the man of the shroud to be in the upright position when the evidence of the blood marks tells us that the man was laid out on his back. Presently there is no known natural mechanism that can explain the body-to-cloth image transfer.

4. DISCUSSION

In keeping with the objective of this paper to decide whether image formation was man-made, natural or supernatural, we can now discuss our results.

Method I. Shroud literature review. In reviewing the shroud literature, we have confirmed that the blood marks are a natural event and that the image is not man-made.

Method II. Medical observations. In asking the question, was image formation a natural event, the following studies tell us that image formation was probably not a natural event.

(A) Medical forensic evaluation of two blood mark studies. **Blood mark study 1.** The blood mark off the left elbow reveals the following: Image transfer worked in an anterior and posterior direction in relation to the body, but it did not allow lateral body-to-cloth image transfer even though the body was in intimate contact with the cloth as illustrated by the off-image blood mark. Furthermore, there are no lateral images to be found anywhere on this image. If lateral images were included as would be the case in a natural event, the resulting image would not be the fine mirror image that we see but would be distorted. This evidence is not consistent with that of a natural event; however, it suggests that it was intentional.

Blood mark study 2. It is shown from the second blood study that the blood marks in the hair originated from the face. In other words, the direct frontal view of the cheeks and temples of the facial image lies in between the blood marks that were originally on the temples and cheeks of the man draped by the shroud. This study does not allow us to reconcile having the same segment of cloth on two areas of the head simultaneously: First on the temple and cheek areas where it soaked up the blood and second at the sides of the face where the hair is seen. The only way for us to comprehend how the blood marks of the temples and cheeks of the face moved out into the hair is to imagine that the cloth moved into a flattened position during image transfer. But of course the forensic evidence tells us that the cloth was sufficiently wrapped around the face in order to cause the blood transfers that we see. The mechanics of the body-to-cloth image transfer cannot be understood nor defined through our ordinary understanding of space and time. This is probably not a natural event.

(B) ***Medical evaluation of gravity's effect on the surface anatomy of the body***. **Gravity study.** The study of the effect of gravity on body position tells us that the image of the upright man of the shroud is in stark contrast to the blood marks which tell us that a man was laid out on his back. In other words, the blood marks, the **first event**, document some areas of dorsal flattening that took place when the body was laid out in burial. It is the image, the **second event**, which documents the upright man. In postulating any theory of natural image formation, one would have to overcome the anatomical reality of the body having been laid out in a supine position, as is documented by the **first event**, the blood marks. How can a natural mechanism have created the dorsal shroud image, the **second event**, which has the body form of an upright man? For those of us who have attempted to discover a natural event that caused the image, the image of the man lifted up adds another major hurdle to the understanding of the mechanics (body-to-cloth relationship) of the event. Just as was found in **Blood mark study 2**, the mechanics of the body-to-cloth image transfer cannot be understood nor defined through our ordinary understanding of space and time. This is probably not a natural event.

Finally, rigor mortis has often been discussed in relation to the shroud. Rigor mortis is the temporary rigidity of muscles occurring after death. It has no effect on overlying fat and skin. Rigor mortis usually peaks in 4 to 6 hours after death, tapers off thereafter and is mostly gone within 24 hours. It is absent after 36 hours [19]. In rigor mortis the rigidity of the muscles runs on a scale over time from the condition of no rigidity, and increases to full rigidity, then from its peak it scales down through less rigidity that is easy to break, to soft and weak rigidity, to complete resolution. Because of body weight, bodies in autopsy rooms all have some flattening of skin, fat, and muscle resulting in loss of dorsal body form. The force of gravity always dominates. In the case of the man in the shroud who was laid out supine, the blood marks (**first event**) document flattened areas of his backside.

Different types of death and their circumstances greatly alter the onset and longevity of rigor mortis. "Whenever death results from violence preceded by intense physical fatigue (as in the case of those slain at the end of a battle), rigor mortis sets in speedily and disappears quickly. Thus it may last one or two hours only, and even be so slight as to be overlooked" [20]. This statement probably comes very close to describing what happened to the man of the shroud.

5. CONCLUSION

The objective of this paper is to decide if the image forming event was a man-made, a natural or a supernatural event. In reviewing the shroud literature, we have confirmed that the image is not man-made. It is unique. From chemical and medical forensic studies of the blood marks, we know that the body of a scourged and crucified man was laid out supine in this shroud. Blood mark formation occurred when moist blood was transferred from body to cloth by a contact process. It was a natural event. From the data of the two blood studies and the gravity study, we have determined the following about image formation: In **Blood mark study 1**, we found that image formation did not allow lateral body-to-cloth image transfer even though the body was in intimate contact with the cloth. Image formation was probably not natural and was likely intentional. In **Blood mark study 2**, we showed that we do not understand the mechanics of the body-to-cloth position that accounts for the transfer of the facial image from body to cloth. This image transfer cannot be understood nor defined through our ordinary understanding of space and time. It is probably not a natural event. In the third study, the **Gravity study**, we found that in stark contrast to what the forensic evaluation of the blood marks reveal -a man laid out supine in burial- the image is consistent with that of a man who is lifted up. Again, just as in **Blood mark study 2**, the mechanics of the body-to-cloth image transfer cannot be understood nor defined through our ordinary understanding of space and time. This is probably not a natural event. In conclusion, the three above studies suggest that a natural event is not the most probable cause of shroud image formation.

Note: The above information clearly increases the statistical probability that this was Jesus' shroud. None of his works can be understood nor defined through our ordinary understanding of space and time. His works were all unique and intended. Furthermore, all that is described in the Gospel of John concerning Jesus' death and resurrection, including the imagery of being lifted up, is seen on the shroud.

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Note: For further information and photographs, see *Unlocking the Secrets of the Shroud* and *Resurrected*, both by Gilbert R. Lavoie, M.D.

THE TILMA AND THE VEIL

The Tilma of Guadalupe

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Abstract

It is discussed how the apparitions of the Virgin of Guadalupe in 1531 to St Juan Diego played a key role in the evangelization of the Aztecs or mexicas, as without her intervention, it had been impossible that both cultures became united. It is also studied how the signs observed at the image of Guadalupe printed on the Tilma of ST Juan Diego convinced the Aztecs that this miraculous image was indeed divine, to the point that they immediately became converted to Christianity. In Some test carried out to the Tilma are mentioned here and the door is left open for new experiments to be done in the future in order to try to explain the origin of the image.

Keywords: Tilma, Guadalupe, signs, tests.

1. INTRODUCTION

When Christopher Columbus sailed in 1492 to what today is known as America, his goal was not to discover a new continent as he did, but to look for a new route to India sailing to the west instead of sailing to the east as Marco Polo did before, so going around the world he could reach India. When he finally arrived to the Caribbean islands he though he had arrived to India so he wrongly called the natives Indians. He later became aware of this.

Later, Hernán Cortés, a soldier of Columbus´ crew, sailed from Cuba to what is today México, he arrived to the coast of Mexico in 1519 and once at land he decided to burn his ships so no one could return. Then, he and his army moved toward the interior of the new lands to the capital of the Aztec (Mexica) Empire called Tenochtitlan, to what is today Mexico city. The Spanish soldiers after several attempts conquered Tenochtitlan using fire weapons and riding on horses (remind this animal was unknown in America at that time), and were helped by some Aztec's enemies tribes as well. Many Aztecs were killed and many more were held prisoners, made them slaves and were obligated to hard works by slaughter them in case they didn't obey. All what Spanish people wanted was the Aztec´s gold and silver so they treated them in such a very hard way without mercy.

By the time the first twelve Franciscans missioners arrived to the New Spain (Mexico) in 1524, they soon became aware of the hard situation the Aztecs were living, so their first action was to protect them against the harassment and bad treatment they received from the Spanish people by giving them shelter.

In 1527, Fray Juan de Zumarraga became the first bishop of Mexico. He was a humble and holy man that loved the Aztecs "as a father love his kids", he founded schools, hospitals and organized the agriculture. The Aztecs loved him so much seeing in him a protector.

In 1528 the first Audience of Mexico was founded leaded by Nuño de Guzman, its aim was to recollect taxes from the Aztecs in favour of the King of Spain Charles I, but the bishop Zumarraga opposed firmly to this decision.

Nuño de Guzman, an evil man disliked the bishop´s position and became angry against he and the missioners as well, forbidding the Aztecs to meet the bishop.

One day, when some Aztecs were running away from the Spanish soldiers they entered into a church looking for shelter at its interior, but Nuño and his soldiers got into the temple making prophanation of it and the Aztecs were held prisoners.

The bishop protested hardly against this, and he decided to write a letter to king of Spain Charles I, in this letter, the bishop Zumarraga denounced the violation of the temple and the bad behaviour showed by the Spanish people toward the Aztecs and to the missionaries as well (in fact, Nuño de Guzman wanted to kill the Bishop).

There existed such a bad extreme situation at the new Spain, to the point that the Bishop Zumarraga had considered the possibility to close all the churches, end the mission and return to Spain, "unless a miracle occurs". In his letter to the king, he wrote "if God does not provide with a remedy, the whole land is about to lose completely" [1].

This was the situation in 1530.

2. THE APPARITIONS

According to the traditions, in 1531 a "Lady from heaven" appeared to a humble Aztec at the hill of Tepeyac his name was Juan Diego now saint, his former Aztec name was Coaltltlatoatzin which means "the one who speak like an eagle" a prophetical name because of the events he was about to live. He was converted to Christianity in 1525.

The blessed Mary appeared five times from December the 9th to December the 12th of 1531. The narrations of the apparitions were collected at the Nican Mopohua a text written in nahuatl, (the Aztec`s language) by Antonio de Valeriano, few years after the apparitions.

The first apparition took place when Juan Diego was on his way to Tlatelolco to attend the mass celebration, when suddenly he heard a voice calling him. When he approached he saw a Lady, her garments where shining like the sun, she identified herself as the ever **Virgin Holy Mary, mother of the true God for whom we live, of the creator of all things, lord of heaven and the earth**. And asked him to go to the bishop and tell him "**my great desire, that here on this plain a temple be built to me**".

Then, he went to visit the bishop Zummarraga and told him what he had seen and the message from the blessed virgin, but the bishop appeared incredible.

Sadly, Juan Diego returned to the Lady and told her that the bishop did not believe it, but the Holy virgin told Juan Diego to return the next day and tell him again her message, so he went again to see the bishop, he saddened and cried as he expounded the mandate of the holy virgin, and the wish of the immaculate to erect a temple, but again the bishop did not give credence of his words.

Nevertheless he asked Juan Diego to tell the Lady that a sign was very necessary, so that he could believe that he was sent by the true Lady from heaven.

When Juan Diego told her about the bishop's answer the Holy Virgin told him to return the next day so she could give him the sign the bishop had requested.

The next day Juan Diego failed to return because his uncle Bernardino was very ill and about to die so he decided to look for a priest, and he surrounded the hill so the blessed virgin could not see him, but the Holy virgin appeared to him and asked where he was going, Juan Diego was grieved, ashamed, but the holy virgin gave him a beautiful answer: "*Hear me and understand well, my son the least, that nothing should frighten or grieve you. Let not your heart be disturbed. Do not fear that sickness nor any sickness or anguish. Am I not here who is your mother? Are you not under my protection? Am I not your health? Are you not happily within my fold? What else do you wish?*"

When Juan Diego heard these words he was greatly consoled, he was happy, and then he climbed the hill to look for the sign the bishop had requested , as he reach the summit, he was amazed that so many varieties of exquisite roses de Castilla were blooming, because it was winter out of season, they were fragrant and covered with dewdrops which resembled pearls, he gathered them all and placed them in his tilma and went down hill and brought the different roses which he had cutted to the lady of heaven , as she saw them , took them with her hand and again placed them back in the tilma saying "*son, this diversity of roses is the proof and the sign which you will take to the bishop, you will tell him in my name that he will see in them my wish. Rigorously I command you that only before the presence of the bishop will you unfold your mantle and disclose what you are carrying, so you can induce him to give his support with the aim that a temple be built and erected as I have asked".*

As Juan Diego entered the bishop palace, he knelt before him, as he was accustom to do, and told the bishop "she condescended to your request and graciously granted your request, some sign and proof to complement your wish."

When he unfolded his white tilma, where he had the flowers, and when they scattered on the floor, suddenly there appeared the drawing of the precious image of the ever virgin Holy Mother of God in the manner as she is today kept in the temple of Tepeyac, which is name Guadalupe.

When the bishop saw the image, he and all who were present fell to their knees, the bishop with sorrowful tears, prayed and begged forgiveness for not having attended her wish and request, then, he took the Tilma and placed in his chapel.

The next day he asked Juan Diego where the blessed Mary wanted the chapel to be erected.

When all the Aztecs looked upon the image printed on the Tilma, they immediately get converted to Christianity because they saw in the image a sign from heaven, the image of Guadalupe talked to them in a very clear way because they were very familiar to write with signs and images printed on feather sheets which they called codex, and the Tilma of Guadalupe was indeed a codex by itself. From then on, many Aztecs accepted the Christian religion as the true one, and thousand of them received baptism, the number of converted was so high that the missionaries hardly had time to rest and on their own words they said "we were so tired that we could no longer hold our arms lifted in the air to baptize them all".

From this moment on, the situation between the Aztecs and the Spanish people became different and changed dramatically, and the situation relaxed to the point that they could get along fine to each other and friendly relations between them emerged making possible that both cultures considered former enemies now could live together creating a new mixed culture.

This is why it is often said that the tilma of Guadalupe is the certificate of birth of Mexico as a nation.

3. THE SIGNS WRITTEN ON THE TILMA

The signs observed on the Tilma spoke to the Aztecs in a very clear way, because when looking at them, they realized immediately it came indeed from heaven, so let us study the symbolic meaning of these signs [2].

The lose hair (see Fig. 1) represent a virgin maid, so different from the married women which used to use their hair tighten.

Figure 1. The lose hair means unmarried woman

There is a four petals flower called Nahui Ollin, the Aztecs related it with the sun and it was the greatest religious conception in Aztecs believes.

It is located at her womb, meaning that Guadalupe is the mother of the baby sun which the Aztecs interpreted as Jesus Christ (see Fig. 2).

Figure 2. Four petals flower (Nahui Ollin)

The black ribbon over her womb is also announcing her maternity, see Fig. 3. Once the native women were pregnant they used to wear a ribbon over her womb.

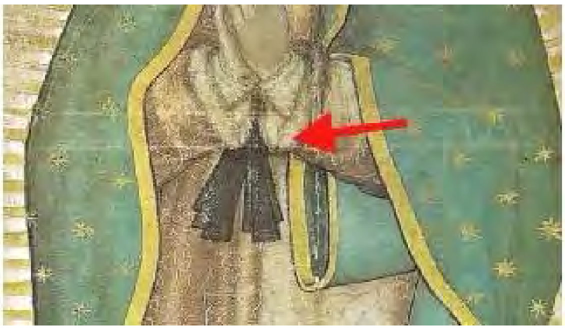

Figure 3. The black ribbon announcing her maternity

There is also an eight petal flower which represented the conjunction of Venus and the sun, and this only happened every 104 years, so this flower represented to them the rise of a new era, see Fig. 4.

Figure 4. The eight petal flower means a new era

Her sixteen year face represents the mixture of both culture Spanish, and Indian, her lips are formed by the folds of the cloth not by any drawing line, see Fig. 5.

Figure 5. The lips are made by folds of the cloth not by lines

The moon at her feet told them that Guadalupe is protecting Mexico, because the meaning of the word **México** in the Aztec´s language was "**in the belly of the moon**" "ME=moon, Xi-ctli=belly, CO=in (see Fig. 6).

The rays behind her, means she is giving birth to the sun, that is Jesus Christ, see Fig. 7.

Figure 6 The meaning of the word Mexico.

Figure 7. The sun in her womb meaning the sun´s birth.

Their hands are united in attitude of praying, the right hand is brighter than the left one which is brownish, meaning the mixture of both cultures the Spanish(white) the and the Aztecs (brown) see Fig. 8.

The sign in Fig. 9 represents a hill, Tepetl, and it was often used in the Aztec codex, meaning that a universal message is given to the mankind from the hill of TEPEYAC, that is the hill of the divine word or the divine chant.

The tunic in beautiful green bluish colours that change as the butterfly when observed at different intensities of light represents the sky crowned with 46 stars as they were at the time of apparitions, see Fig. 10.

Figure 8. Hands in attitude of prayer: the union of two cultures.

The cloak is pink colour representing the earth which has nine types of flowers meaning the 9 tribes that arrived to Tenochtitlan from a place known as Aztlan, where the Aztecs once belong [3].

The flowers have their roots at the tunic, with water flowing out from them as shown in Fig. 11, which means that from the sky or heaven water is flowing down to earth, fertilizing the fields and producing food and life, this sign represented the Aztec past, and a new nation guided by Mary had arisen.

The clouds surrounding the image were associated with the highness.

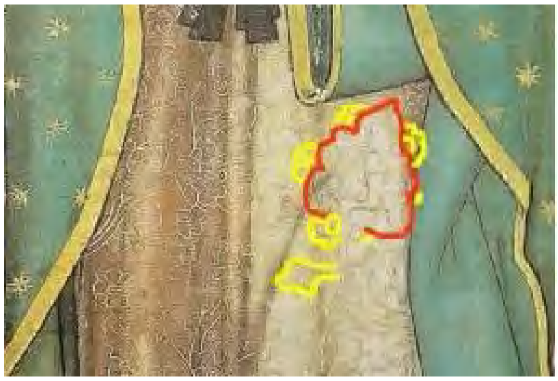

Figure 9. The hill of Tepeyac where an universal message is given.

Figure 10. Forty-six stars as they appeared on December the 12th 1531.

Figure 11. The flowers have their roots at the tunic.

The angel (see Fig. 12) is an Aztec eagle warrior, and it is associated to Juan Diego since his former Aztec's name was COATLTOATOATZIN which in nahuatl means "the one that speak like an eagle". He is holding with his right hand the tunic (heaven) and with his right hand the Virgin's dress (the Earth), meaning that Juan Diego is joining heaven and earth.

Figure 12. The union of heaven and earth.

4. THE TILMA OR AYATE

The tilma or ayate, is made of ixtle or agave extracted from the Mexican plant called maguey its scientific name is agave popotule, it measures 1.68 m. × 1.05m. The tilma was used by the Aztecs to recollect the seeds and the fruits from the fields. The Juan Diego's tilma are in fact two cloths united by a single thread, these kinds of cloths are very rough and hard, but in the case of the Guadalupe´s tilma unexplained it feels very soft when touching it. Hardly a painter had chosen some material like this to paint on it. These cloths spoils within 20 or 30 years, but miraculously the tilma and the image are still in very good shape remaining intact no matter the span of time with its bright colours still in a good state of conservation. To test how this kind of cloths behave along the time, in the 17th century, some cloths similar to the Juan Diego's tilma were painted and left them for a span of time in an environment similar to the original was, in order to see what happened to them as time went on. As time passed by (10 years after), the cloths had suffered deterioration to a great extent.

For more than hundred years the tilma was exposed without any protection at all, there were not any crystal to protect it, it was exposed at the altar, it was touched and kissed by millions of pilgrims that came to visit the Virgin of Guadalupe, thousands of candles burned before the tilma but the smoke didn't damage it.

An unexplained fact is that the tilma repels all kinds of insects and dust.

Nowadays for a classic paint to be conserved at the museums, it is recommended a 60% of humidity, 60º Fahrenheit and a small room to avoid contamination. And also is recommended to avoid excessive exposure of light.

The tilma remained without any mark at all surrounding it, until the 17th century, when a golden mark was sent by the queen of Spain as a gift to protect it, but as the image was bigger, it didn´t fit at all in the new golden mark because it was smaller than the tilma, unfortunately it was decided to cut the upper part of the tilma in order to fit the new mark. Where does this portion of the tilma remained? Nobody knows the answer.

In the 17th century it was spilled by accident with nitric acid when cleaning it, unexplainable the tilma or ayate didn't suffer any damage at all. After the accident, many people were witnessing of the mark left by the acid at the upper right corner. At the beginning it was observed in great extent, but as time goes by, it has become less and less visible, see Fig. 13.

In 1921, when the Mexican church was persecuted by an anticlerical government, a powerful bomb was hidden under a flower arrangement, putted just in front of the altar and placed it directly before the image, the bomb exploded during the mass celebration causing damage in great extent to the floor made of ivory, it broke the large windows, the altar was devastated , a nearby cross of hard iron was folded , but the image didn't suffer any damage at all, not even the crystal that cover it broke, fortunately nobody became hurt.

Figure 13. The acid mark is still visible

Richard Khun, the 1939 winner of the Nobel prize in chemistry, carried out some test on two fibbers of the Tilma (one red and one yellow) at the Kaiser Wilheim Institute in German, and concluded that "there are no colors of any kind in the fibbers" and " not of animal, vegetable or mineral dyes".

Some pictures using UV and IR has been taken to the image, but there exist the great necessity to perform in the near future spectrometric analyses in the UV, IR region, and Raman spectra as well, that could give us some clues of what the image is made of, and also how the image could have been formed.

In the same way, the pollen left by the roses of Castilla collected by Juan Diego on his tilma in 1531 could be searched at the Tilma in order to look if there is still exists on it. It is believed that the roses played a key role in the formation of the image of Guadalupe.

3-D studies would also be carried out to the image to see if there exists any 3D pattern on it.

Studies performed on both eyes of the image of Guadalupe by Dr Aste Tomsmann [4] showed the silhouettes of 11 people (including a whole family at the pupils) observed on both eyes when the pictures were scanned, enhanced and digitalized, see Fig. 14. These silhouettes are the people that were present at the moment of the Virgin´s apparitions, which were reflected as in natural eyes by an effect known as the Purkin- Sampson´s images [5], see Fig. 15, and they appear as to be printed on the Tilma.

The images are observed on both eyes with a slight rotation of some degrees due to the different angle the light arrived to the eyes, just like it occurs in living bodies.

5. CONCLUSION

It is true that the image on the Tilma of Guadalupe is today addressed as an acheiropoietos image, because according to the vast majority of researchers that have studied it with a rigorous scientific method, its origin goes beyond the natural explanation and until now, no satisfactory explanation has been formulated.

Figure 14. Eleven silhouettes are observed at the eyes.

Now, we are aware that several studies have been conducted to the cloth and the image, but they have been not conclusive, so the necessity of performing more experiments on the fabric will lead us know a little more of how this image was made. However, as in the case of the Shroud, these experiments need the authorization of the people in charge of them.

Figure 15. Example of Purkin-Samson image in a human eye.

Something similar to what Giulio Fanti et al. [6] did with the Shroud, that is recompiling those tests with a scientific rigor could be done to the Tilma as well in order to list them and differentiate from those “facts” that lacks the scientific rigor.

Finally, I would like to mention that the cities of Turin and Mexico City, because both of them has cloths with acheiropoietos images (the Shroud and the Tilma of Guadalupe) will be united as sister dioceses in the near future.

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The concept of "acheiropoietos", the iconography of the face of Christ and the veil of Manoppello

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Abstract *In the New Testament there is first the concept of "acheiropoietos" meaning not made by human hands. This word is opposed to "cheiropoietos" that means made by human culture. There are especially two objects in the Bible which were always named with this term: the temple and the idols. God cannot live in a handmade temple, and the idols are nothing, specially, not gods, because they are handmade. Not hand made in the New Testament is the transfigured body of Christ. Only centuries later we find the same word used by byzantine writers and now "acheiropoietos" is an icon that was translated in the year 574 from Kamoulia in Cappadocia to Constantinople. The icon disappeared from the capital of the byzantine empire in the year 705 ca. After the iconoclastic quarrels the byzantine army conquered Edessa and translated the other authentic image of Christ, the so called Mandylion from this town to Constantinople in the year 944 in order to substitute the disappeared Kamoulia image with this relic as banner for the byzantine soldiers. Now it is the question, if we have some traces in the eastern iconography of these two relics, of the Mandylion and the Kamoulia image. We find there exactly two different authentic icons of Christ with different hair styles: the pantocrator icon and the Mandylion. The hair style of the pantocrator icon corresponds to the Shroud of Turin, but the Shroud of Turin corresponds also to the Mandylion. So the confusing title "Mandylion" should be changed because the different hair style can only fit with another authentic relic of Christ. As the old descriptions of the Kamoulia image by the byzantine writers corresponds with only one other object that is still present, with the veil of Manoppello, and the veil of Manoppello with the hair style of the Mandylion icons, we have to conclude that the original Kamoulia image should be the veil of Manoppello. Always with one supposition that "acheiropoietos images of Christ are not to be found, than only realized in one exemplar, we can now give the statement, that the Mandylion is the Shroud of Turin, the Kamoulia "acheiropoietos" the veil of Manoppello. A scientifically recognizable fact is that the technique of the fabrication of the Shroud of Turin is not known until the day; the veil of Manoppello with his changing colors in different lighting, forces us to the same conclusion.*

Keywords: Byzantine writers, icons of Christ, idols, relics as models for the icons

1. THE CONCEPT IN THE BIBLE

The word "acheiropoietos" is first to be found in some few texts of the New Testament and means the opposite of "cheiropoietos", made by human hands. This item is applied to very few objects in the Old Testament, in first line to the temple and the images of gods, the "eidola". God cannot live in a hand-made temple and all images of gods are nothing because they are hand-made. So Salomon in his prayer during the dedication of the temple in Jerusalem asks himself, if God can live in the house, that he has built for him [I Kings 8, 27]. King Ezequias prays before the Lord in the peril of the invasion of the Assyrian army, which was destroying all gods of all countries, but this gods are only hand-made and not the real God who creates all things on the earth and in the heaven [II Kings 19, 18]. The same description of the idols we find also in the famous Psalm 115, where we read on the verses 2- 4: " Why do the nations say, «Where is their God?» Our God is in heaven; he does whatever pleases him. But their idols are silver and gold, made by the hands of men."

The idols are images, but they are hand-made, with other words objects of human culture. When we go from the word "cheiropoietos" to the word "acheiropoietos" adjoining the denying element "a", that will mean that the object is like one of the creation of god, o supernatural one. In this meaning we find this word first only in the New Testament. In the gospel of Mark 14, 58, is said by the false testimonies before the tribunal of Jesus, that he was saying: "I will destroy this man-made temple and in three days will build another, not made by man."

The false accusation hides a very profound meaning, given by the gospel of John. There we read in the second chapter verse 21: "But the temple he had spoken of was his body." So, reading the two quoted texts together, the temple, which is not hand-made, is an image: the body of the risen Christ. In the letter to the Hebrews we find in the chapter 9, 11: "When Christ came as high priest…he went through the greater and more perfect tabernacle that is not man-made, that is to say not a part of this creation." What is this greater and more perfect tabernacle? It could not be the sky, the image of heaven or heaven itself, all created things, visible and not visible. Could it mean the transformed body of the risen Christ? But even this interpretation does not make sense, if there is not an allusion on another object. That will mean, not only through the material cloth, but even through the bloodstains and the traces of the image on it. As this is a problem for exegetic interpretation, I will not go further than insisting that the concept of "acheiropoietos" is typical for different New Testament writers.

2. THE KAMOULIA IMAGE

Only centuries later the expression "acheiropoietos" appears in the writings of byzantine poets [1] and specially in a text of a byzantine historiographer of the 12Th century, named Kedrenos. He informs us that in the year 574 were translated two important objects to Constantinople: parts of the true cross from Apameia in Syria and the "acheiropoietos" image of Christ from Kamoulia in Cappadocia [2]. The second object served as the banner of the byzantine army, and when the campaigns were victorious, the victory was not attributed to the Generals but to this marvelous image. In this occasions poems were formulated and the icon described. For instance after the battle on the river Arzamon in the year 587 Theophylaktos Simokatta described the image as made by divine art, not wowed as a textile and not painted [3].

Georgios Pisides writes on the war of the emperor Heraclius (610-640) against the Persians and the role of this image during the battles. He says that the emperor has taken the "divine figure and venerable image of the not written scripture, that was not designed by human hands, but made by the art of the Logos who was begotten without human seed, made by the Logos who forms the whole universe…". Than the writer follows saying that the emperor "in trust on this archetype, that God has designed, began the battles" [4]. The same writer has done a poem in the image. Here we find the expression: "as not having a beginning, it was not produced by art, as not to say, it was paint without pencil." [5]. The famous textile with his image of Christ disappeared from Constantinople even before the beginning of the iconoclastic disorders, exactly between the two periods of the reign of Justinian II, in the year 705 ca [6].

3. THE TWO ICONS OF CHRIST IN THE EASTERN ICONOGRAPHY

Which are the traces that left the "acheiropoietos" of the town Kamoulia, a small place in Cappadocia, in the iconography of the byzantine artists? That is not a trivial question, because another relic with traces of the face of Christ appeared already in the year 544 in Edessa and remained there until the year 943; the date of the beginning of his translation to the capital of the byzantine empire [7]. This other image on a textile is called Mandylion or image of the King Abgar. Now we have in the orthodox church, until the day, two principal representations of Christ, the pantocrator type and the icon of the Mandylion. The pantocrator type is already present on an icon of the St. Catherine convent in the Sinai (see fig. 1) [8].

Figure 1. Jesus pantocrator 6th century St. Catherine Conv. Sinai (from Weitzmann).

Specially the division of the hairs in two different directions, one part laying on one shoulder, the other behind the neck, is characteristic for this type. It is used also on clear representations of the material cloth called Mandylion in order to represent the head of the Lord on all first representations of the Mandylion that are related in some way with the translation of the relic from Edessa to Constantinople during the years 943 and 944 (see fig. 2).

Only centuries later, beginning with an example of the 12th century, appears a icon of Christ, now always called Mandylion, with a totally different hair style. The two parts of the long hairs are symmetrically disposed and divided at least in four branches. This type is represented by different Russian icons of the face of Christ from the 12th century onwards, always paint on a cloth. The first examples are in the Tretjakow Museum of Moscow (see fig. 3).

Now we ask ourself, if this other and second type of the true likeness of Christ could not better reflect elder disappeared icons of the Kamoulia veil, of the first textile, that was called "acheiropoietos"? We must never forget that the Mandylion had to substitute the disappeared Kamoulia image in his role as the banner of the byzantine army.

Perhaps the still existing two relics with a mysterious image of Christ on a textile, the shroud of Turin and the veil of Manoppello can shed more light to this difficult and intricate problem.

Figure 2. Sakli Kilise, fresco, 10th century (photo Marinelli).

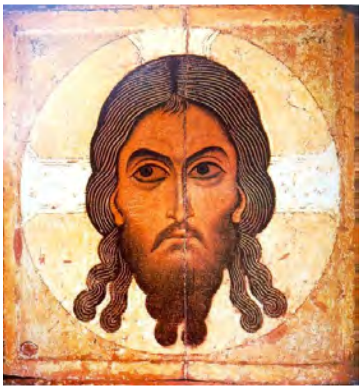

Figure 3. Mandylion, 12th century, Moscow Tretjakow Museum (Photo from Volto dei Volti Cristo I).

First of all there is to show the dependence of the hairstyle of the pantocrator type from the shroud of Turin. There is a bloodstain on the hair that enhances and creates for the observer the impression that one part of the hair of Christ is conducted behind the neck (see fig. 4). Always we can say, that all details, which are casual on the shroud, and also are to be found on works of art, especially in the iconography of Christ, determine a relation between the two. Only the casual and natural forms of details on the shroud can be first and the artwork second. With our observation and this principal we can say that all pantocrator icons depend on the shroud. It is only the question, if the Kamoulia image or the Mandylion is to identify with the Turin shroud. We have to find out which of the two materials was once described as painted with blood, and this is only the case of the Mandylion.

Indeed the Codex Vat. Graec. 511 of the Biblioteca Apostolica Vaticana says that Gregory a official of the great church Sancta Sophia gave a speech in the presence of the holy relic when he arrived in Constantinople in the eve of the feast of the Assumption of Mary in the year 944 [9]. He relates that the image on the material is not painted with the usual colors of an icon, but with sweet and blood. Now it does not exist in the whole world an object that fits so well with the description done by Gregory as the Turin shroud. So we can conclude that a bloodstain on the shroud caused nothing more than the hair style of the pantocrator type, and so the first iconographic reading and artistic interpretation of the head of the person who we can see on the Shroud. This means that the first and most important Christ type was the result of such a reading, and this was only possible with the Mandylion in Edessa.

Figure 4. The face of the shroud of Turin (photo Enrie).

4. THE VEIL OF MANOPPELLO

What we can say on the Kamoulia type? All descriptions of this textile and his image on it, which we quoted above, correspond with the veil of Manoppello. The human face on it appears in a first moment like a painting, but if You study with detailed observations this very strange object, You cannot determine its fabrication with every known technique. You are forced to say like the old byzantine descriptions of the Kamoulia Veil, it is not painted and not weaved. Only the men of our times have difficulty with the conclusion of the byzantine writers and poets: "made by divine art". Scientifically we can only say, that we don't know the technique of the image fabrication on the veil of Manoppello.

Let us give at least one, but possibly definitive reason, why byzantine writers and even the scientific researcher of our days have to confirm that the nearly totally transparent image on the veil of Manoppello is made by a still unknown technique. That is the strange fact that the colors are changing in different light.

The whole image can appear in a grey tone without special illumination. If we put a light on the veil or we have sunshine on it, there comes out a yellow brownish color, and the lips and blood on the tempers will appear in a clear red tone (see figs. 5 and 7). These different appearances of colors in different light were never to produce with some technique before our times, and were only present in the nature: for instance fishes in the tropical sea can change their color in the same way, often from gray to blue. Now we remind that one sense of acheiropoietos was exactly identical as made by nature. In Manoppello we have a very interesting and curious fact: the inversion of the sequence. In general we have first nature, for instance threads from plants or animals, and then a cultural object like a textile, but now we find a textile with an image on it that has newly properties as the nature, that is the change of the colors in different forms of light.

Figure 5. Manopello, Santuario del Volto Santo, the veil with the image of Christ (photo Pallin).

The second oriental type of Christ, called even Mandylion, has the hairs symmetrically divided at least in four parts corresponds clearly with another Christ type (see fig. 3). Was his model the Kamoulia image? It is probable, but we cannot be sure. Here helps us the veil of Manoppello. Its hair style corresponds with the second version of the Christ icons in such a way, that we can call it the model of all these other Christ icons which are always called Mandylion (see figures. 5 - 7). It is unlike that once existed two acheiropoietos images of the same shape, but in each case, only the Manoppello veil can give us the right impression as the Kamoulia image was a like.

The Manoppello veil clearly shows the division of the moved hairs in more than only two parts and appears so as the model for the later type of the Mandylion icons (see fig. 6).

It is always valid the sentence that all what appears in a more natural or casual way in relation to similar elements in art objects has to be first and considered as the model for the same or similar detail in a work of art. In these latter we find the subdivision of the hairs always in a more formal and artificial way than the same more living details on the veil of Manoppello. As this veil reveals itself as first model of all later Mandylion icons, and even as the unique object that corresponds to the old description of the Kamoulia image, we can say now that the Mandylion icons should be called with very much reason Kamoulia icons.

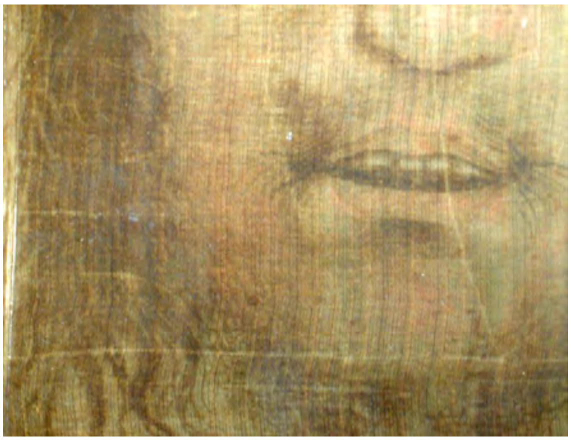

Figure 6. The veil of Manoppello. Detail of the hairs (Photo Pallin).

Figure 7. The veil of Manoppello seen without special illumination (photo Pallin).

We remind that the Mandylion had to substitute the lost Kamoulia image from 944 onwards.

Now, we have to distinguish between the first version of Mandylion representations (see fig. 2), which show always the pantocrator type that depends, as we have seen, on a reading of the shroud and the later Mandylion icons (see fig. 3), falsely called with this title, because they depend on the Kamoulia image or on some copy of it, that should have been present in Constantinople at least until the 12th century when a Russian artist made a copy of it.

5. CONCLUSIONS

1) The shroud of Turin or his model, was really once the Mandylion in Edessa, and it was the archetype for all pantocrator icons of the orthodox churches in the east.
2) This special and first reading of the features, which are to be seen on the shroud, was so important that it determined the iconography of Christ for centuries.
3) The Mandylion icon is in reality a Kamoulia icon.
4) The Kamoulia image is still present in the Manoppello veil.
5) The Manoppello veil as acheiropoietos is the model for all later Mandylion icons.

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2. See Dobschütz, 125*. Cfr. Werner Bulst and Heinrich Pfeiffer, *Das Turiner Grabtuch und das Christusbild II*, Das echte Christusbild (with an appendix of Gino Zaninotto on the Vat. Graec. 511 in the Biblioteca Apostolica Vaticana), Frankfurt am Main 1991 [=Bulst and Pfeiffer] 22; Heinrich Pfeiffer (ed.), *Il Volto Santo di Manoppello.* Text of Heinrich Pfeiffer, Blandina Pascalis Schlömer, Adriano Ghisetti Giavarina, Pescara 2000 [= Pfeiffer] p. 17.

3. See Dobschütz, 51f., 127*.

4. See Dobschütz, 53, 129*. The english transl. is mine.

5. See Dobschütz, 54, 129*.

6. Cfr. Pfeiffer, 18.

7. See Pfeiffer, 18f.

8. See Kurt Weitzmann, *The Monastery of St. Catherine at Mount Sinai The Icons I*, Princeton 1976, 12-15, Cat. N°BI, plate 1f., 39f. Cfr. Bulst and Pfeiffer 29, 95f.; Pfeiffer, 36.

9. See Gino Zaninotto in *Bulst and Pfeiffer*, 127-152. Cfr. Pfeiffer, 69.

Properties of byssal threads, the chemical nature of their colors and the Veil of Manoppello

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Abstract
Considering the hypothesis that the Veil of Manoppello is made from byssal threads, their physical and chemical properties were analyzed in relation to the possible origin of image colors seen on the Veil. Most of these colors are similar to the colors of byssal threads, either natural (brown) or after their chemical degradation (yellow, gold, pale straw, reddish). Pheomelanin was found to be the main pigment of byssal threads. Preliminary examinations of threads after bleaching by the polarized light microscopy are reported.

Keyword: byssus, bleaching, pheomelanin.

1. INTRODUCTION

The image on the Veil of Manoppello is worshipped in the Manoppello Sanctuary in the Abbruzzi region, Italy, as the Holy Face of Jesus. It corresponds to the traditional presentation of the Face of Jesus and reveals some similarities with the Face of the Shroud of Turin. The similarities were well established by Schlömer and Resch [1 - 5] and encompass not only the general appearance but also some details includind the marks of wounds. The documented history of the Veil in Manoppello has been known since the 16th century but its origin is uncertain. The Veil is highly transparent when strongly illuminated and the image can be seen on both sides of the Veil. The microscopic and spectroscopic studies (performed through the glass of the reliquary) did not lead to clear conclusions as to the nature of the image. Microscopic photographs show serious contaminations on the surface of the threads. Some researchers recognized them as pigments [6 - 8], while others consider the image as the *acheiropoietos* and point to its unique characteristics, especially to the fact that different details can be seen on it depending on the kind of illumination applied, and also to the fact that the technique used to paint the Veil still remains unknown.

The Veil of Manoppello is made either from linen or from byssal threads. The latter origin was claimed by Chiara Vigo from S. Antioco, near the island of Sardinia, Italy who produces byssus cloths using traditional methods known for generations. However, no experimental scientific support of that was reported. Byssus threads are non-living, completely acellular, delicate silky fibers, golden or brown in color, which are secreted by glands of some mussels in order to anchor the bivalve to the hard surfaces and to secure it against the waves. Among marine mussels, the pen shell (*Pinna nobilis*) living offshore in the coastal regions of the Mediterranean Sea has been best known since ancient times because of its very large shell (which can grow up to 1 m). Its threads were spun to form yarn and then woven to produce exceptionally fine, valuable and rare fabric.

The dominant color on the Veil of Manoppello is brown, which corresponds to the natural color of dry byssus threads of *Pinna nobilis*. Some other properties of byssus described in popular literature, like its being fireproof appear however to be only legendary; in fact, its threads glow in red and burn away like hair.

It should be added here that byssal threads secreted by other marine mussels, in particular those from *Mytilidae* family, have been intensively investigated in recent years [9 - 17] in search of inspirations as concerns the use of biomimetic materials in engineering and also for medical purposes. The research has been focused on understanding the structure of natural fibers in order to explain their unusual properties such as the ability to secure stiffness and elasticity in different parts, their extremely high strength, great capacity of absorbing and dissipating energy and strong adhesion to different (even wet) surfaces. As a result of the above-mentioned investigations, byssal threads were found to consist of molded collagenous fibers coated with a fine (2 μm – 4 μm) protective cuticle. Each thread of *Mytilus* species can be divided into two morphologically and mechanically distinct parts of different composition: proximal (soft, elastic and crimped) and distal (smooth and stiff), with a gradual transition between them [9 - 12, 17]; the distal part has an adhesive plaque at the end. The principal protein components are three byssal collagens known as preCols: in the distal region preCol-D, in the proximal section preCol-P and uniformly presented through the thread preCol-NG. Each of them includes a central collagen domain, variable flanking domains, and histidine-rich terminal domains. Flanking domains for preCol-D, preCol-NG and preCol-P resemble spider dragline-silk, Gly-rich plant cell wall protein and elastin, respectively. The graded distribution of preCols with different flanking domains is responsible for unique mechanical properties of the threads. Histidine and residues of dihydroxyphenylalanine (DOPA) in terminal domains form reversible coordination bonds with transition metal ions which play a role of sacrificial bonds in yield and self-healing in the distal region of the thread. On the other hand, the cuticle is hard, yet highly extensible due to its ultrastructure with nanoscale granules [13 - 16].

It should be pointed out that in recent investigations there is no information about pigments responsible for the color of byssal threads.

In this report physical and chemical properties of byssus threads from pen shell (*Pinna nobilis*), obtained from the S. Antioco region near the island of Sardinia, Italy were examined. In particular, the change of color due to chemical bleaching and the chemical analysis of the threads pigments by the high-performance liquid chromatography (HPLC) are reported. Finally, preliminary investigations of the threads using the polarized light microscopy (PLM) are discussed.

2. EXPERIMENTAL

Physical properties of natural byssal threads. Natural threads have different tints of a brown color from reddish to brownish-black, but some beige threads can also be found. Threads are lustrous, elastic, up to 7 – 9 cm long and they form irregular waves, as is illustrated in Figure 1 showing the scanning electron microscopy (SEM) image. SEM images were obtained using a LEO 435VP (Zeiss) microscope, EHT = 15 kV and samples coated with gold.

The threads have circular or slightly elliptical cross section and their diameter (or thickness), determined from SEM images, ranges from 10 ± 2 μm to 45 ± 5 μm but even for the same thread the thickness can change twice in different parts. The average diameter is of ca. 25 μm.

Fanti reported [6] the value of 14 ± 6 μm for threads in the Veil of Manoppello, estimated from the number of threads in a yarn and its diameter in microphotographs. Obviously, finer threads could be used for more delicate fabric. The thread surface is rather smooth (Figure 2), without any overlapping scales in the cuticle, as for human hair.

Under stronger illumination the threads are semi-transparent and the edges of the bottom thread at the crossing area are well visible under microscope (Figure 3). The complete transparency is evident for colorless threads after bleaching.

The thread surface is hydrophobic as could be seen after attempts to cover it by water-colors: no absorption and no uniform surface coverage were obtained, as in the case of linen threads, but separate microgranules were seen on the surface in microscopic images. This behavior corresponds to the protective role of the cuticle in natural aqueous environment of mussels. Moreover, it remains in agreement with the reported results [11] claiming that strong incorporation of iron in the cuticle occurs only during the secretion of a new thread, whereas threads already formed are unable to sequester iron from the iron-supplemented seawater.

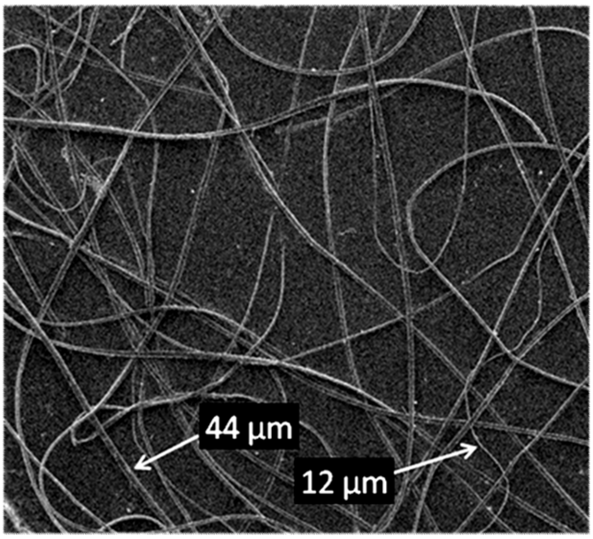

Figure 1. SEM image (x100) of byssus threads; threads of extreme thickness are shown.

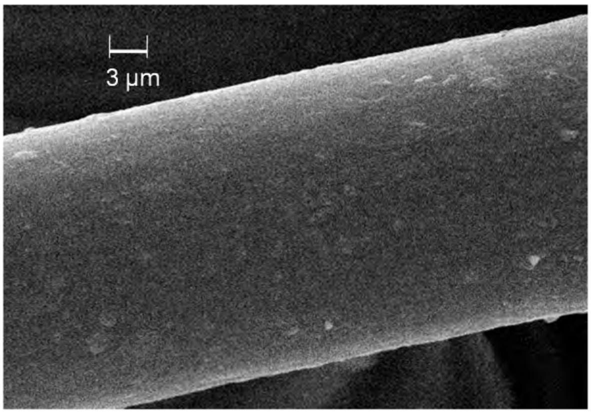

Figure 2. SEM image (x6000) of the byssus thread.

Chemical bleaching of byssus threads. The brown color of threads is unaffected by common organic solvents (e.g., methanol, acetone, ethyl acetate, toluene), diluted acids and bases, and reductants such as sodium thiosulphate, $Na_2S_2O_3$, and hydrazine hydrate $N_2H_4 \cdot H_2O$, as well as temperature and UV irradiation (overnight, 254 nm or 365 nm from an 8 Watt Spectroline lamp). However, the use of strong oxidants (like hydrogen peroxide, H_2O_2) in proper media can easily change the color to yellow, gold or pale straw, or even make the threads completely colorless.

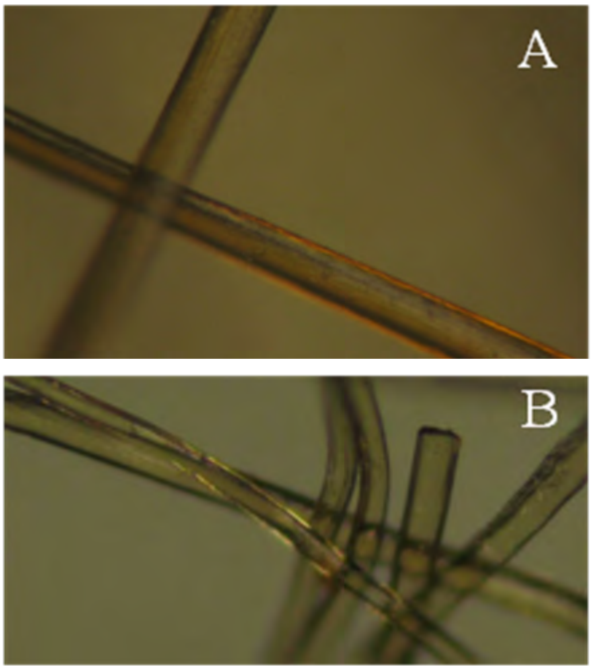

Figure 3. Microscopic photographs of byssus threads showing their transparency under strong illumination: (A) natural brown threads and (B) colorless threads after the 20-h degradation in ammonia with hydrogen peroxide.

The H_2O_2 oxidation was performed using alkaline solutions of sodium hydroxide NaOH, ammonia NH_3 or potassium carbonate K_2CO_3. The reddish color was also obtained in parts of the thread after hydrolysis in hydriodic acid, HI. Some examples of typical bleaching results are presented in Table 1. The media used in these experiments were chosen following literature procedures proposed for the degradation of melanin pigmented tissues [18 - 22], in particular mammalian hair, in order to obtain melanin markers among fragmentation products. A complete dissolution of the keratin matrix was obtained then. However, shorter time of degradation and more diluted solutions allowed us to obtain the changes in color without substantial damage to the byssus thread. No evidence of damage was observed in SEM images, for instance there was no change in thickness of the threads after the degradation used for the HPLC determination. It should be added that the final colors as presented in Table 1 were observed in natural daylight but the change from pale yellow or gold to colorless could be seen with the change of illumination and thickness of the threads layer. It is evident from the results obtained that most of the colors that can be seen on the Veil of Manoppello (except black) correspond to the colors of byssus threads, either natural or after bleaching.

TABLE 1. Chemical bleaching of byssal threads at room temperature

Medium (volume ratio)	Conditions	Final color
1.5% H_2O_2 [a]	5 min	brown, lustrous
1 M NaOH + 1.5% H_2O_2 [a]	1) 35 min 2) 65 min 3) 4 h	1) pale gold, lustrous 2) 3) colorless, lustrous
1 M NaOH + 30% H_2O_2 (2 : 1)	50 min	colorless, lustrous
1 M NaOH + 30% H_2O_2 (20 : 1)	1.5 h stirring	colorless
24% NH_3 + 1.5% H_2O_2 [a]	1) 5 min 2) 30 min	1) brown 2) pale brown
25% NH_3 + 30% H_2O_2 (2 : 1)	30 min	pale yellow, lustrous
2 M NH_3 + 30% H_2O_2 (1 : 1)	20 h	yellow [b,c]
1 M K_2CO_3 + 30% H_2O_2 (2 : 1)	1) 5 min 2) 10 min 3) 30 min 4)1 h 5) 3 h 6) overnight	1) pale reddish-brown 2) dark yellow 3) pale gold, lustrous 4) pale yellow 5) straw to colorless 6) colorless
1) 1 M K_2CO_3 2) after cooling + 30% H_2O_2 (1 : 0.07)	1) 0.5 h 80°C 2) 5 days room temp.	pale gold
3% $KMnO_4$ + 1 M H_2SO_4 (1 : 90)	40 min stirring	colorless
ca. 57% HI + H_2O + 50% H_3PO_2 (50 : 5: 1)	20 min ca. 100°C	red and gold fragments

[a]Final concentrations. [b] Colorless under microscope.
[c] Procedure used in HPLC determination.

Determination of byssus pigments. The observed change of colors of byssus threads after their degradation performed under similar conditions as described for mammalian hair suggested the presence of the same pigments – melanins – in both.

Melanins are the most popular pigments in animal world. They are responsible for the color of skin, hair, eyes and feathers. There are two types of melanins: the black to dark-brown insoluble eumelanin and the yellow to reddish-brown pheomelanin which is soluble in alkali [21, 23]. Their natural synthesis requires amino acids: L-tyrosine for eumelanin and both L-tyrosine and L-cysteine for pheomelanin. Both melanins are heterogeneous macromolecules formed from fundamental monomeric building blocks: 5,6-dihydroxyindole and 5,6-dihydroxy-indole-2-carboxylic acid for eumelanin, and cysteinyldopa for pheomelanin. However, the detailed structure of melanins is still under debate [23]. Unique physical and chemical properties of melanins (like broad band UV-visible absorption, electrical conductivity and photoconductivity, paramagnetism, and redox properties) are responsible for their enormous biological importance, first of all as photoprotective and antioxidant agents [23].

It was established in recent years that in the case of black, brown and blond hair which contains approximately from 99% to 95% eumelanin, the color depends on melanin quantity rather than on the ratio of eumelanin to pheomelanin, whereas red hair contains 67% eumelanin and 33% pheomelanin [20]. Moreover, the color of hair strongly depends on the structure and dispersion of these pigments.

Chemical analysis of eumelanin and pheomelanin as recently proposed in the literature is based on chemical degradation of biological material (pigmented tissues) in strictly definite media, which results in the fragmentation of melanin macromolecules to a number of small organic molecules. Some of them are chosen as specific markers of melanins. The degradation is followed by the HPLC chromatography with the electrochemical, spectroscopic UV or mass spectrometric (MS) detection of markers.

In order to determine melanins in byssal threads the alkaline hydrogen peroxide degradation at room temperature was used following the procedure of Napolitano group [22] but with some modifications (e.g., ammonia was used instead of sodium hydroxide which was not convenient for the MS detection applied). Pyrrole-2,3,5-tricarboxylic acid (PTCA) and 6-(2-amino-2-carboxy-ethyl)-2-carboxy-4-hydroxybenzothiazole (BTCA) were used as markers for eumelanin and pheomelanin, respectively [19, 22].

HPLC equipment (Shimadzu) and a Luna C-18(2) chromatographic column (100 mm x 2.1 mm, 3 μm; Phenomenex, USA) with a pre-column were used, with formic acid/methanol as the mobile phase at a flow rate of 0.2 ml/min. To detect both markers a mass spectrometer 3200 QTRAP (Applied Biosystems) was used. MS conditions for the multiple reaction monitoring (MRM) approach were optimized for the synthetic PTCA standard (synthesized by the oxidation of 5-hydroxyindole-2-carboxylic acid) which was supplied continuously to the spectrometer at a rate of 10 μl/min. The MS2 spectrum of PTCA in the negative ions mode shows four peaks at *m/z* = 197.9 ($[M\text{-}H]^-$ = 198), 154.1 ($[M\text{-}H\text{-}CO_2]^-$ = 154), 109.9 ($[M\text{-}H\text{-}2CO_2]^-$ = 110) and 66.1 ($[M\text{-}H\text{-}3CO_2]^-$ = 66). For MRM analysis two pairs of ions 199/110 and 199/154 were chosen. The determination of BTCA was based on the MS2 spectrum in positive polarity of ions showing the original signal at *m/z* = 283.2 ($[M+H]^+$ = 283) and the following signals of fragmentation products: 177.0, 133.2, and 89.2. The same signals were found in the red hair sample after the same degradation (283.1, 177.3, 133.1, and 89.0, as well as the additional small signal at 196.3). For MRM analysis two pairs of ions 283/89 and 283/133 were used. More details on the HPLC-MS/MS determination will be published separately.

The whole procedure used was checked first for the determination of both melanins in human hair of different colors: black, brown and red. In accordance with the literature data [19, 20], the highest amount of eumelanin marker PTCA was found in black hair, a lower amount was found in brown hair whereas in red hair the amount of PTCA was practically nondetectable. The pheomelanin marker BTCA was found in amounts following the reverse order.

For byssus threads after the same chemical degradation a substantial amount of BTCA was found but PTCA marker was under the limit of determination. Figure 4 shows a comparison of chromatograms obtained for light brown human hair (40 mg sample) and byssus threads (9.5 mg sample); the amount of BTCA marker looks comparable in both samples. BTCA found in byssus threads is an average amount for the threads collected from different mussel species, with different tints of a brown color. Thus, a more quantitative comparison is not advisable.

The results obtained show evidently the presence of pheomelanin as the main pigment in byssus threads and explain similar bleaching procedures to those established for mammalian hair.

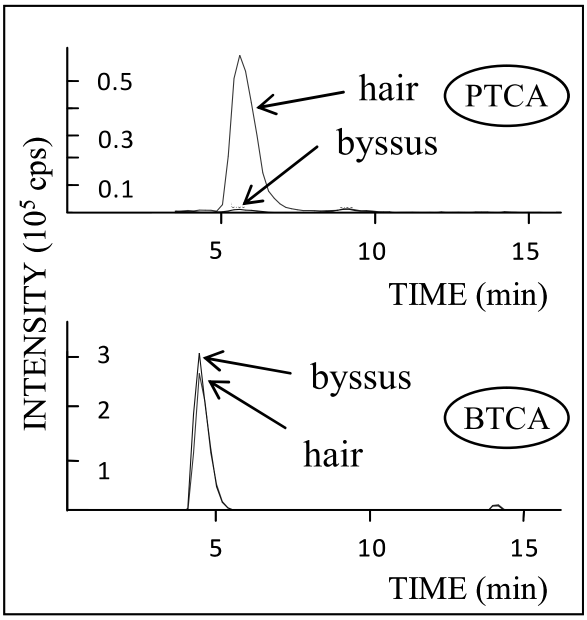

Figure 4. Comparison of HPLC chromatograms (MRM approach) for human light brown hair and byssal threads after the same chemical degradation in ammonia with H_2O_2.

It should be added here that bleaching processes cannot be fully understood unless the melanins structure is known. Nevertheless, it was proposed [24] on the basis of the small-angle X-ray scattering that during the chemical bleaching of synthetic eumelanin the oxidative disruption of hydrogen bonds between oligomer sheets occurs, leading to deaggregation and delamination of origin stacked oligomers. A similar change can be expected during the bleaching of byssus threads.

Polarized light microscopy of byssal threads. Very recently Fanti obtained PLM images in crossed-polarized light of some broken threads in the Veil of Manoppello [8]. These threads showed intense interference colors, the so-called second- and third-order colors. Very similar images are obtained from linen fibers which are built from crystalline cellulose, a birefringent material. Moreover, Fanti did not find similar colors for a sample of byssal threads and concluded [8] that the Veil was made from linen.

Byssal threads of *Mytilus* species are made in mussels from prefabricated smectic polymer liquid crystals in a process similar to the reaction injection molding [9, 10]. The thread core under the outer cuticle is a crystalline area [10]. The birefringence of the distal part of the thread parallel to its axis was reported [25] for the Mediterranean *Mytilus galloprovincialis*. In full agreement with those results, our preliminary examination of *Pinna nobilis* threads under crossed polarizers (using an Eclipse LV100 POL (Nikon) microscope in the transmission mode) showed that the threads had a light blue color between brown edges parallel to the thread axis. The image was completely different from the images of linen fibers and those found in the Veil. Nevertheless, the structure of collagens and melanins in byssus threads is complex, as was mentioned earlier, and at least for melanins it changes substantially during the bleaching process. Thus, the chemically bleached threads may appear in various interference colors, even very different from the natural one.

In PLM images obtained in the reflection mode, using an AXIO observer.A1m (Zeiss) microscope, most of the threads after bleaching according to the procedures presented in Table 1 are pale gold-yellow (Figure 5A), which is contrary to the human red hair (containing the same pigment - pheomelanin) which showed blue and red interference colors (Figure 5B).

In the transmission mode the majority of byssus threads after bleaching appeared in PLM images in light blue and red colors along the thread axis (Figure 6A). The saturation of colors is weak and the pattern of colors is also different from that observed for linen fibers, where the transition between colors is situated perpendicularly to the fiber axis (Figure 6D).

Some byssus threads after bleaching also appeared in other colors (yellow, green) in a more complicated pattern (Figures 6B and 6C), yet different from the images of linen fibers, which are most similar to PLM images obtained from the Veil [8].

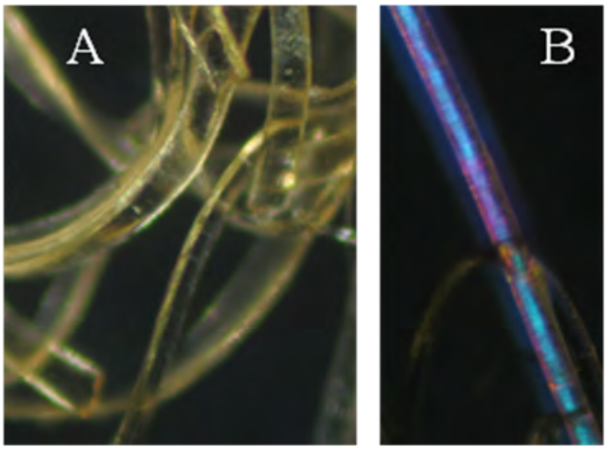

Figure 5. PLM images in reflection mode of byssus threads (A) and human hair (B) after the same bleaching in a solution of ammonia with hydrogen peroxide.

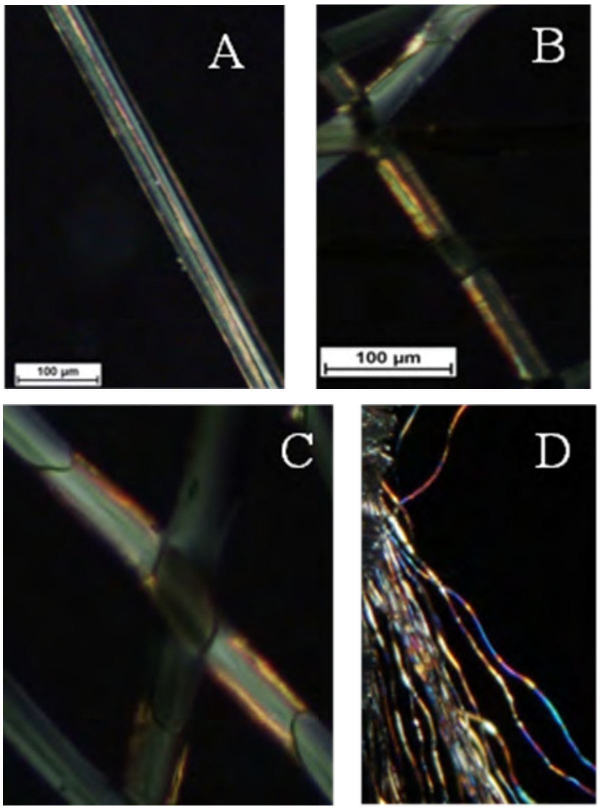

Figure 6. PLM images in transmission mode of byssus threads after bleaching:
(A) 45 h in 1 M K_2CO_3 + 30% H_2O_2 (2:1);
(B) and (C) 35 min in 1M NaOH + 1.5% H_2O_2;
and PLM image of linen fibers (D).

3. CONCLUSIONS

A. Considering the properties of byssus which could be related to colors and other optical characteristics of byssus fabrics the following conclusions can be drawn.

(i) It was found using chromatographic analysis that pheomelanin is the main pigment of byssal threads responsible for their natural brown color.

(ii) The original brown color of threads can be chemically changed to yellow, golden, pale straw, reddish and finally colorless.

(iii) It was confirmed that under strong illumination the bleached byssus threads are completely transparent.

(iv) Preliminary examinations revealed that after degradation byssus threads could have interference colors in PLM images with cross-polarization.

B. As regards the images seen on the Veil of Manoppello, the following conclusions can be drawn.

(i) There are some interesting properties of byssal threads, which could be related to the unique properties of the images on the Veil of Manoppello. They include the transparency of threads under a strong illumination and the possibility to obtain most of the colors seen on the Veil from the natural pigment of byssus threads after their modification, e.g., by chemical bleaching. A possibility of the change of byssus colors by other modifications of pheomelanin, e.g., by applying UV irradiation, should be verified experimentally.

(ii) The byssus hypothesis offers an additional similarity between the images on the Veil of Manoppello and on the Shroud of Turin, besides similarities in the appearance of the Face. Namely, both images appear to be similar as concerns their chemical nature, which is related to some modifications of the fabric itself: the oxidation / dehydration processes of cellulose of the linen in the case of the Shroud and bleaching processes of pheomelanin in byssal threads (at least in some parts of the image) in the case of the Veil.

(iii) PLM images of byssal threads after bleaching were different from those found by Fanti for the threads in the Veil of Manoppello. Taking into account the very complex structure of byssus threads and melanins as well as the lack of knowledge about the relations between bleaching procedures and interference colors seen in PLM images, the byssus hypothesis should be further investigated. However, at present the results obtained by Fanti [8] point to the linen as a more probable material of the Veil.

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The Face on the Shroud of Turin and on the Veil of Manoppello

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Abstract
The following article deals with the correspondences between the face on the Shroud of Turin and the face on the Veil of Manoppello as well as with the possible influence of both on the portrayal of Christ. The author tried to prove the correspondences by an especially elaborated sketch.

Keywords: Shroud of Turin, Veil of Manoppello, Image of Christ.

1. INTRODUCTION

In his research the author [1] came across the international symposion "La Sindone e le icone" held in Bologna on May 6–7, 1989, where in a comparative analysis the features on the Shroud of Turin were compared with the artistic, and in particular the Byzantine, portrayals of the face of Christ. G. Tamburelli and N. Balossino [2] compared the face on the Shroud with seven portrayals of the face of Christ from the 6th to the 12th century by translating them into a numerical form, thereby discovering corresponding features. Nothing was said about the Sudarium, however. This is why the author, inspired by the work of B. Schlömer [3] and H. Pfeiffer [4], felt induced to check the correspondences between the face on the Veil of Manoppello and the face on the Shroud of Turin as well as of several portrayals of Christ from the 3rd up to the 12th century.

2. EXPERIMENTAL METHOD

Material used in this research:

A photo of the face on the Shroud; photos of the obverse and the reverse side of the Veil of Manoppello, each taken by the author in order to guarantee an equal distance.

Photos of the portrayals of Christ in the catacombs obtained from the *Commissione di Archeologia Sacra*, Rome; photos of the images of Christ on the Reliquary Cross of Justine II purchased at the Tesoro di S. Pietro; some other photographs taken by the author as well as out of the personal archive.

Using Photoshop, the digitalised images of the face on the Veil were put on top of the photonegative of the face on the Shroud so that a significant level of congruence could be achieved in 6 common particularities of the two (see Fig. 2, points 5, 7, 13, 14, 16, 18). Twenty points of orientation were defined (it might also have been 100 or 1000) so as to make a sketch on the computer and check the correspondences between the two faces and the portrayals of Christ in the catacombs and in iconography.

The sketch (see Fig. 1) was made on the photonegative of the face on the Shroud and the front side of the Veil of Manoppello and checked with the original of the face on the Shroud as well as with the reverse side of the Veil.

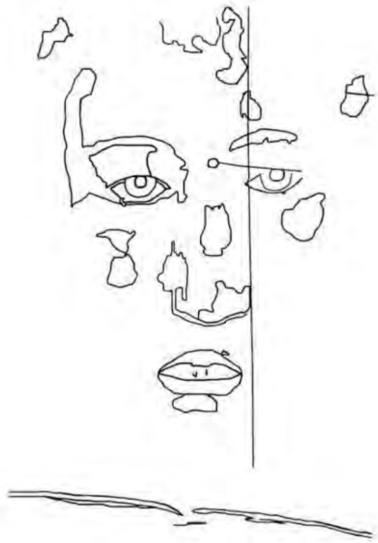

Figure 1. Sketch.

Points of orientation (S = Shroud, V = Veil) and points of congruence (V, S), see Fig. 2

1 Tuft of hair (V): The tuft of hair on the Veil has become an identification characteristic in the iconography of Christ.

2 Vertical line (S): The line runs across the whole face on the Shroud and serves as the basic orientation for the sketch.

3 Traces of blood (S): There are four traces of blood which can only be located on the Shroud.

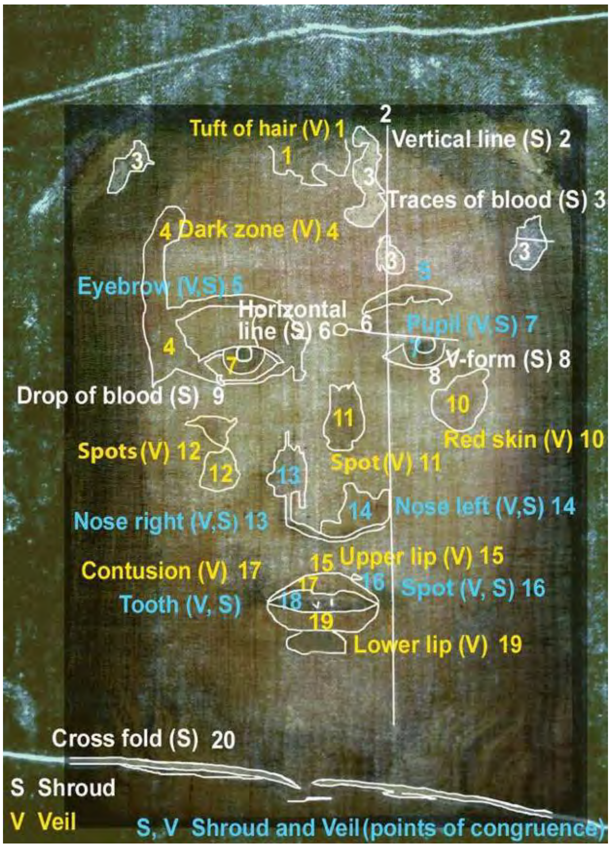

Figure 2. Shroud, photonegative, Veil, sketch, points of orientation and points of congruence.

4 Dark zone (V): at the side of the right eye on the Veil.
5 Eyebrows (V, S): Whereas the eyebrows are rather prominent on the Veil, only contours of them are visible on the Shroud. This detail is of special significance as far as a comparison with the images of Christ in the catacombs and in iconography is concerned.
6 Cross line (S): The white line across the left eye on the Shroud provides a very striking point of orientation.
7 Pupils (V, S): Whereas on the Veil the pupils come out very well, on the Shroud they are only indirectly visible because the eyes seem to be closed.
8 V-form (S): This refers to a triangular white spot on the lower lid of the left eye on the Shroud which enables a quite exact congruence with **9**.
9 Drop of blood (S): The drop of blood on the lower lid of the right eye on the Shroud together with **8** guarantees a significant congruence of the sketch.
10 Reddish spot (V): The reddish spot on the Veil facilitates the adjustment of the sketch.
11 Dark spot (V): On the left side of the nose (front side of the Veil) there is a dark spot which is not only of great significance for adjusting the face on the Veil to the sketch as well as to the Shroud, but also helps to distinguish the front side from the reverse side of the Veil. On the reverse side this spot is on the right.
12 Other spots (V): The right cheek of the face on the Veil shows another dark triangular spot as well as a brownish one, which guarantees a further refinement when adjusting the sketch.
13 Nose right (V, S): On the right side of the nose on the Veil one can see a particularly dark spot which has only a vague correspondence on the face of the Shroud.
14 Nose left (V, S): There is a dark spot on the right side of the nose on the Shroud which also has a correspondence on the face of the Veil.
15 Upper lip (V): The upper lip on the Veil is very distinctive and makes possible a quite precise adjustment of the mouth section.
16 White spot (V, S): A small white spot on the upper lip of the face on the Veil helps to adjust this section to the corresponding white spot on the photonegative of the face on the Shroud.
17 Contusion (V): The upper lip of the face on the Veil apparently shows a contusion the contours of which are clearly visible.
18 Lines (S), tooth (V): Two white lines in the mouth section of the face on the photonegative of the Shroud – one of them V-shaped – are congruent with the lower end of the upper tooth section of the face on the Veil. This correspondence means a final help when putting the two images (Shroud and Veil) on top of each other.
19 Lower lip (V): The lower lip on the face of the Veil is quite distinctive, too, and also supports a precise adjustment of the mouth section.
20 Cross fold (S): The broad white cross fold below the face on the Shroud is indispensable for working out the sketch and bringing it into correspondence with the faces on Shroud and Veil.

Correspondences between the faces on Shroud and Veil

The following figures illustrate the correspondences between the face on the Shroud (see Figs. 3-4) and the face on the Veil (see Figs. 5-6):

The photonegative (Fig. 4) of the face on the Shroud is better suited to illustrating the congruence between the face on the Shroud and the face on the Veil because the original face on the Shroud does not allow an exact congruence. For this reason it's quite improbable that the face on the Shroud served as a prototype for the images of Christ in the catacombs and in iconography.

As to Fig. 5 and 6, the sketch was adjusted to the remarkable features of the face on the Veil which come to full expression. Of course, some more points of orientation could have been chosen, but the ones shown here are absolutely sufficient to guarantee the correspondence.

The two images are based on two different photographs each taken from the front and the reverse side of the Veil. The one is not simply the inverse image of the other.

One of the most important features on the Veil is the *tuft of hair* which is particularly significant for the dating of the Veil and, thus, also of the Shroud (see Figs. 5-6).

Figure 3. Original face of the Shroud with sketch.

Figure 5. Front side of the Veil with sketch.

Figure 4. Photonegative of the face of the Shroud with sketch.

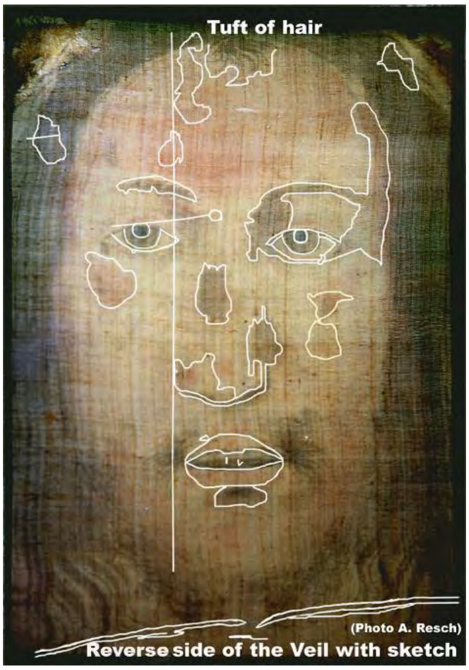

Figure 6. Reverse side of the Veil with sketch.

What is particularly worth mentioning in this context is the double face image discovered by G. Fanti [5] on the reverse side of the Shroud (see Figs. 7-8). Whereas the sketch turns out completely congruent with the contours of the face, the traces of blood seem to have moved out of place because – when penetrating the linen – the blood went the usual way of the fabric. This is to say – and has amply been demonstrated by others – that the traces left on the Shroud by the corpse as well as the blood traces do not interfere with the image of the body. This is definitely shown by the sketch on the double image which turned out as a major contribution to the understanding of the Shroud of Turin. The sketch shows a very good correspondence with the faces on Shroud and Veil and clearly demonstrates the difference between body image and blood traces.

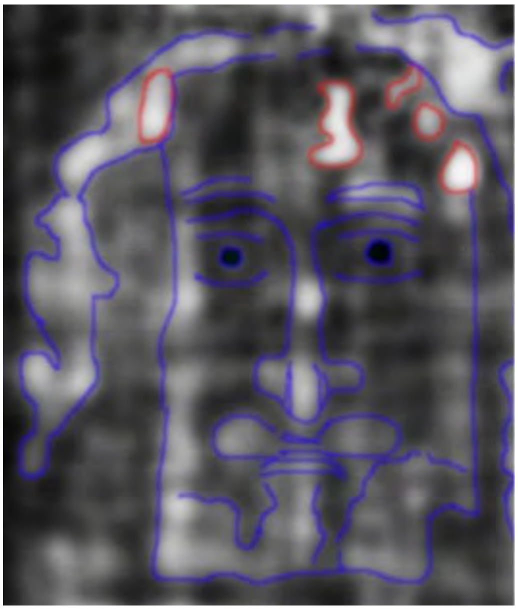

Figure 7. Double face image (Fanti).

Figure 8. Double face image, sketch.

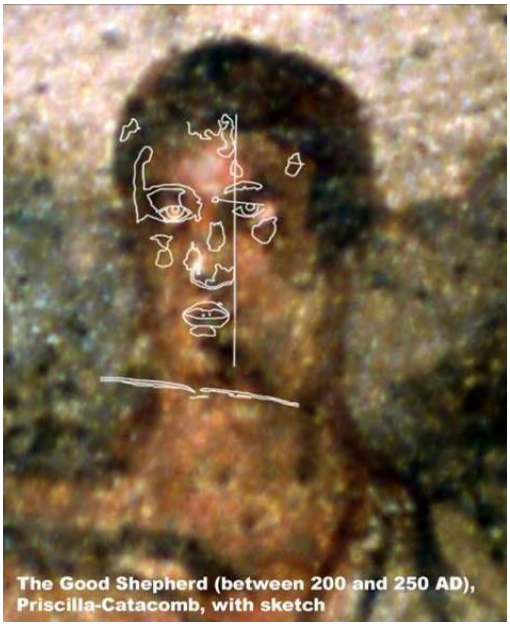

Figure 9. Good Shepherd with sketch (Priscilla Catacomb).

Figure 10. Good Shepherd with sketch (Aurelian hypogeum).

Correspondences with images in the catacombs

Amazingly, it turned out that even with the image of the Good Shepherd (200–250 AD) in the Priscilla Catacomb [6] the proportions are almost perfect (see Fig. 9).

The image of the Good Shepherd, portrayed as a Cynic philosopher [7] in the hypogeum of the Aurelians (before 270), shows a significant degree of correspondence, too (see Fig. 10).

The fresco „Christ with disciples“ in the Domitilla Catacomb [8] dates back to between 330 and 340. The young Christ on the chair in the centre takes more than a quarter of the painting and – as the sketch shows – proves an impressive degree of correspondence with the face on the Shroud and on the Veil (see Fig. 11).

It should be pointed out that the sketch only adjusts in the way it does on the original face on the Shroud (see Fig. 3).

Particularly impressive is the correspondence of the sketch with the first portrayal of Christ, i.e. Christ Enthroned in the catacomb of Peter and Marcellinus [9], Via Labicana, Rome (see Fig. 12). Again, the correspondence of the sketch is like the one on the original face on the Shroud. The imposing painted ceiling showing Christ between the apostles Peter and Paul dates back to 375.

Figure 11. Christ among the disciples, with sketch

Figure 12. Christ Enthroned with sketch

Figure 13. Image of Christ, Comodilla Catacomb, with sketch

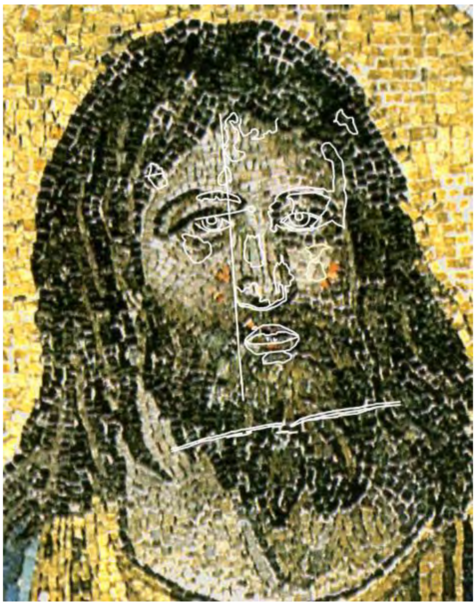

Figure 14. Christ among the apostles, with sketch

Also the splendid image of Christ in the Comodilla Catacomb (375 AD; Fig. 13) shows a significant correspondence with the original face on the Shroud and, thus, with the reverse side of the face on the Veil of Manoppello [10].

Even the proportions in the large mosaic painting in the apse of the Basilica of Santa Pudenziana in Rome (see Fig. 14), dating back to between 401 and 417, correspond to those of the sketch and, thus, to the face on the Shroud and on the Veil [11].

Of particular historical interest is the correspondence of the sketch with the medallion of Christ on the Cross of Justin II (see Figs. 15-16) given by him to the Pope John III in 570 AD, which can still be admired in the Treasure of St. Peter in Rome [12].

Besides other points of congruence, it is the tuft of hair which deserves a special attention and which also appears on the Veil of Manoppello (see Figs. 5-6). The author is therefore convinced that the Veil had served as a model in the portrayal of Christ.

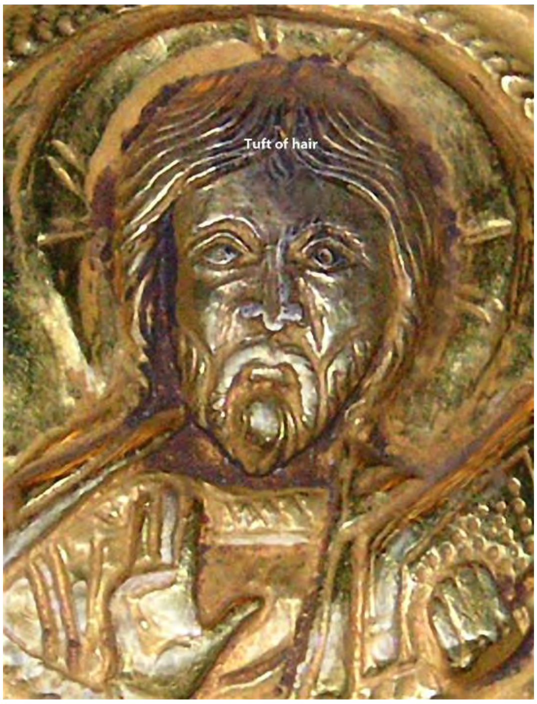

Figure 15. Medallion of Christ, Cross of Justin II

Figure 16. Medallion of Christ, Cross of Justin II, with sketch

Correspondences with images in iconography

The Santo Volto (see Fig. 17) was made in Constantinople, brought to Genoa by Leonardo Montaldo in 1362 and donated to the Church of St. Bartholomew of the Armenians in 1384 [13]. Its style is similar to that of the Vatican Mandylion; the time of origin may have been the same, too.

The sketch can only be fitted in like on the photonegative of the face on the Shroud resp. on the front side of the Veil.

Figure 17. Santo Volto of Genoa (St. Bartholomew of the Armenians)

The Vatican Mandylion (see Fig. 18) was also made in Constantinople and its style virtually corresponds to the style of the Santo Volto of Genoa. Even the holes for suspending them correspond to each other [14]. It is assumed to have reached the Occident at the same time. The sketch can only be adjusted like on the original of the face of the Shroud and on the reverse side of the Veil.

The representation of the image of Christ on the famous icon of the Novgorod School [15] exactly follows the Byzantine tradition (see Fig. 19), showing enlarged eyes and a sharply pointed nose. The tuft of hair is of particular importance.

The sketch fits in the image in the same manner as it does on the Shroud original.

Nevertheless, it should be mentioned that there are also well-known images of Christ with which the sketch as used above does not harmonize in an appropriate manner [16].

The famous image of Christ Pantocrator may serve as an example (see Fig. 20).

In any case, apart from the different artistic representations, the icons showing the tuft of hair are most impressive from a historical point of view.

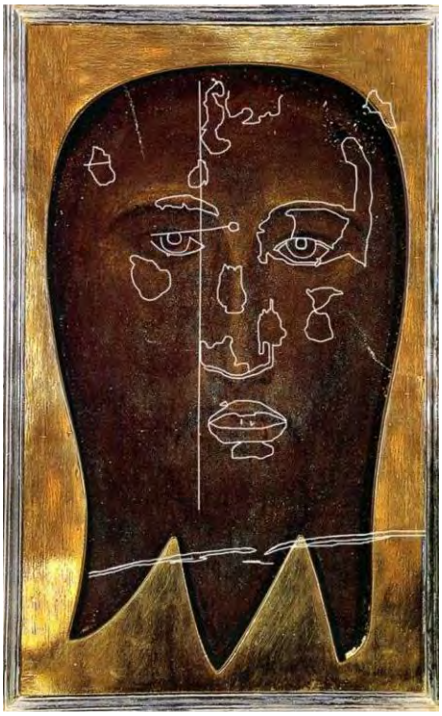

Figure 18. Vatican Mandylion (Galleriola del Romanelli)

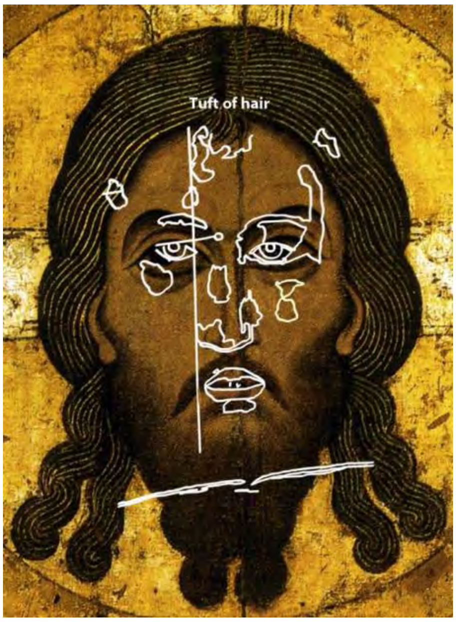

Figure 19. Mandylion of Novgorod (Tretajakovskaja Galeria, Moscow)

3. CONCLUSIONS

Since the face on the Veil of Manoppello seems to be congruent with the face on the Shroud of Turin (see Fig. 21), it may be concluded that both faces refer to one and the same person.

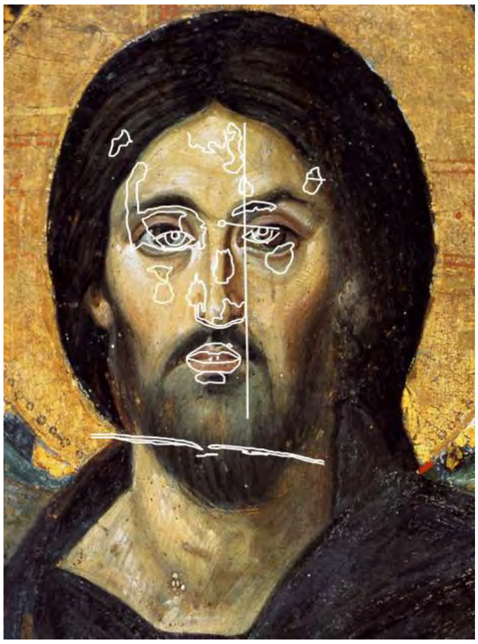

Figure 20. Christ Pantocrator, St. Catherine's Monastery, Sinai

The correspondence with the face of Christ on the Cross of Justin II (see Fig. 22) by the characteristic tuft of hair is a very convincing proof of the face on the Veil having served as a model. This detail is quite significant so that any counterargument becomes superfluous. Because of the correspondences described above this fact is also important as far as the dating of the Shroud is concerned.

That the person on the Shroud of Turin might be Jesus Christ can only be deduced from the correspondence of the Gospels with the specific features of the body image on the Shroud. The face on the Veil alone does not suffice.

The investigations also made clear that – if the face on the Veil of Manoppello dates back to Jesus Christ – the impregnation is likely to have occurred between the flagellation and the crucifixion, because the image is that of a tortured (nasal bone fracture and lip contusion) but living and self-assured man.

The fact that the face on the Veil, by means of the sketch, may at least be dated back to the Cross of Justin II if not even to the Good Shepherd is also a point in favour of the age of the Shroud. It also appears that the proportions used in the iconography of Jesus Christ were taken from the Veil, as the original face on the Shroud would not deliver such exact measures.

In addition, the correspondence of the sketch sometimes only with the front side and sometimes only with the reverse side can just be explained by the fact that because of the peculiarity of the Veil one did not exactly distinguish between front side and reverse side.

Still, as regards the mode of expression in the iconography of Christ, the influence of the face of the

Shroud is not to be excluded.

Finally, the significant correspondences of the face on the Shroud and the face on the Veil with images of Jesus Christ dating back to the third century prove that even in those days there existed stringent norms concerning the proportions when portraying Jesus Christ.

Figure 21. Shroud, photonegative, Veil, and sketch

Figure 22. Medallion of Christ, Cross of Justin II, Veil, and sketch

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The face of Manoppello and the veil of Veronica: new studies

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Abstract
In recent years, studies on the Holy Face have experienced substantial growth, although, up to date, no scientific study has been published in a peer-reviewed journal. Art-historical studies have suggested a possible identification of the Face of Manoppello with the Veil of Veronica kept in the Basilica of St. Peter in Rome. But how far and how can you take this path of research? This study proposes to address this issue in the light of recent new studies carried out by the author on the original manuscript Opusculum de Sacrosancto Veronicae Shroud (Code H3) by Giacomo Grimaldi kept in the Vatican Secret Archives and repeatedly brought as a crucial document by supporters of that thesis. Further research has been effected on the frame of the Holy Face, dating back to the fourteenth century and now preserved in the Museo del Tesoro in San Pietro.

Keyword: Giacomo Grimaldi, Manoppello, Veronica's veil, frame of the Volto Santo

1. INTRODUCTION

In 1999 Father Heinrich Pfeiffer [1] announced at a press conference in Rome that he had found the real Veronica's veil in a monastery in Manoppello (figure 1), a little town in Abruzzo. Pfeiffer believes that the Volto Santo was stolen from St. Peter's and was passed from family to family until it came to the monastery [2].

Figure 1. The veil of Manoppello.

In a contrasting story, André Chastel, in his book *The Sack of Rome 1527*, wrote that the Veronica's veil was put up for sale in the taverns of Rome by Lutheran soldiers of the imperial army. Of a similar opinion is the scholar Saverio Gaeta [3].

In this report I will not refute such studies but only make a contribution with my personal observations about some points in this exciting research. There is no denying that in recent years interest in the veil of Manoppello has increased dramatically worldwide, although for centuries it had been only a local devotion confined in a remote village in the province of Abruzzo. In addition to Father Pfeiffer several other scholars are working on the study of the veil of Manoppello, to mention a few of them I can recall Sister Blandina Paschalis Schlomer [4], prof. Giulio Fanti [5], prof. Pietro Baraldi, Andrea Resch [6], Paul Badde and Saverio Gaeta.

I myself, as well as having made photographic analysis, suggested the identification of the veil with a portrait of Albrecht Durer donated to Raphael, which was remembered by Vasari [7].

2. VERONICA'S VEIL

The original ciborium for the Volto Santo (figure 2) was a marble parapet in the north aisle paved with porphyry and marble. It remained in this enclosure until Pope Clement III commissioned a new ciborium at the end of the twelfth century. The new ciborium, recorded by Giacomo Grimaldi, included [8] an altar table with an image of the Veronica displaying the veil above it. Four columns support a second story that covers the altar space. In the second register, there is another image of the Veronica holding the Volto Santo [9].

It too contains two columns that support a third story on which the reliquary is housed. The reliquary is contained within a tabernacle that has two twisted columns, a grille, and a small door, which presumably opened to the reliquary. On March 21, 1606 the Veronica was solemnly placed in a niche carved inside the pylon of the Veronica. But does it look like the relic of the Veronica preserved in St. Peter's?

Journalists Paul Badde [10] and Saverio Gaeta [11], who like me have had the opportunity to see it, tell in their publications about their encounter with the Roman Veronica [12], but they radically put into question its authenticity, describing it as a decaying object, an image "in ruins", which is sometimes impossible to identify [13].

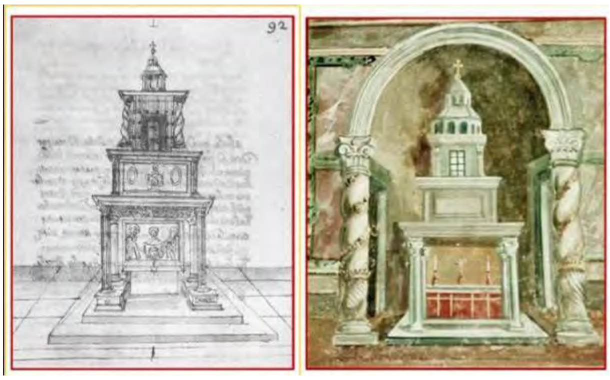


Figure 2. The ancient cyborium of the Veronica.

I can confirm that strongly, as in October 2005 I had a special permit to be able to closely observe it from the gallery where it is kept in St. Peter's [14]. The two authors above claim that we are faced with a false history. (figure 3).

Figure 3. Veronica's veil exhibition in St. Peter in Rome.

The description of the scholar De Waal, now from the last century, is revealing: *"The beard is divided into three points ... and it is dark brown, the same color, for a length of about two fingers, can be found on the forehead; supposing it is hair, it is not possible to see or distinguish its pattern ...of the eyes, the nose, the mouth…you cannot see anything at all…"*. It is known that nobody has ever been allowed to take photographs closely. Unexpectedly, however, a photograph (figure 4) of the relic has recently appeared on the website of the Holy Face of Manoppello [15]. Although technically bad (this is obviously a picture taken without permission) it confirms the current state of the relic.

Figure 4. Detail of the Veronica's veil.

3. GIACOMO GRIMALDI AND THE CODE H3

Some scholars like Saverio Gaeta have suggested that the Veronica was stolen during the sack of Rome in 1527. To support the theory of theft they propose that, since the type of representation of the Veronica changed from approximately that time, the original was stolen and replaced with a fake that shows a completely different iconography.

Saverio Gaeta has tried to emphasize this issue by proposing an intuition about a work of 1618 by Giacomo Grimaldi *Opusculum de sacrosancto sudario Veronicae*. (figures 5 and 6).

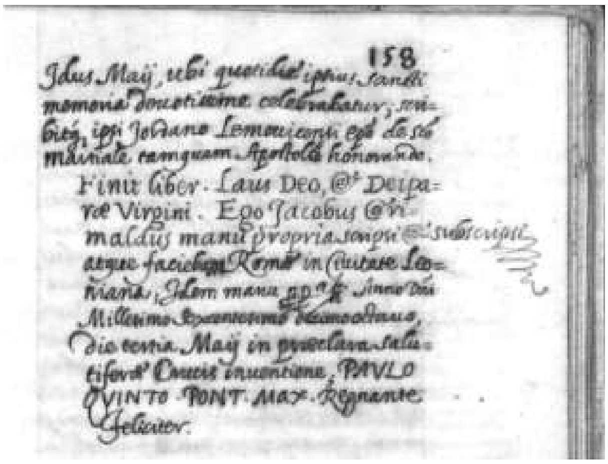

158
Finit liber. Laus Deo, et Deipa-
rae Virgini. Ego Jacobus Gri-
maldus manu propria
PAVLO
QVINTO PONT. MAX. Regnante
Feliciter.

Figure 5. The unpublished book of Giacomo Grimaldi.

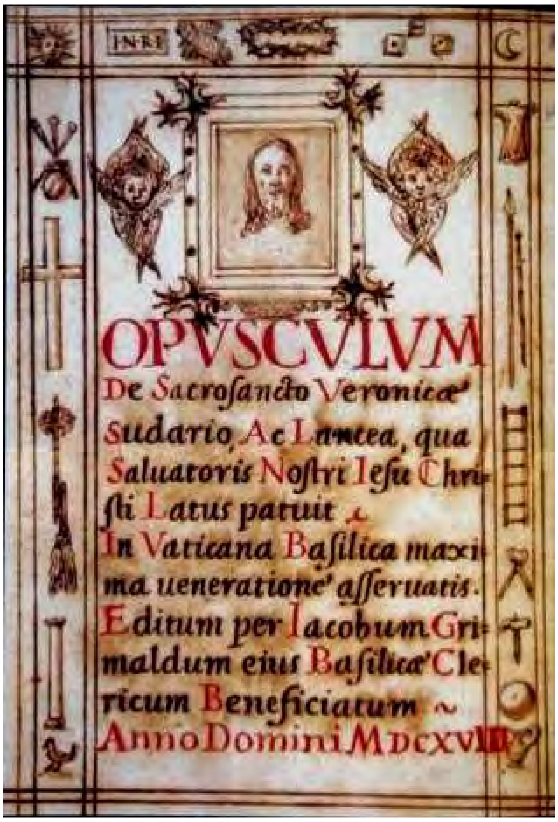


Figure 6. Cover of Grimaldi's book dated 1618.

He states that the date of 1618 present in the title was replaced with that of 1616 because it had to give the impression that, following the request for a copy of the relic by the Queen Constance of Austria, wife of the Polish king Sigismund III, everything was regular and that the original Veronica was still there. Without going into historical details here, the hypothesis proposed by Gaeta is rather curious.

Examining the original code H3 [16] preserved in the Vatican Library I could easily see the following: (figure 7).

1. The frame appears on the title of Veronica, prior to that of 1675, which had a plaque at the bottom where it was written that Peter Strozzi said frame restored in 1617. This restoration is described on page 108 of the manuscript: *"Instauratum cura Petri Strozae canonici anno d.ni 1617 Orate Deum pro eo"*.

2. The date of the manuscript is clearly stated by Grimaldi on page 158 stating:
   "*Finit liber. Laus Deo, e Deiparae Virgini. Ego Jacobus Grimaldus manu propria scripsi e subscripsi atque faciebam Romae in Civitate Leoniana; idem manu propria* ***Anno Domini Millesimo Sexcentesimo decimo octavo****, die tertia Maiy in praeclara salutiferis Crucis inventione; Paulo Quinto Pont. Max regnante feliciter"*.

3. Note that the date of completion of the manuscript is written in Roman numerals, but not fully and that the calligraphy shows no remorse whatsoever. It is, moreover, questionable the observation of Gaeta that the title is drawn with formal care.

Figure 7. Dating of Grimaldi's book.

There are a number of designs that do not fall into double lines demarcating the page (figures 8, 9). It seems clear that these lines have been drawn after penned letters and drawings. The case however is not isolated.

On the frontispiece of the 1620 manuscript copy preserved in Florence it is clear that the writing of the date, even if this is penned in full, lacks lines of demarcation.

It is sure that the date of the work of Grimaldi was not counterfeited. How would it be possible to describe an operation taking place in 1617 in 1616? (figure 10).

I think that all scholars who hold this view have not bothered to study directly the original Giacomo Grimaldi, but instead have followed a line of research that is not documented or worse, not verified.

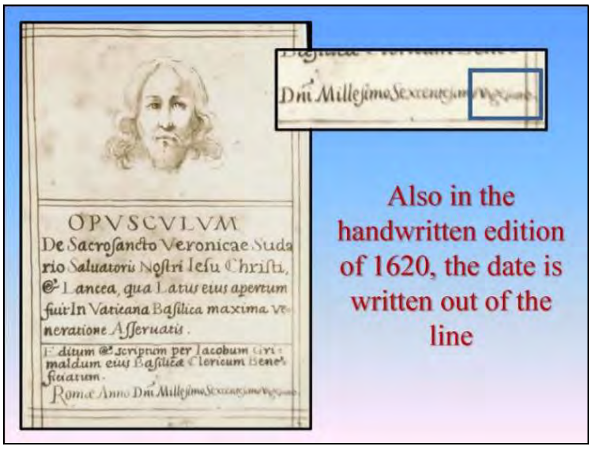


Figure 8. Edition of Florence.

Figure 9. Graphic imperfections.

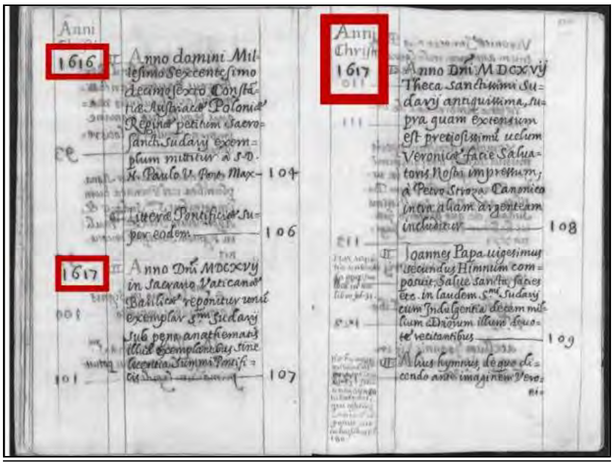


Figure 10. Table of contents.

4. THE 1675 FRAME

In the frontespice of Grimaldi's volume of 1618, Veronica's veil is represented whithin a frame that he considers very ancient. The occasion was its restoration carried out by the canon Pietro Strozzi. Could it be the 13th century frame used again, adding an outer clothing with crescents? (See figures 11, 12). This particular decoration with crescents at the sides was interpreted by some scholars as belonging to the coat of arms of the Piccolomini family.

Instead I think I can state with certainty that this symbology belongs to the family Strozzi, whose coat of arms shows this graphics.

The present frame (pictures 13, 14) was made by the goldsmith Carlo Spagna by request of Cardinal Francesco Barberini and dates back to 1675 [17].

Let's start examining if the measurements of the 16th century frame, reported by Badde and Gaeta, as well as by De Waal, have been taken precisely. Badde writes he has been able to measure the relic: cm 32 × cm 20 inside the golden frame, while the "face" alone is cm 28.5 long.

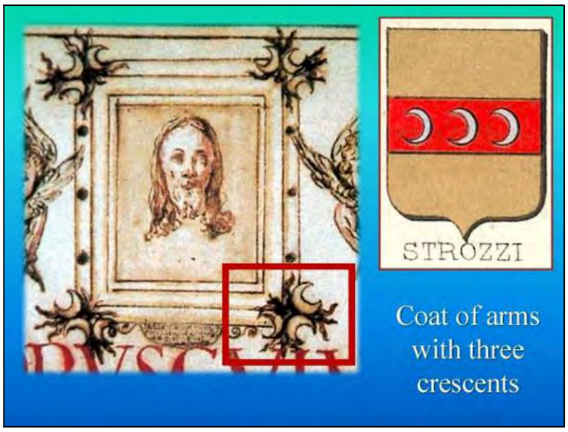


Figure 11. Detail of coat of arms.

Figure 12. Comparison with 1350 frame and the 1635 edition of Grimaldi's book.

Figure 13. Front of 1675 frame.

My personal measurements of the frame are: 34.4 × 23.3 for the gold leaf and 29.7 × 19 for the face area. Badde's figures would seem therefore unreliable.

Figure 14. Back of 1675 frame.

De Waal says: " *A modern silver frame with the emblem of Gregory XVI, cm 63 high and cm 51 wide, keeps under a glass an ancient plate of golden metal, on which there is a very fine net of silver thread. The golden plate is surrounded by some small decorations…In this plate the space for the Holy Face was cut. The plate is cm 31 high and cm 20 wide; the Holy Face appearing below is high, from the end of the beard cm 25 and cm 16 wide; his ears and maybe a part of the face and hair are covered by the plate…so that only cm 21 × cm 12 of the face are visible..."* [18].

5. THE 1350 FRAME

In November 2007 I got a special authorization to study at close range the 13th century frame (figure 15) kept in the museum of the Treasury in the Vatican Basilica. Also Paul Badde took some measurements. According to him the frame is cm 25 × 25 in the area we are interested in.

It is necessary to stress that these measures were taken by Badde empirically from outside the museum glass case and not directly on the frame.

Even in this case I think his figures are wrong. I could observe and measure the frame (figure 16) outside the glass case and it measures 40 × 38 in the outer part and 31.7 × 29.5 inside.

Something doesn't correspond. Another important point to analyze is whether the frame had crystal on both sides to favour the veil transparency, as many scholars have taken for granted. We can quote Grimaldi: "*A beautiful plate of pure white and transparent rock crystal, still kept in the same Archive, adorned with a frame of fine silver and images engraved all around, split into two parts probably because of the carelessness of its attendants"* [19]. In conclusion it seems obvious that Grimaldi is speaking of one crystal, (figure 17) but he doesn't say if originally the frame had crystal on both sides.

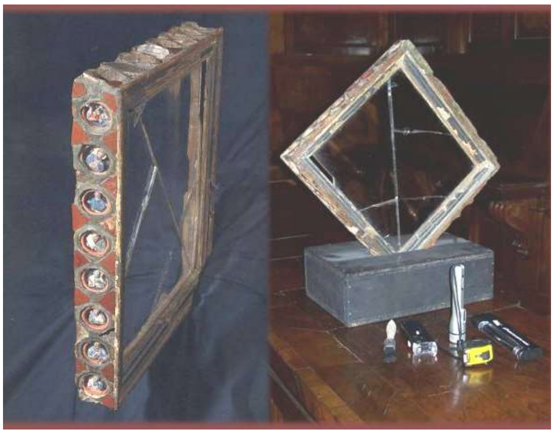


Figure 15. Analysis of the frame.

Figure 16. The author analyzes the frame.

6. VERONICA'S VEIL COPIES

Between 1616 and 1617 Pietro Strozzi painted at least four or five copies of the Veronica. Besides the one for the Vatican vestry and the one for the Queen of Poland, the others were destined to the Pope, the grand duke of Tuscany and the bishop Roberto Ubaldini di Montepulciano.

Figure 17. Damaged glass.

On 7th September 1616 a peremptory letter was written on behalf of Pope Paolo V, who forbid any new copy under penalty of excommunication.

In the first months of 1628 the new Pope Urbano VIII gave even severer provisions, as documented by two circular letters sent to all archbishops by cardinal Bernardino Spada on behalf of the Pope, where all faithful were ordered to hand in any copy representing " *the real sacred Image of the Holy Face*" under penalty of excommunication (figure 18).

Figure 18. Copies of the Veronica's veil.

An important copy of the Veronica is kept in the Schatzkammer in the Hofburg Palace in Vienna (picture 19). It dates back to 1617 and belonged to the family Savelli until 1720, when Caterina Savelli gave it to the Emperor Charles VI.

Another copy dating back to 1617 has been found in Chiusa Sclafani, (figure 20) a small centre near Palermo in Italy. Pope Clemente VIII gave it to a Franciscan friar, Innocenzo, who was his personal counselor in Rome.

The copy kept in the Chiesa del Gesù in Rome (figure 21) was donated by the Pope Gregorio XV to the Duchess Sforza in 1621. Finally the copy kept in Venetico in Sicily (figure 22) dates back to the time of di Urbano VIII.

It seemed that other copies have not been available until recently. During archival research, I was able to find a copy of the Strozzi Veronica from 1617 in Bologna, in the church of St. Jerome, known as the Certosa [20].

Figure 19. Copy of Wien.

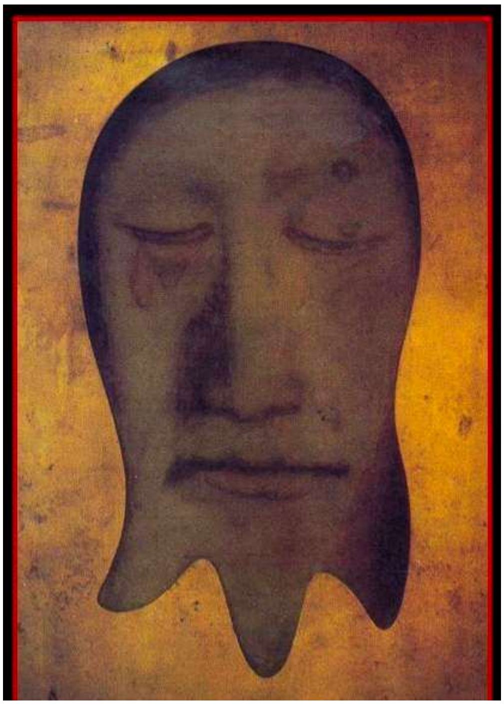


Figure 20. Copy of Chiusa Sclafani.

Figure 21. Copy of Chiesa del Gesù in Rome.

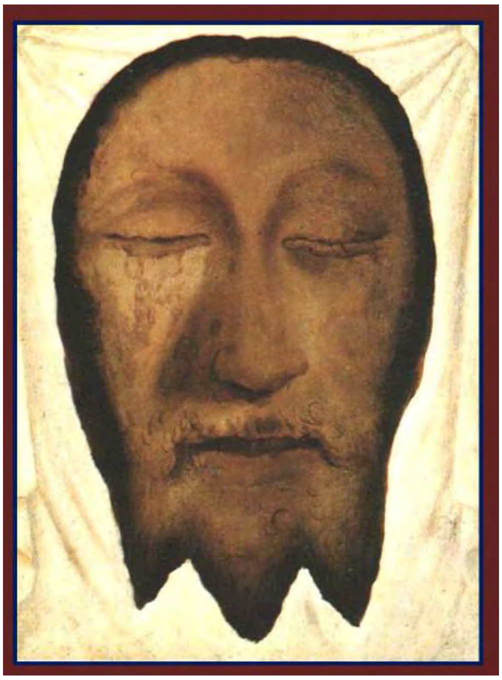


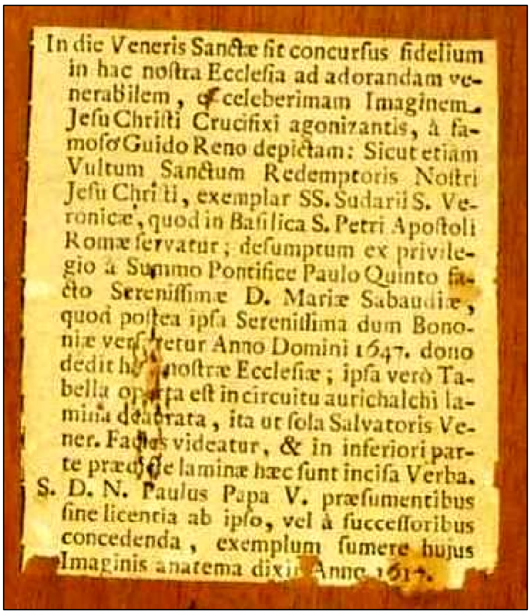
Figure 22. Copy of Venetico.

Currently it has not been exposed to the public for several years and perhaps for this reason it has not been reported (figure 23). I state that I am gathering more historical references as the discovery is very recent.

In the back of the complicated outer frame there is a scroll that describes briefly the origin (figure 24).

The image is in all respects equal to the copy of Vienna. We find, in addition to engraving on gold plate, even the exact same frame (figures 25, 26) and the same engraving by Pietro Strozzi. This copy [21], which was not known to exist, was donated by Pope Paul V to Apollonia Maria of Savoy [22] who in turn gave it to the Capuchin convent in Bologna in 1647 (figure 27).

Figure 23. New discovery: the copy of Bologna.



In die Veneris Sanctæ fit concursus fidelium in hac nostra Ecclesia ad adorandam venerabilem, & celeberimam Imaginem Jesu Christi Crucifixi agonizantis, à famoso Guido Reno depictam: Sicut etiam Vultum Sanctum Redemptoris Nostri Jesu Christi, exemplar SS. Sudarii S. Veronicæ, quod in Basilica S. Petri Apostoli Romæ servatur; desumptum ex privilegio à Summo Pontifice Paulo Quinto facto Serenissimæ D. Mariæ Sabaudiæ, quod postea ipsa Serenissima dum Bononiæ ver[illegible]retur Anno Domini 1647. dono dedit h[illegible] nostræ Ecclesiæ; ipsa verò Tabella op[illegible]ta est in circuitu aurichalchi lamina deaurata, ita ut sola Salvatoris Vener. Fa[illegible] videatur, & in inferiori parte præd[illegible]e laminæ hæc sunt incisa Verba. S. D. N. Paulus Papa V. præsumentibus sine licentia ab ipso, vel à successoribus concedenda, exemplum sumere hujus Imaginis anatema dixi[illegible] Anno 161[illegible].

Figure 24. Scroll in the back of the frame.

Figure 25. Wien and Bologna: the same frame.

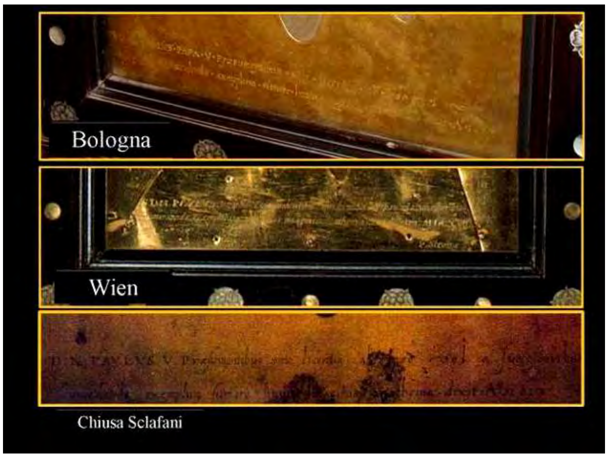


Figure 26. Detail of the inscriptions of Strozzi.

Figure 27. Mary Apollonia of Savoy.

7. CONCLUSION

In this research I attempted to clarify whether the current veil of Veronica, preserved in the basilica of S. Peter's in Rome, is still the original or has been replaced in an unspecified date unknown to us. My careful study of the code H3 of Giacomo Grimaldi, who is still unpublished, allowed me to shed light to determine the exact date of the manuscript. The direct study of the two frames of the relic has clarified many doubts and uncertainties. The error in dating the manuscript by some scholars shows that the documents should always be studied directly, especially if unpublished. I think that the exploratory path on history and iconography of Veronica's veil will be in future still full of surprises. I left open the various hypotheses proposed relying on a clear comparison with the other scholars involved.

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13. "*Es ist ein Objekt in Auflösung: ein fleckiger dunkler Stoff ohne jede Kontur ... Ich tastet mit dem Strahl meiner Stablampe das Gewebe ab: doch es ist kaum auszumachen, daß es überhaupt Gewebe ist. Das Bild ist eine Ruine"*, in: Badde, P., *Das Muschelseidentuch*, cit., pag. 259

14. I was also allowed by the Sanctuary's rector to observe the Holy Face through a portable microscope, for a more detailed approach.

15. http://holyfaceofmanoppello.blogspot.com/

Picture, in all probability, taken by Mr. Raymond Frost.

16. A very special thanks to Mons. Dario Rezza, dott. Mirko Stocchi and dott. Vincenzo Piacquadio for helping me in Archivio Capitolo di San Pietro.

17. See: Montagu J., *The frame of the Volto santo*, in Bollettino Monumenti, Musei e Gallerie Pontificie, XIII, Città del Vaticano, 1993, pp.39-48.

18. De Waal, A., *Gli antichi tesori sacri della Basilica Vaticana*, in Dissertazioni della Pontificia Accademia Romana di Archeologia, Roma 1894. The translation is mine.

19. Grimaldi, G., *Liber de sacrosancto sudario Veronicae*, cit., fol. 53 recto.

20. A warm thanks for helping me to Father Mario Micucci, Prior of the Chiesa Monumentale San Girolamo della Certosa di Bologna.

21. n° catalogo E 2877 Avanti: lamina dorata: 19,5 x 29,8.Cornice con madreperla: 30,7 x 41.Cornice dorata teca: 31,5 x 42,4 (all'interno). Cornice dorata teca: 35,6 x 47,1 (all'esterno). Retro: solo tavoletta: 35 x 38,2. Con striscia tavola superiore e striscia tavola inferiore: 35 x 50. Quadro complessivo con fregi: 74 x 89.

22. Daughter of Duke of Piemonte Carlo Emanuele I of Savoia (Rivoli, 1562 - Savigliano, 1630) and of Caterina d'Asburgo (1567-1597) daughter of the king Filippo II di Spagna, Maria Francesca Apollonia was born in Turin in 1594 and dead in 1656.

TURIN SHROUD DATING

Can Contamination Be Detected on the Turin Shroud to Explain Its 1988 Dating?

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Abstract
This paper proposes future testing that could examine every fiber on the Shroud of Turin. It also proposes specific tests for the presence of neutron-created C-14, Cl-36 and Ca-41 on control samples and on linen, blood, charred material and limestone from the Shroud of Turin and/or Jesus' reputed burial tombs. These tests could refute the Shroud's 1988 radiocarbon dating and establish its actual age. The proposed tests could also demonstrate that the Shroud linen and its blood was irradiated with a neutron flux and indicate when and where the event took place.

Keywords: Turin Shroud, radiocarbon, neutrons, chlorine-36, calcium-41.

1 INTRODUCTION

Perhaps, the most important dichotomy in all of history is before us and the world. Extensive scientific tests and experiments for the last four decades, along with a wealth of medical, archaeological and historical examinations throughout the 20th and 21st centuries have yielded a wide array of objective, independent and corroborating evidence that the Shroud of Turin wrapped a dead human male who had intimate contact with this burial cloth. This man had been beaten about the head and face. He was scourged throughout his body with a Roman flagrum and crowned with a bundle of sharp pointed objects or thorns. He had broad excoriated areas across the back of his shoulders, endured falls and was crucified. After dying in the vertical position, he was pierced in the side by a Roman lancea causing blood and watery fluid to flow from the wound. Afterward his body was wrapped in a linen shroud and buried according to detailed Jewish burial customs in the same rock shelf in which Jesus was reputed to have been buried. All of these events appear to have occurred in Jerusalem in the spring of the first century. However, within two to three days of having been wrapped in the Shroud, the body left the cloth in a mysterious manner.

An unprecedented event occurred to this body prior to or during its disappearance that caused the man's full-length frontal and dorsal body images and 130 blood marks (along with several secondary features) to be encoded on this burial shroud. The full-length body images and blood marks are so unique they have never been duplicated in any age by any artist, scientist, physician or anyone utilizing any type of artistic, naturalistic or other method. While the most sophisticated science of today has been unable to duplicate the Shroud's body images and blood marks, it has discovered and revealed scores of unique features throughout the cloth that have never been seen before. These features not only appear impossible to forge or occur naturally, but seemingly defy the laws of chemistry and physics.

2. BACKGROUND

Of the thousands of scientific tests that have been performed on the Shroud only one result is inconsistent with its authenticity as the burial garment of the historical Jesus Christ and that is its medieval radiocarbon dating of 1988. This date was ascribed by and based on data from three laboratories following an arduous and controversial eight year process, whose result has been questioned by many on a variety of grounds.

Among the problematic challengers, Dr. Leoncio Garza-Valdès has asserted that the Shroud itself contains an invisible clear bioplastic coating of bacteria and/or fungi that contaminated the cloth and altered its dating. [1] Three problematic invisible repair hypotheses have also been offered to explain the cloth's dating. [2, 3, 4, 5]

A decade ago, The Resurrection of the Shroud Foundation commissioned a study by Dr. James Chickos, the head of the Chemistry Department at the University of Missouri, St. Louis, who found that tallow, which candle wax is made from, can become chemically bound to cellulose by a process known as transterification. [6] Wax has been identified on samples removed from the Shroud by STURP scientists John Heller and Alan Adler, and also by Walter McCrone. [7] Wax can also be seen with the naked eye in places on the Shroud itself, see fig. 1.

The sample from which Dr. Adler positively identified wax came from the edge of one of the relatively small, round holes found in a pattern and first observed in a painting of the Shroud in 1516.

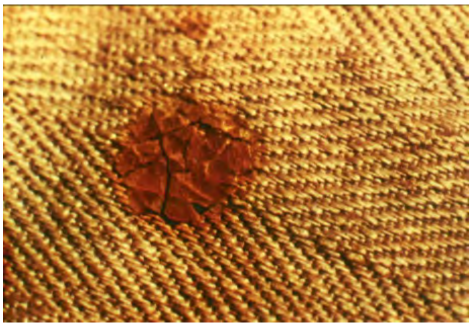

Figure 1. Wax on the Turin Shroud.

Wax is an excellent substance with which to stiffen cloth in order to give it strength and support. This would help keep the cloth from fraying or tearing at the edges of these burn holes, and could very well have been applied intentionally.

Of all the locations on the entire Shroud cloth from which to choose a sample for carbon dating, perhaps a worse location could not have been selected than the one chosen in 1988. Many of the reasons why were not known to those participating in the sampling nor apparent to the naked eye. For instance, starch was found on a thread from the Raes sample that is located immediately adjacent to the radiocarbon site. Starch could have been used to stiffen cloth and aid in any of the known repairs in this area. In 1982, without permission from the cloth's custodians or knowledge at the time that the thread contained starch, STURP sent a thread from the Raes sample to be radiocarbon dated. Interestingly, one end of the thread dated to A.D. 200 while the opposite end — containing starch — dated to A.D. 1000. [8] The molecular structure of starch is very similar to that of cellulose. Like wax, it, too, could chemically bind to cellulose, not be detected with the naked eye, and not be removed by the standard pretreatment processes. It could also alter the thread's radiocarbon date by many centuries.

This test was performed at a nuclear accelerator facility using a linear accelerator mass spectrometer technique, which was one of the methods developed for dating small samples. This was not a dedicated laboratory that regularly carbon dated samples, but the results from both ends are worth noting. If one end of the Shroud thread dated to A.D. 200, the error range of the dating could place the Shroud in the first century A.D. The presence of starch could possibly explain why the other end of the thread dated to A.D. 1000. Since starch was located near the 1988 Shroud radiocarbon sample site, this and all future sampling locations on the Shroud should be investigated.

3. PROPOSED TESTS

One of the best ways to test these various hypotheses is to perform imaging spectroscopy on the Shroud with a multi spectral camera. The application of this technology to the Shroud was advocated by Dr. Warren Grundfest in 1998, [9] and is similar to a proposal by Dr. Giulio Fanti in 1997 to take multi-spectral pictures of the Shroud.

Figure 2. The light triangular area depicts the former location of the Raes sample on the Shroud. To its right is the location from which the radiocarbon samples were removed.

When the human eye sees an object, it perceives only the colors of the visible spectrum from red to violet. Below red lies the infrared part of the spectrum. Every chemical compound has a unique infrared spectrum, and this characteristic is routinely used to determine the chemical composition of unknown materials. Previously, one of two procedures was used to obtain spectral information from an object: either obtaining a complete spectrum of only one point on the object and repeating for all points of interest, or obtaining a complete image of the object at only one wavelength in the spectrum and repeating for all spectral wavelengths of interest. However, with this new technique, an object can now be viewed under the entire visible and infrared light spectra simultaneously, allowing its composite image to become visible from all spectra simultaneously. Items such as the vessels in a retina, the hemoglobin bands in the eye, and the spectral patterns of human chromosomes are routinely viewed and examined with this new spectral-imaging technique.

This new technology could scan the entire Shroud in only six hours, thereby allowing scientists to spend years analyzing all of its data. It could map the entire cloth and its samples, and identify not just every fiber of every thread, but what is on every fiber. It can even identify tissue at the molecular level. By using carefully calibrated light sources, the pattern of reflected light can identify individual chemical compounds on the Shroud. This type of detailed imaging of the entire cloth could demonstrate or refute any of the above hypotheses and allow us to learn much more about the Shroud.

This technology may also allow us to view whether chemical bonds in the cellulose have been broken or whether conjugated carbonyls (double-bonded carbons) are more prevalent on the body images than the rest of the cloth. This is very important for if radiation caused the

Shroud's body images, it would break the cloth's single-bonded carbon, hydrogen and oxygen bonds allowing its broken carbon bonds to conjugate or double bind to each other. Imaging spectroscopy technology might also reveal whether non-body image encoding is present over either eye of the man in the Shroud and whether plant images could be on the cloth.

Similarly, this technique could allow us to view whether substances such as wax or starch had attached themselves to the molecular structure of the cellulose. As we saw, both contaminants are known to be on the Shroud with starch present, yet invisible, immediately next to the radiocarbon site. While the application of this technique on remaining samples at each of the carbon dating laboratories or from or near the radiocarbon site would not necessarily tell us whether these contaminants were present on the samples that were dated and destroyed, their presence would strongly indicate and confirm that these substances did chemically bind to the molecular structure at the radiocarbon site. The application of this nondestructive technique on the rest of the cloth could also tell us what other locations may have such foreign substances physically or chemically attached to the linen, and, thus, what area to avoid.

Imaging spectroscopy technology should also be attempted on each sample that has been or will be removed from the Shroud. This technology should also be applied to the back surface of the Shroud behind the facial and hand regions of the frontal image. Images at these locations were identified by computer enhancement of the back side of the Shroud after its 16th century backing cloth was removed in 2002 [10]. Cloth discolorations at these locations on the back side of the Shroud are possible with the two radiant cloth-collapse image forming methods involving ultraviolet and particle radiation, as well as a corona discharge method. Only these radiant hypotheses have accounted for these features. If broken chemical bonds or conjugated carbonyls are more prevalent at these locations on the back side of the cloth, this could confirm the presence of radiation at the time of image formation.

Recently Dr. Bruno Barberis, director of the International Centre of Sindonology in Turin, stated in a BBC report that the Centre plans to produce an accurate map of the Shroud to determine whether it is one cloth or contains repairs [11]. This would be an excellent opportunity to perform imaging spectroscopy with a multi-spectral camera on the entire Shroud, which would not only definitively answer the repair and other hypotheses, but provide an unprecedented wealth of information from the entire cloth, whose data could be analyzed by scientists for years. Now that the 1534 backing cloth has been removed, it would also be an excellent opportunity to examine both sides of the Shroud for limestone analysis and conduct X-ray fluorescence on the entire cloth. The 1534 backing cloth should also be extensively examined for the presence of limestone.

Dr. Barberis also recently stated that once the mapping of the cloth has been completed that another carbon dating would be considered [12]. Such a test would be premature and should not take place before other recommended tests are complete that could not only refute the Shroud's 1988 radiocarbon dating, but allow the cloth's true accurate age to be determined with the same accuracy as radiocarbon dating. These new tests could also demonstrate how this erroneous date occurred and explain the differing, inconsistent, internal data from the 1988 dating.

4. DISCUSSION

Three years of dramatic, critical tests and experiments have just been completed that can easily explain the 1300 year aberration in the Shroud's radiocarbon date. These tests involve irradiating linen with a neutron flux, one of the key components of particle radiation. As previously indicated, there is extensive evidence that radiation caused the images on the Shroud and that the source of this radiation was necessarily the dead, tortured and crucified body wrapped in the Shroud. [13, 14] There's not only extensive evidence indicating the radiation was particle radiation, but particle radiation emanating from this body will explain numerous things that no other image forming method begins or even attempts to explain. This method, called the Historically Consistent Method, accounts for all primary and secondary body image features; the more than 130 coagulated, unbroken and unsmeared blood marks that are still red and were embedded into the cloth in the same shape and form as when they flowed and coagulated on the entire body; the man's skeletal and dental features; the discoloring identified on the back side of the Shroud; the possible coin and flower images; the excellent condition of the cloth; as well as several resurrection-related or post-resurrection events that have never been explained before. No other method remotely begins to account for all of these features or events, or even attempts to [14, 15].

Experimental results presented at this conference demonstrate the well-known scientific principle that if linen, or any other nitrogen containing object, is irradiated with neutrons that carbon 14 (C-14) will be created within the irradiated linen. [16] These new C-14 isotopes are converted from nitrogen (N-14) within the molecular structures of the irradiated objects by the process illustrated in fig. 2.

These results demonstrate that the C-14 created from nitrogen in the air within or surrounding the linen fibers will disappear by natural aging in approximately six years. The new C-14 isotopes created from nitrogen within air will also disappear by the application of heat and by stringent standard pretreatment cleaning processes [16].

When carbon dating labs "date" an object they first apply standard stringent pretreatment cleaning techniques to the sample to eliminate any extraneous C-14 that is not native to the sample itself. Only then do they count the number of C-14 isotopes and compare them to the sample's carbon 12 (C-12) isotopes. From this ratio a date is ascribed to the sample. Inherent within this ratio and date is a critical assumption that all the extraneous C-14 was removed from the sample, and that only its indigenous C-14 was counted. If extraneous C-14 isotopes remained in the sample, they would alter its ratio and cause its corresponding radiocarbon age to appear much younger (or older) than its actual age.

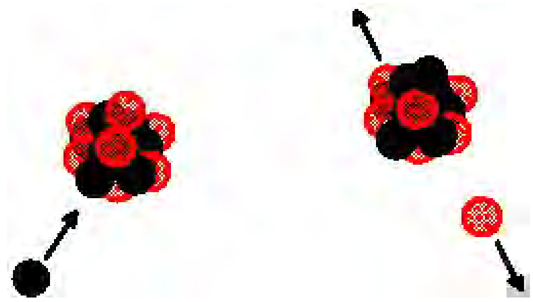

Figure 2. Before collision of neutron (black) with nitrogen-14 nucleus, 7 protons (red) and 7 neutrons. After collision, neutron is captured and proton is ejected, resulting in carbon-14 with 6 protons and 8 neutrons.

Unlike C-14 created by neutrons from nitrogen in air, as well as other sources of extraneous C-14, the C-14 created by neutrons from N-14 that is part of or indigenous to the linen itself remains within the molecular structure of the linen. These experiments show that these newly-created C-14 isotopes remain despite natural aging, the application of heat at temperatures that the Shroud was exposed to during the fire of 1532, or when pretreated and cleaned by all seven standard pretreatment methods that were applied to the Shroud's cloth samples in 1988. These tests and experiments even demonstrate that combinations of natural aging, as well as the above applications of heat and the above standard pretreatment cleanings, will not remove the C-14 created by particle radiation from the indigenous N-14 within linen [16]. These experiments demonstrate that a neutron flux within particle radiation could easily account for the Shroud's 1300 year aberration.

In an influential study from 1999, statistician Dr. Bryan Walsh applied a series of statistical evaluations to the 1988 radiocarbon data that led to the conclusion that the Shroud subsamples each contained differing or non-homogeneous levels of C-14 that were directly related to the physical location of the samples [17].

Dr. Marco Riani gave the results of an extremely robust statistical analysis of hundreds of thousands of combinations and configurations from the limited published data of the Shroud's 1988 radiocarbon dating report [18]. This study not only rejects the report's conclusion that the dates are homogeneous, but clearly suggests the presence of an important contamination in the 1988 radiocarbon samples removed from the Shroud of Turin.

In an article published on Shroud.com, Dr. Remi Van Haelst confirms the non-homogeneity of the Shroud's C-14 samples [19].

Dr. Walsh also reported his statistical evaluations techniques demonstrated statistically significant differences in the mean values computed and the error terms reported by the three labs that radiocarbon dated the Shroud in 1988. He reports that the labs inadvertently masked significant underlying differences in the data [20].

Dr. Van Haelst reports that recalculations were undertaken by the labs and the British Museum to minimize the range of dates, mean values and error terms found in their unreported raw data.

Dr. Riani's report strongly suggests that the data from Arizona's second Shroud sample was eliminated from the British Museum's and the laboratories' calculations or recalculations.

According to the scientific protocols that the radiocarbon labs agreed to, the labs were also supposed to report their raw data to Italian analyzing institutions and the British Museum before a date was assigned to the Shroud; however, this data was reported only to the British Museum. Even with the minimized reporting undertaken in 1988, the radiocarbon dates varied more than two hundred years over a distance of only 5 centimeters. According to Walsh's statistical evaluations, the subsamples given to Oxford, Zurich and Tucson "each contained differing levels of 14C" [21].

While conducting the above research to explain the 1300 year aberration between the Shroud's 1988 radiocarbon date and its other extensive evidence indicating a first century origin, Dr. Lind and his colleagues may also have found the explanation for the inconsistencies and aberrations in the Nature report pointed out by Walsh, Van Haelst, Riani and others.

The answer lies in the varying amount of nitrogen indigenous to the linen. Unsurprisingly, since the nitrogen content within the molecular structure of woven linen is acquired from the soil and remains in the interior part of the flax plant after the retting and hulking (beating) processes prior to weaving the cloth, its content will not be consistently level throughout the cloth or from location to location.

This has never been a problem when radiocarbon dating linen or any other objects containing nitrogen. This will only be a problem if the linen or object has been irradiated with a neutron flux at any time in its history. Then it is a problem that cannot be resolved because if a linen cloth or other object has been irradiated by a neutron flux, the additional C-14 created from its indigenous nitrogen cannot be removed by aging, the application of heat and/or standard pretreatment cleanings as incurred or received by the Shroud. While scientific tests could readily indicate the various amounts of nitrogen on the Shroud, that is the least of information that can be acquired from our proposed tests and experiments.

5. FURTHER PROPOSED TESTS / DISCUSSION

Scientific tests could be conducted on the Shroud of Turin or its samples that could completely refute the Shroud's 1988 radiocarbon dating by proving conclusively the Shroud was irradiated with particle radiation, the amount of radiation, and the actual age of the cloth and its blood. Scientific tests could even prove where such an unprecedented event occurred while this dead body was wrapped within the Shroud.

The neutron flux within particle radiation causes two other reactions to occur that are of tremendous importance and are known to science, but have never been tested before in connection with the Shroud of Turin. Since linen, blood, charred materials and limestone samples have all been removed from the Shroud during previous examinations these materials could be tested for such reactions. Particle radiation will leave unique amounts of isotopes within the molecular structures of objects, including the Shroud and its various samples — that cannot possibly exist or occur in any other manner. Two new chemical isotopes that virtually do not exist in nature, calcium 41 (Ca-41) and chlorine 36 (Cl-36), will be created in objects containing calcium or chlorine, but only if the objects have been irradiated by particle radiation. These new chemical isotopes occur because the neutron flux within particle radiation converts a limited number of Ca-40 and Cl-35 isotopes (the principle elements of calcium and chlorine) into Ca-41 and Cl-36 as seen in figures 3 and 4.

Figure 3. Before collision of neutron (black) with chlorine-35 nucleus, 17 protons (red) and 18 neutrons. After collision, neutron is captured, resulting in chlorine-36 with 17 protons and 19 neutrons.

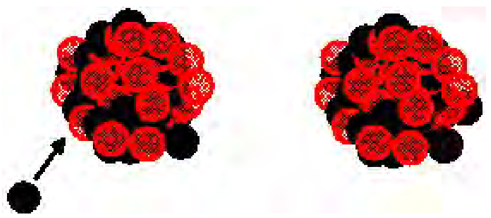

Figure 4. Before collision of neutron (black) with calcium-40 nucleus, 20 protons (red) and 20 neutrons. After collision, neutron is captured, resulting in calcium-41 with 20 protons and 21 neutrons.

Calcium has been identified throughout the Shroud linen cloth [22] and is known to naturally exist in blood, pollens and limestone. Calcium would also remain in charred samples removed from the Shroud [23]. Chlorine also occurs naturally in blood, pollen and limestone and should also be present on the Shroud linen [24]. If Ca-41 or Cl-36 were detected in any of these objects above their naturally negligible limits, their presence at such levels would prove these objects were irradiated by neutron particles, an event that could not possibly have occurred before the 20th century and could not possibly have occurred naturally.

Like the creation of C-14 isotopes by neutron radiation, the chemical isotopes, Cl-36 and Ca-41, are also created at established rates known to science. Like C-14, the quantities of Cl-36 and Ca-41 can be predicted from the amount of neutron radiation. If Shroud samples contain either of these two new chemical isotopes, scientists can calculate the amount of neutron radiation that each of the various samples received. Moreover, if the Shroud was irradiated by a neutron flux, scientists could calculate the age of its irradiated samples with the same accuracy as radiocarbon dating. For example, from the amount of neutron flux determined to have irradiated the Shroud's linen sample, scientists can calculate the amount of extraneous C-14 isotopes created and remaining within them following their standard stringent pretreatment cleanings. When this amount of C-14 isotopes is subtracted from the number within the C-14 to C-12 ratio from 1988 — the true age of the Shroud linen could be accurately determined — with the same accuracy as radiocarbon dating. In the case of the Shroud of Turin, it could be with far more accuracy than its radiocarbon dating of 1988.

Only the Shroud cloth was radiocarbon dated in 1988. We propose to also carbon date the Shroud's blood. Because blood has much more nitrogen within it than linen, if the Shroud's blood was irradiated by a neutron flux, it would not "date" to the Middle Ages, as the Shroud linen did in 1988 — it would date thousands of years into the future. This result alone would also refute the cloth's 1988 medieval radiocarbon date; however, so would many other of our proposed test results.

Chromium 53 (Cr-53), an isotope that exists in nature but not in blood, would also be created by conversion from Iron 56 (Fe-56) in predictable amounts in neutron irradiated blood. By measuring the Cl-35 to Cl-36, Ca-40 to Ca-41, and Fe-56 to Cr-53 ratios in neutron irradiated control and Shroud blood samples, we can determine with even more corroboration, the amount of neutron flux the particular Shroud blood samples received. From such tests on control blood samples, scientists can determine the amount of extraneous C-14 created and remaining within control and Shroud blood samples. This process would allow scientists to determine only the indigenous C-14 isotopes within the Shroud's blood samples — and to arrive at their actual age. The indigenous C-14 to C-12 ratios in the Shroud's cloth and blood could yield first century dates. Similar Ca-40 to Ca-41 and C-14 to C-12 measurements, ratios, age and event calculations can also be performed on control and Shroud charred cloth and limestone samples, which could also yield first century dates. (Pollens are probably too light and insubstantial to adequately measure the Cl-36 or Ca-41 isotopes within them.)

Several of the scientists who participated in the Shroud's 1988 carbon dating subsequently acknowledged that if the cloth had been exposed to a neutron flux, such an event would invalidate the radiocarbon date which they assigned to it [25]. Proof that the Shroud was irradiated with just a minimal amount of neutron flux <u>alone</u> would invalidate the cloth's 1988 carbon dating.

Among the faint secondary images possibly discerned on the Shroud are features of a Pontius Pilate lepton (coin) over the man's right eye that was minted in the years 29-32 A.D., and various flowers that collectively grow only in the vicinity of Jerusalem, placed around the sides of the body. Particle radiation emanating from the length, width and depth of the dead body wrapped in the Shroud not only accounts for the Shroud's primary and secondary full-length body images, but also its possible faint coin and flower images. [13, 14] Coins and flowers in contact with linen cloth should be neutron irradiated in control tests to determine if their faint images appear on the cloth. Neither the Shroud's full-length body images nor its coin and flower images have ever been accounted for, let alone duplicated, by any artistic or naturalistic methods. If such experiments duplicate the Shroud's coin features, they will indicate that the radiating event occurred some time after the years 29-32 A.D., which is far more specific than the +/- range of accuracy for a radiocarbon date (approx. 150 years).

Duplicating the flower images would also help confirm the events occurred in Jerusalem; however, our proposed tests and experiments could even determine the <u>precise location</u> of this radiating event. There is a real chance that Jesus' burial tomb still survives in one of three possible locations within Jerusalem. Fortunately, all of these locations are contained within the same limestone rock shelf. Limestone has been found within the threads of the Shroud that match this same rock shelf, but does not match samples from other tombs in Israel [26]. The most likely tomb in which Jesus was buried has been enclosed by marble since 325 A.D. and is located within the Holy Sepulchre. Limestone samples from this tomb, as well as samples from the other possible locations of Jesus' burial tombs should be obtained. Since limestone is mainly comprised of calcium with trace amounts of chlorine and nitrogen, these samples should be examined for Ca-40 to Ca-41, Cl-35 to Cl-36 and C-14 to C-12 ratios.

No limestone rock shelf in the world contains C-14 isotopes. Since these rock shelves were formed millions or billions of years ago, all of their indigenous radioactive C-14 isotopes long ago disappeared at predictable rates. (Although unlikely, there could be enough trace N-14 and C-13 within limestone to convert to detectable levels of C-14 from a neutron flux.) Since Ca-41 virtually does not exist in nature, no limestone rock shelf in the world could contain this isotope above naturally negligible limits. Such presence within can only be created by neutron radiation. To have created detectable C-14 or the above levels of Ca-41 or Cl-36 in the molecular structures of the limestone within the marble enclosed tomb inside the Holy Sepulchre (or any other tomb within or nearby), would have required the construction of a neutron generator over the Holy Sepulchre.

Since C-14, Cl-36 and Ca-41 are produced and decay at predictable rates, if any of these isotopes are detected above their naturally negligible limits, scientists could calculate the amount of neutron flux received within the limestone tomb and when the unparalleled event occurred. Such presence of any of these unfakable isotopes within specific limestone walls would also strongly indicate the actual extant burial tomb of the historical Jesus Christ.

If these scientific measurements and calculations corroborate previous ones from Shroud cloth, blood and charred material, it would mean that several new scientific test results from several different materials would provide evidence of a miraculous radiating event. The results for three different isotopes from four sets of materials would not only refute the Shroud's 1988 radiocarbon dating, but could scientifically date the cloth and/or its radiating event to the first century.

Before any of these tests are undertaken on Shroud samples or samples from Jesus' reputed burial tombs, they should all be performed on control samples first. All of these vital and critical tests are destructive so extensive tests on control linen, blood, charred linen, and limestone should be undertaken first in order to learn the factors that could affect obtaining the most accurate results from Shroud samples. A good example of unexpected results on neutron irradiated cloth control samples was the varying amount of C-14 created by its varying content of nitrogen. We now know that the nitrogen content of any Shroud, blood and limestone samples must be obtained before their C-14 content is measured.

Organic chlorine-35 and organic calcium-40 that are indigenous to the cellulose of the flax plant comprising the linen textile would both be present on the Shroud cloth. During the retting process in which the flax plants are soaked and/or repeatedly rinsed, inorganic chlorine and calcium would become part of the linen; however, these particular inorganic isotopes would have been present once the linen was woven and the hypothetical radiant event occurred. However, since other inorganic chlorine and calcium could also have gotten on the Shroud, and these inorganic amounts may not be evenly distributed, the inorganic chlorine and calcium on the Shroud linen should be measured separately for Cl-36 and Ca-41 in order to be as certain as possible of the amount of neutron flux received by the Shroud sample.

Control testing should also be performed to determine the minimum size Shroud cloth or blood sample that will be needed for each critical measurement in order to destroy as few samples as possible. In this vein, it should be noted that Jesus' actual burial tomb may not be known or extant. If it is the reputed tomb located at the Holy Sepulchre in Jerusalem, it should also be pointed out that Arabs attempted to destroy this tomb in 1009, but hopefully did not completely destroy every part. A small part of the original limestone is all that would be needed to measure its C-14 and Ca-41. According to Dr. Arthur Lind and Dr. David Elmore, the newly-created C-14 and Ca-41 isotopes would be found about 3 feet within the limestone walls of the tomb because the neutron flux would have penetrated this distance into the limestone.

Most likely the radiocarbon laboratories have Shroud cloth samples and ash or burn residue remaining from their 1988 radiocarbon dating. The size of the Shroud samples given to the laboratories were much larger than necessary for accurately dating the cloth. Even parts of the laboratories' remaining Shroud cloth and ash samples would be large enough to conduct previously described Cl-36 and Ca-41 testing after testing on control samples were completed. In light of the various new research presented at this conference regarding radiocarbon dating, especially the critical, permanent and measurable effects from a neutron flux (along with the other unprecedented effects that particle radiation could also have on the Shroud cloth and its images), it is incumbent on the radiocarbon laboratories to donate parts of their Shroud cloth samples and burn residue still remaining with them. Among the reasons this duty is incumbent is that it may prove their controversial 1988 dating of the Shroud to be erroneous and establish the cloth's actual age. Another reason is that it would make up for the unprofessional conduct that some of the directors of the radiocarbon laboratories displayed during the lengthy eight year process of radiocarbon dating the Shroud [27].

The authorities in Turin, Rome and Jerusalem should also provide the above cloth, blood, charred material and limestone samples from the Shroud and/or Jesus' reputed burial tombs for the proposed tests following the completion of the above control tests. The authorities should not undertake another C-14 test of the Shroud until the tests for particle radiation have taken place on control and Shroud cloth samples. If the Shroud has been irradiated with a neutron flux, but has not been tested for this, then another radiocarbon date is still going to yield a date in the approximate range of 800-1500 A.D. Such a date would not only be erroneous, but could greatly prejudice the public as this would be the second dating demonstrating that the cloth could not have wrapped Jesus. It would make little difference to the public when the Shroud was forged. The public would be much less likely to listen to an explanation about particle radiation after the Shroud was carbon dated twice to the Middle Ages.

I am also very interested in learning about Dr. Campanella's sensoristic approach to dating cellulosic materials presented at this conference. If this dating method can be developed and demonstrated to the scientific community to consistently and accurately date linen it would be much preferable to carbon dating the Shroud for several reasons. There is a good chance that carbon dating the Shroud will yield an erroneous result, if not an inconsistent non-homogenous result. Dr. Campanella's method attempts to date linen independently of its carbon content. If the Shroud was irradiated with a neutron flux, this method could possibly confirm or establish the cloth's true age. While carbon dating and neutron testing are destructive, Dr. Campanella's method only seems to be intrusive.

I would also like to note that Dr. Fernandez Sanchez spoke on the Sudarium of Oviedo that is of interest to many. While this cloth does not have nearly the amount of evidence for its authenticity as the Shroud, the same new tests for particle radiation that are called for with Shroud cloth, blood and charred samples, and on limestone samples from Jesus' reputed burial tombs, could also be conducted on linen and blood samples from the Sudarium of Oviedo. If this cloth was in Jesus' tomb at the time the hypothesized radiant event occurred, unique and otherwise unexplainable levels of Cl-36, Ca-41, Cr-53 and newly created C-14 would also be found within the Sudarium and its blood.

6. CONCLUSION

All naturalistic and artistic methods that have been proposed to explain the Shroud's images or its 1988 radiocarbon dating or other aspects, have not only been tested, but have been found wanting. The proposed tests could establish whether a critical event occurred to the Shroud cloth; its blood and limestone; when the event occurred; the age of the cloth; and where the event occurred. In combination with long established, as well as continually accumulating evidence, the source of this event can easily be determined.

The above tests involving particle radiation, in combination with many other studies with radiation and the Shroud, could readily establish that:

- particle radiation irradiated the Shroud linen, its blood and limestone;
- the particle radiation emanated from the length, width and depth of the dead body wrapped within the cloth;
- the event occurred to a 1st century cloth;
- the event happened inside the reputed Jesus' burial tomb.

Moreover, just by refuting the Shroud's 1988 radiocarbon dating, the proposed tests in combination with all the other extensive evidence acquired throughout the 20th and 21st centuries, would provide a wealth of objective, independent and corroborating evidence that every element of the passion, crucifixion, death, burial and resurrection of the historical Jesus Christ literally and actually occurred just as these events are described in the Gospels.

ACKNOWLEDGEMENTS

While our foundation has many to thank for their support, we especially want to note the years of donations from Dick and Sandy Nieman and Pat and Patty Byrne. Several years ago Francis DeStefano literally gave all of his savings toward our foundation's tests and experiments. Most of all, the foundation's tests and experiments to date would not have occurred without the dedication, determination and financial support of Paul and Mary Ernst and their friends in Boulder, Colorado.

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PHOTO CREDITS

Figure 1. Aurelio Ghio.
Figure 2. ©1978, Vernon Miller.

A robust statistical analysis of the 1988 Turin Shroud radiocarbon dating results

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Abstract
Using the 12 published results from the 1988 radiocarbon dating of the TS (Turin Shroud), a robust statistical analysis has been performed in order to test the conclusion by Damon et al. (1998) that the TS is mediaeval. The 12 datings, furnished by the three laboratories, show a lack of homogeneity. We used the partial information about the location of the single measurements to check whether they contain a systematic spatial effect. This paper summarizes the results obtained by Riani et al. (2010), showing that robust methods of statistical analysis can throw new light on the dating of the TS.

Keywords: ANOVA, Forward Search, Robust methods, t-statistics, Turin Shroud.

1. INTRODUCTION

The results of the 1988 radiocarbon dating [1] of the TS were published as providing conclusive evidence that the linen fabric dates from between 1262 and 1384 AD, with a confidence level of 95%.

However, after publication of the result, many speculated that the sample had been contaminated due to the fire of 1532 which seriously damaged the TS, or to the sweat of hands impregnating the linen during exhibitions, others that the date was not correct due to the presence of medieval mending and so on. We give references to some of these concerns in Section 7.

The purpose of this paper is to summarize the results obtained in Ref. 2 which show how robust methods of statistical analysis, in particular the combination of regression analysis and the forward search [3] combined with computer power and a liberal use of graphics, can help to shed new light on results that are a source of scientific controversy. Throughout we analyse only numbers from the data given in Ref. 1.

2. DESCRIPTION OF THE DATA

The samples for radio carbon dating were taken from a strip of material cut from one corner of the TS. The strip was divided into five parts; the three parts on the right of Figure 1 were sent to laboratories in Arizona, Oxford and Zurich. Arizona also received the fourth, smaller, part on the left. A larger part on the left of Figure 1 was taken by the Arcidiocesi of Turin as a "Riserva".

Figure 2 indicates the cutting of the strip in question.

These samples were divided into a total of 12 sub-samples for which datings were made. The resulting dates ranged from 591 BP for a reading from Arizona, to 795 BP from Oxford.

3. HETEROGENEITY ANALYSIS

Damon et al. [1] noticed that the data show some heterogeneity, which they assessed using a chi-squared test. In this section we instead use the analysis of variance to test whether these 12 observations can be considered as homogeneous, i.e. as 12 repeated measurements coming from a single unknown quantity.

More formally, a general model for observation j at site i is

$$y_{ij} = \mu_i + \sigma v_{ij} \varepsilon_{ij} \quad (i = 1, 2, 3; j = 1, ..., n_i), \quad (1)$$

where the errors ε_{ij} have a standard normal distribution.

Our central concern is the structure of the μ_i; at this point whether they are all equal. However, before proceeding to the test this hypothesis we need to establish the error structure. Riani et al. [2] suggest the three following possibilities

1. **Unweighted Analysis**. Standard analysis of variance: all $v_{ij} = 1$

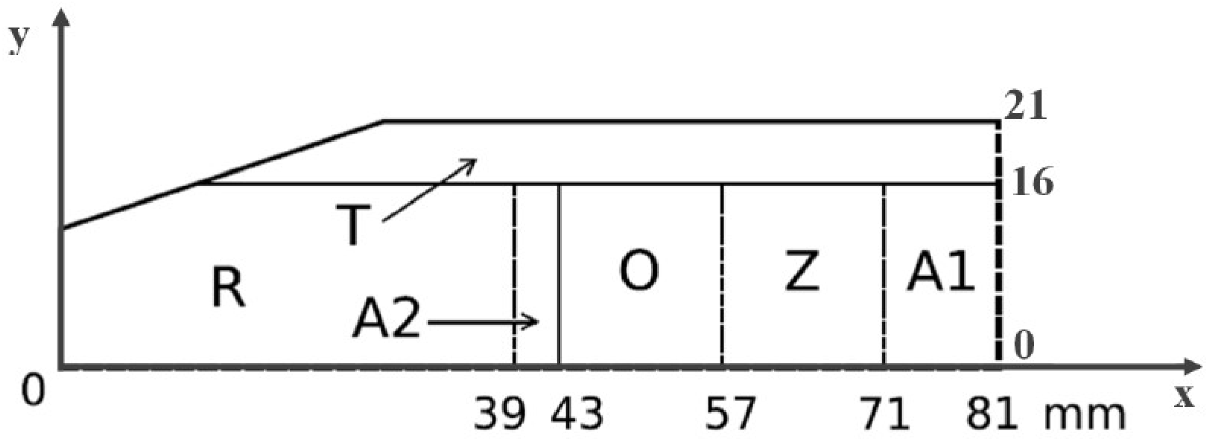

Figure 1. Diagram showing the piece removed from the TS and how it was partitioned. T: trimmed strip. R: retained part called "Riserva". O, Z, A1, A2: subsamples given to Oxford, Zurich, and Arizona (two parts) respectively.

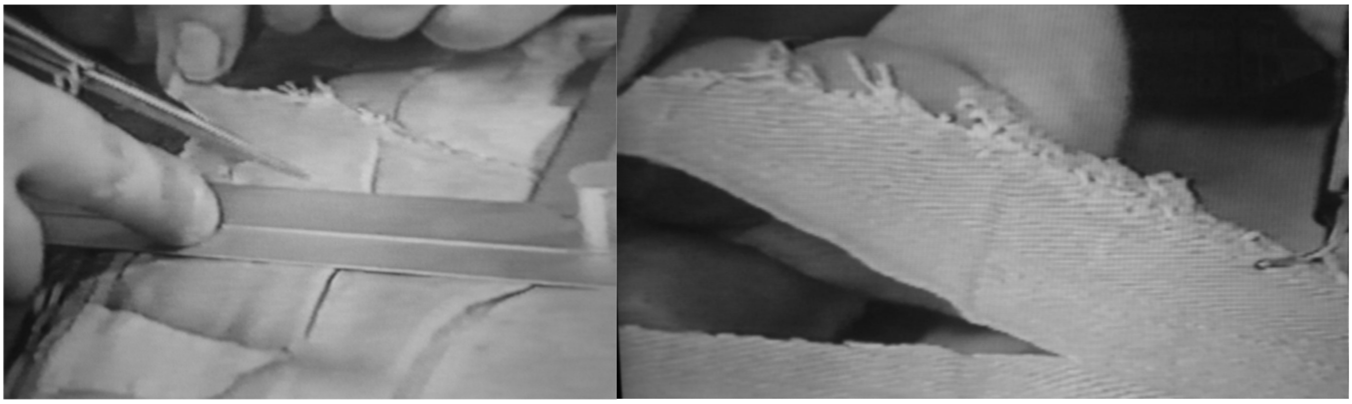

Figure 2. Cutting of the linen strip from the TS for the 1988 radiocarbon dating. (G. Riggi di Numana, Fototeca 3M).

2. **Original weights**. We weight all observations by $1/v_{ij}$, where the v_{ij} are the standard errors published by Damon et al. [1], that is, we perform an analysis of variance using responses:

$$z_{ij} = y_{ij}/v_{ij} \,. \qquad (2)$$

3. **Modified weights for Arizona**. This last formulation takes into account the fact that according to Damon et al. the standard errors for Arizona, unlike the two other laboratories, include only two of the three sources of error.

Reference 2 shows that irrespective of the kind of ANOVA which is used, while the test for homogeneity of the variances among the 3 laboratories never turns out to be significant (the minimum *p*-value is greater than 0.3), the test for homogeneity of means is always significant at the 5% level.

Christen [4] used these data as an example of Bayesian outlier detection with a mean shift outlier model (Abraham and Box [5]) in which the null model was that the data were a homogeneous sample from a single normal population. He found that the two extreme observations, 591 and 795 were indicated as outlying. When these two observations were removed, the data appeared homogeneous, with a posterior distribution of age that agreed with the conclusion of Damon et al. [1].

4. SPATIAL HETEROGENEITY

We have appreciable, but only partial, knowledge of the spatial layout of the samples from Damon et al. [1]. Three pieces were dated by Oxford, four by Arizona and five by Zurich. However it is not known how the samples in Figure 1 were divided within the laboratories, nor is it known whether the four readings from Arizona came only from A1 or from A1 and A2.

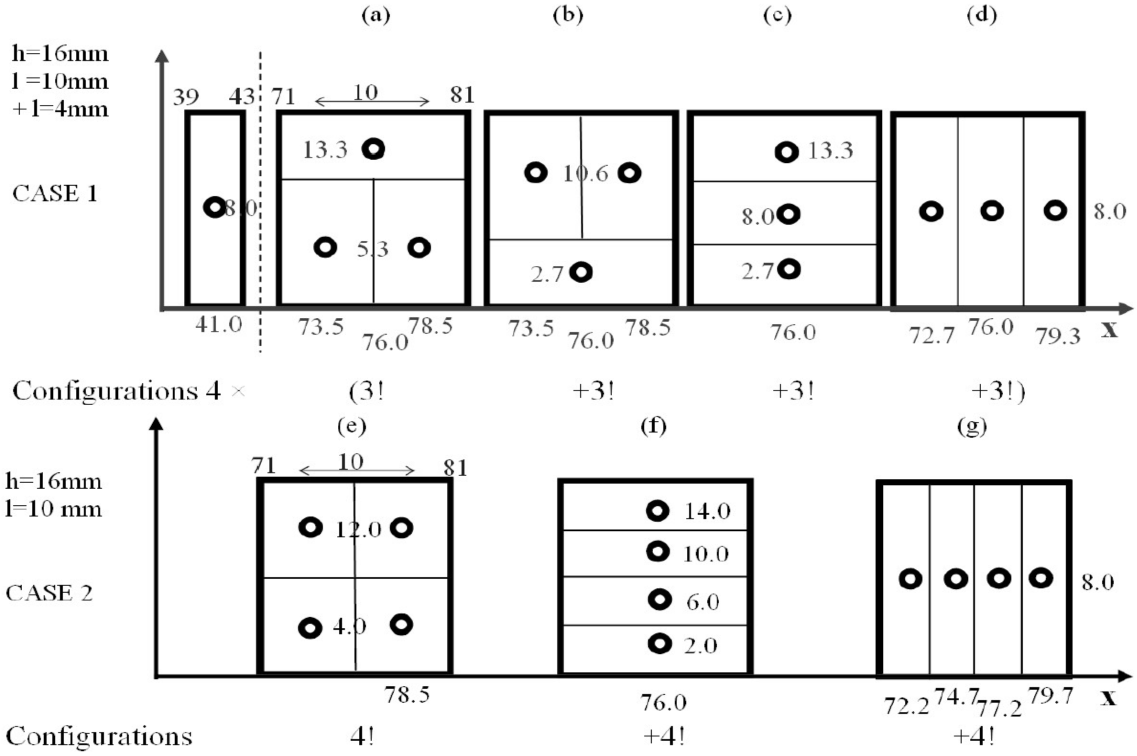

Figure 3. Arrangements investigated for the Arizona sample. The image on top assumes that Arizona dated both pieces (A1 and A2). The image at the bottom assumes that Arizona only dated piece A1. Total number of cases considered is 168 = 96+72.

On the assumption that the four readings from Arizona all came from A1, Walsh [6] showed evidence for the regression of age on the known centre points of the pieces of fabric. Ballabio [7], as well reviewing earlier work, introduced a second spatial variable into the analysis, the values of both variables depending on how the division into subsamples was assumed to have been made. He was defeated by the number of possibilities.

The possible configurations for the subsamples from Arizona are shown in Figure 3. If we also consider all possible plausible ways in which cuts could have been made by the laboratories of Oxford and Zurich, we end up with 96 and 23 configurations. In summary there are 387,072 possible cases to analyse.

5. MULTIPLE REGRESSION

To try to detect any trend in the age of the material we fit a linear regression model in x_1 (longitudinal) and x_2 (transverse) distances. The analysis is not standard. Riani et al. [2] permute the values of x_1 and x_2 and perform all 387,072 analyses.

The question is how to interpret this quantity of numbers. Without any trend in the longitudinal and transverse directions we expect to obtain a distribution of *t*-statistics for the regression coefficients which is centred around zero and we approximately expect to obtain half of the 387072 configurations with a positive value of the *t*-stat and the other half with negative values. The top panel of Figure 4 (taken from Ref. 2) shows the distribution of the *t*-statistic for x_2. This has a *t* like shape centred around 0.5. The bottom panel of Figure 4, the *t*-statistic for x_1, is however quite different, showing two peaks. The larger peak is centred around −2.9 whereas the thinner peak is centred around −1. It is also interesting to notice that for each of the 387,072 configurations we obtain a negative value of the *t*-statistic for the longitudinal coordinate.

As we have shown that x_2 is not significant (even if it is surprisingly not centered around 0), we continue our analysis with a focus on x_1. In particular, we want to discover what feature of the data leads to the bimodal distribution in Figure 4. If we consider the longitudinal projections of the 387,072 configurations we obtain 42,081 possibilities.

Summarising the results in Ref 2 which performs a detailed analysis of all these longitudinal configurations, it comes out that inference about the slope of the relationship depends critically on whether configuration A2 (see Figure 1) was analysed. More precisely, the only configurations which give rise to non-significant values of the t-statistic are those associated with:

1) configuration A2 (that are based on the assumption that Arizona dated both A1 and A2), see Figure 1.
2) the response at the longitudinal coordinate $x_1 = 41$ is y=591 or y=690.

We now analyse the data structure, taking typical members inside the configurations 41-591 and of 41-690 and look at some simple diagnostic plots.

To determine whether the proposed data configuration 41-591 is plausible we look at residuals from the fitted regression model. In order to overcome the potential problem of masking (when one outlier can cause another to be hidden) we use a forward search [3] in which subsets of m carefully chosen observations are used to fit the regression model and see what happens as m increases from 2 to 12. Figure 6 shows a forward plot of the residuals of all observations, scaled by the estimate of sigma at the end of the search, that is when all 12 observations are used in fitting. The plot shows the pattern typical of a single outlier, here 41-591 which is distant from all the other observations until $m = n$, when it affects the fitted model.

The conclusion from this analysis is that whether one of the lower y values, 591 or 606, or one of the higher y values, 690 or 701, from Arizona is assigned to $x_1 = 41$, an outlier is generated, indicating an implausible data set. The comparable plots when it is assumed that Arizona only analysed A1 are quite different in structure. There is a stable scatter of residuals in the left-hand panel as the forward search progresses, with no especially remote observation. We conclude, that there is statistical evidence that Arizona only analysed A1 and that there is a significant trend in the longitudinal coordinates.

6. CONCLUSIONS

The Shroud data relative to the 1988 radiocarbon dating show surprising heterogeneity. This leads us to conclude that the twelve measurements of the age of the TS cannot be considered as repeated measurements of a single unknown quantity.

The presence of a linear trend explains the difference in means that was found using the ANOVA test.

The evidence of the heterogeneity together with the evidence of a strong linear trend lead us to conclude that the statement of Damon et al.: "*The results provide conclusive evidence that the linen of the Shroud of Turin is mediaeval*" [1] needs to be reconsidered in the light of the evidence produced by our use of robust statistical techniques.

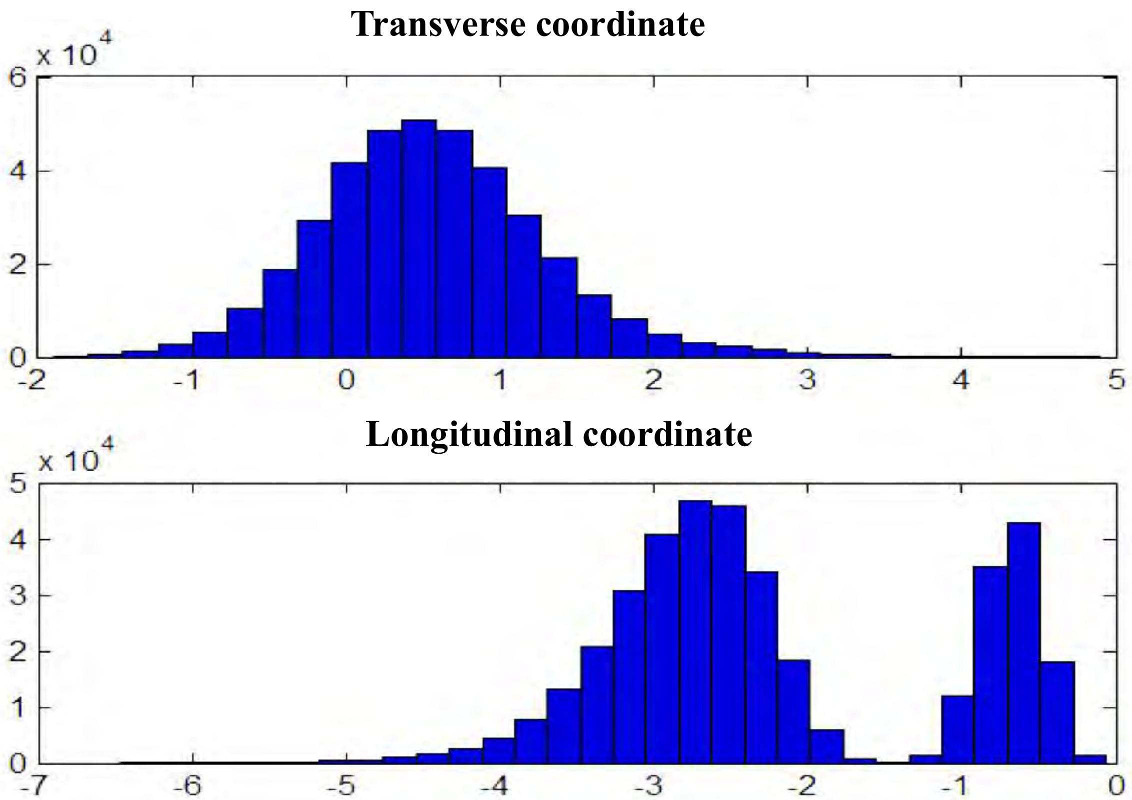

Figure 4. Two variable regression. Histograms of values of t-statistics from 387,072 possible configurations. Upper panel x_2 (transverse coordinate), lower panel x_1 (longitudinal coordinate).

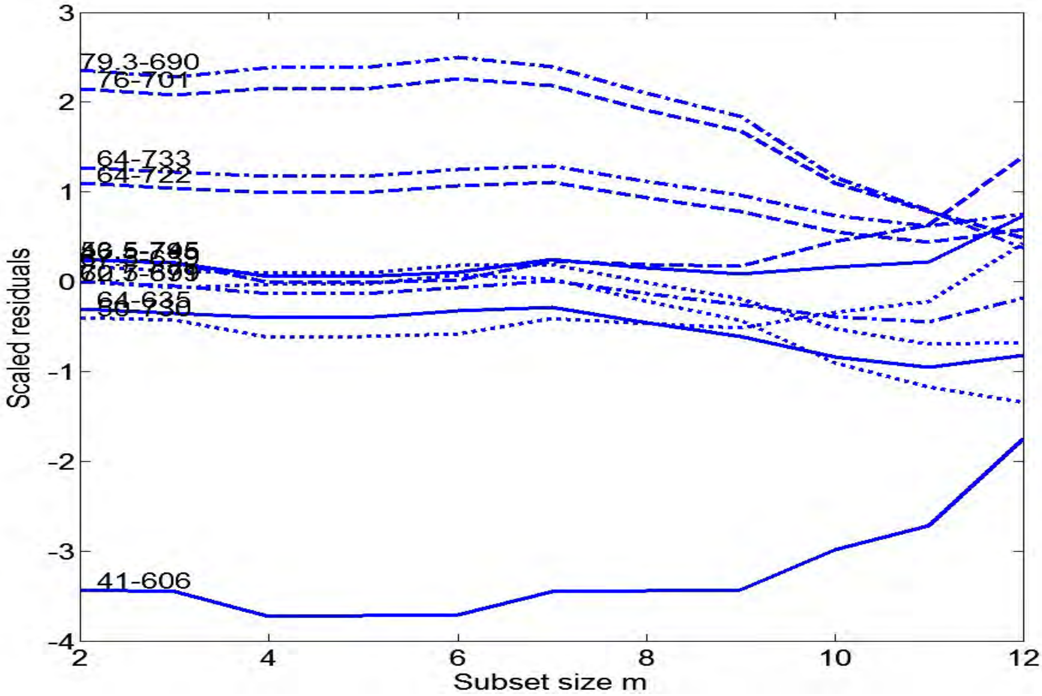

Figure 5. Analysis of residuals for one typical configuration when x1=41, y1=591. Forward plot of scaled residuals showing that this assignment produces an outlier.

7. DISCUSSION

The arguments in favour of the authenticity of the TS are rehearsed in other papers in this volume. For example, the formation mechanism of the body images has not yet been scientifically explained. One so far unexplained feature is that the body image is extremely superficial in the sense that only the external layer of the topmost linen fibre is coloured [8]. See also [9] and [10].

At a more mundane level, we note that the weights used in Section 3, taken from Ref. 1, were obtained from up to 8 repeat determinations. Burr et al. [11] describe the process of analysis used at Arizona. As always, in any data analysis, it is a help in understanding and modeling the truth of a situation to work with the original data, rather than data which have already been summarized, even if only lightly.

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Production of Radiocarbon by Neutron Radiation on Linen

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Abstract

Experiments were performed on modern linen to study the hypothesis that the 1988 radiocarbon dating of the Turin Shroud was in error by about 1300 years because the Shroud had received neutron radiation that produced contaminant radiocarbon by reactions with nitrogen indigenous to the linen. Measured spatial variations in linen nitrogen content caused radiocarbon age gradients as large as 261 yr-cm^{-1} for the neutron fluence needed to reduce its radiocarbon age by about 1300 years. Because of these variations and because measurements of radiocarbon and nitrogen contents were destructive, one to one comparisons could not be made between calculated and measured quantities of radiocarbon. Within this limitation, it was determined that the radiocarbon produced by neutron irradiation was not removed by high temperatures or by the chemical cleaning treatments used in the 1988 tests.

Keywords: Radiocarbon, neutron, radiation, nitrogen, linen.

1. INTRODUCTION

The 1988 tests determined that the Turin Shroud's radiocarbon date was approximately 1325 AD [1]. Radiocarbon dating is susceptible to error because of contamination, but the three laboratories used a number of standard chemical cleaning treatments to remove all usual types of contamination. Phillips [2] proposed a different type of contamination, nuclear radiation to produce unnatural radiocarbon that would artificially reduce the radiocarbon age of the Shroud. Hedges [3] stated that neutron reactions with trace nitrogen in the linen would be the principle mode for producing radiocarbon in the linen. Rinaudo [4], Moroni[5] and Barbesino [6] conducted experiments on a piece of 1st century Egyptian Lyma mummy linen that verified Hedges statement. Riani [7] conducted a robust statistical analysis of the 1988 data that rejected the null hypothesis that the ages measured by the three laboratories are homogeneous and suggest the presence of an important contamination in the 1988 Shroud samples. The effects of inhomogeneities had not been studied in the prior neutron experiments. This study supposed that neutron radiation can explain the erroneous radiocarbon date as well as the inhomogeneity and contamination of the Turin Shroud samples suggested by Riani [7],Walsh [8] and Van Haelst [9].

The three goals of these experiments were to (1) predict the concentration of radiocarbon produced using the measured nitrogen content of the linen and the measured neutron fluence,(2) measure the loss, if any, of the produced radiocarbon as a function of various heat and chemical treatments and (3) investigate inhomogeneities.

2. THEORY

Carbon has two stable isotopes, ^{12}C, which is 98.90% abundant and ^{13}C, which is 1.10% abundant. Radiocarbon, ^{14}C, is unstable and is only about 10^{-10}% abundant.^{14}C nuclei are continuously produced in the upper atmosphere by cosmic ray secondary neutron collisions with nitrogen to create ^{14}C and a proton; this reaction is denoted by $^{14}N(n,p)^{14}C$. This reaction is not constant, so the concentration of ^{14}C in the atmosphere varies over time. In 1950 a standard concentration of ^{14}C was defined as 100 percent Modern Carbon (pMC) when the ratio of the number of ^{14}C nuclei to the number of ^{12}C nuclei was equal to 10^{-12}[10].

When living plants take in carbon dioxide for their growth, they take in some ^{14}C and when the plant stops growing, this ^{14}C slowly emits electrons to decay back to ^{14}N with a half-life of 5730±40 years.

Thus, the percent Modern Carbon, *pMC(t)*, *t* years after it stops growing, is given by

$$pMC(t) = pMC_0\, e^{-\lambda t}, \qquad (1)$$

wherepMC_0 is the percent modern carbon in the plant when it stopped growing and λ is equal to1.2097×10^{-4} yr^{-1}, which corresponds to its 5730 year half-life.

Equation 1is solved below to yield the time, *t*, between the time the plant stopped growing and the time of measuring *pMC(t)*.

$$t = ln[pMC_0/ pMC(t)]/\lambda. \qquad (2)$$

Since pMC_0 is not constant, t must be corrected to obtain the true time by using measured historical values of $pMC_0$from such things as tree rings.

The true age differs from the radiocarbon age by Δt if pMC_0 is incorrectly assumed to be equal to 100, but it is not. The value of Δt is given in Equation 3 below.

$$\Delta t = ln[pMC_0/100]/\lambda. \qquad (3)$$

Figure 1 plots Equation 3 for different initial values of pMC_0 and shows that when pMC_0 is equal to 116.92 pMC, the radiocarbon age appears to be 1300 years younger than actual, as appeared to be the case in the 1988 radiocarbon dating of the Turin Shroud.

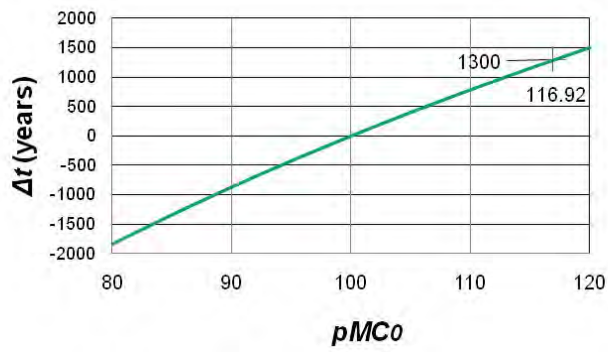

Figure 1. Radiocarbon age appears Δt years younger if the initialpercent Modern Carbon,pMC_0, is greater than 100 and no correction is made.

Because linen contains trace amounts of nitrogen, if linen receives neutron radiation, additional ^{14}C will be produced in the linen. This will increase its pMC_0 valueby an unknown amount and causes an error in the true age unless the neutron fluence and nitrogen content are known to make the proper correction using Equation 3.The increase, ΔpMC, in pMC_0caused by the $^{14}N(n,p)^{14}C$ neutron reaction is given by the following equation.

$$\Delta pMC=10^{12}n_0\sigma[M_C/f_C]\ [f_N/M_N] \times 100\ pMC, \qquad (4)$$

Where n_0 is the neutron fluence in $n{\cdot}cm^{-2}$,

σ is the $1.81\times10^{-26}m^2$ cross section for thermal neutrons,

f_C is the weight fraction of ^{12}C(for the linen used, this was 0.4322, obtained from total carbon weight fraction by multiplying it by the 0.9890 natural abundance of ^{12}C),

$f_N$is the weight fraction of ^{14}N(obtained from total nitrogen weight fraction by multiplying bythe 0.9963 natural abundance of ^{14}N),

M_C is the isotopicweight of^{12}C (12.000 g) and

$M_N$is the isotopic weight of ^{14}N (14.003 g).

3. EXPERIMENTAL

Linen Used: A sheet of unbleached modern plain-woven flax linen[11], which measured 0.99 m in the warp direction by 1.56 m in the weft direction, was used in this study. It was thoroughly washed in a mild detergent and rinsed repeatedly in distilled water before using. The areal density of the linen was 25 $mg{\cdot}cm^{-2}$, the mass density of the fibers determined by weighing in air and water was 1.45 $g{\cdot}cm^{-3}$and the thread density was 13 threads/cm in the warp and 15 threads/cm in the weft directions. Its measured total carbon weight fraction was 0.4370±0.0002. Three pieces were taken from this sheet at two major locations for neutron irradiation at three different times, as shown in Figure 2. Two ≈0.5 g samples were taken from region 2; one was irradiated in carbon dioxide with $1.07\times10^{14}\ n{\cdot}cm^{-2}$ and the other in air with $1.04\times10^{14}n{\cdot}cm^{-2}$. Approximately 12 g of Region 5 was irradiated with $1.07\times10^{14}n{\cdot}cm^{-2}$ and ≈0.5 g of this piece, denoted as Region 4, was used for radiocarbon measurements. Samples measured for radiocarbon content weighed between 7 and 20 mg.

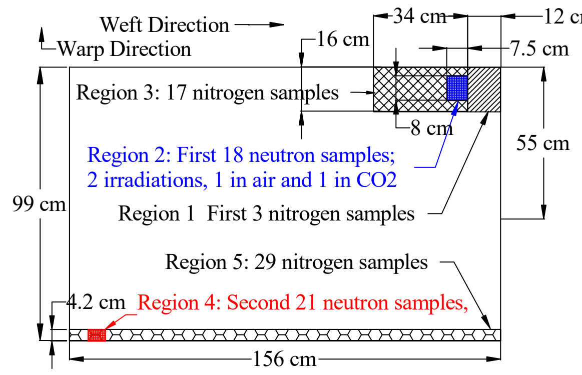

Figure 2. Unbleached modern flax linen used in experiments, showing locations of samples.

Nitrogen Concentration Measurements [12]**:**The first measurements of nitrogen weight fractions were made using three samples each weighing about 1.5 g taken from Region 1. The result was 720±32 ppm, so this value was used in calculations for the 18 neutron-irradiated samples in the adjacent Region 2. Subsequent nitrogen measurements were made on 10 mg samples to better conform to the sizes of the radiocarbon samples and so that spatial variations in nitrogen content could be determined; the accuracy of these measurements was5%.Seventeen measurements in Region 3surrounding Region 2 yielded a nitrogen content of 614±50 ppm. Region 4 contained another 21 neutron–irradiated samples; surrounding this region, 29 samples in Region 5 were measured for nitrogen content and yielded a weight fraction of 566±62 ppm, so this value was used for calculations for Region 4 samples.

Figure 3 plots the results of all the nitrogen measurements. The normalized distributions of nitrogen weight fractions for samples plotted in Figure 3 are shown in Figure 4. In the following, the measured radiocarbon that was produced by neutron irradiation was compared with the calculated amount using Equation 4. For this comparison to be valid, it is necessary to measure both the weight fraction of nitrogen, f_N, and the radiocarbon content, pMC, in the same sample. Unfortunately, both measurements are destructive and the nitrogen content varies significantly from place to place in the linen, so precise one-to-one comparisons were not possible. Fortunately, the Region 2 samples that were studied appeared to be fairly homogeneous because the measured results were consistent with a nitrogen weight fraction of 720 ppm.

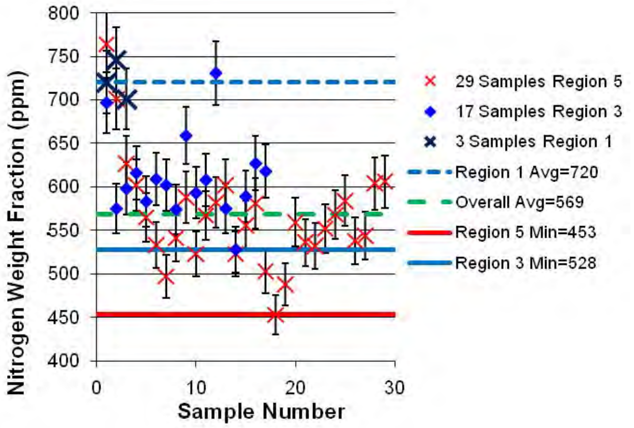

Figure 3. Measured total nitrogen contents for all samples.

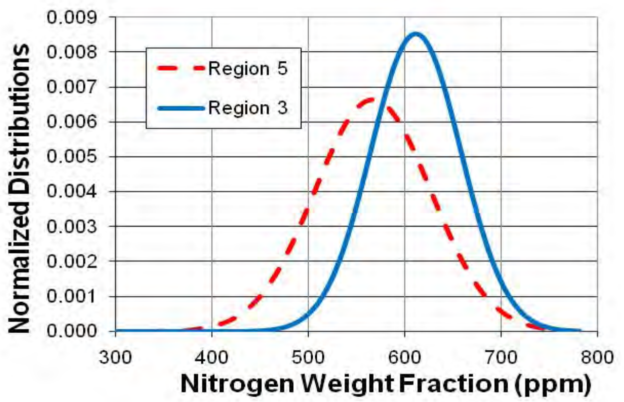

Figure 4. Normalized distributions of nitrogen weight fractions.

Radiocarbon Measurements [13, 14]**:**All radiocarbon measurements had errors of about ±0.75 pMC; none were larger than 1.1 pMC. The percent Modern Carbon of a virgin linen sample from Region 2 measured 107 pMC; this is larger than 100 pMC because of the remnants of radiocarbon produced in the atmospheric nuclear tests in the 1950's. A linen piece from Region 2 was neutron irradiated in carbon dioxide gas with a neutron fluence of 1.07×10^{14}n·cm^{-2}. Equation 4, using the average720 ppm nitrogen content, predicted an increase of 27.55±1.38 pMC which when added to the 107 pMC yields 134.55±1.38 pMC. Errors of ±5% are included because nitrogen measurements had this accuracy. The measured value was 134.89±0.76pMC. This good agreement demonstrates the validity of Equation 4.

This good agreement is in contrast to the result obtained for linen irradiated with a fluence of 1.04×10^{14}n·cm^{-2} in a2.7cm^{3}polypropylene vial containing four small1 mm diameter holes to the outside air. The calculated value was 133.77±1.34 pMC, but the measured value was 224.6±0.9 pMC. Subtracting the baseline value 107 pMC from each of these indicates that the increase in radiocarbon when irradiated in air was 117.6 instead of the predicted 26.77 pMC, a factor of 4.39 times more than predicted. Calculations described below in Effects of Chemical Pretreatments show that collisions of neutrons with nitrogen in the air that surrounds the sample create radiocarbon that diffuse into the sample to cause this increase in radiocarbon. The radiocarbon produced in the air most likely combines with oxygen in the air and diffuses into the linen as carbon dioxide, $^{14}C^{16}O_2$.

Experiments were conducted to determine ifthe radiocarbon that was produced in the surrounding air would diffuse out at room temperature. After waiting 116 days, the measured radiocarbon content had dropped only 12.2 pMC to 212.4±1.1 pMC, which was too slow to obtain an accurate rate at which the radiocarbon was diffusing from the linen. To speed the diffusion process as well as obtain temperature dependent diffusion data, elevated temperature diffusion experiments were conducted. Five samples were heated for 75 minutes at different temperatures,130, 175, 200, 225, and 245 ˚C. Figure 5 shows these samples after heating along with a non-heated sample.

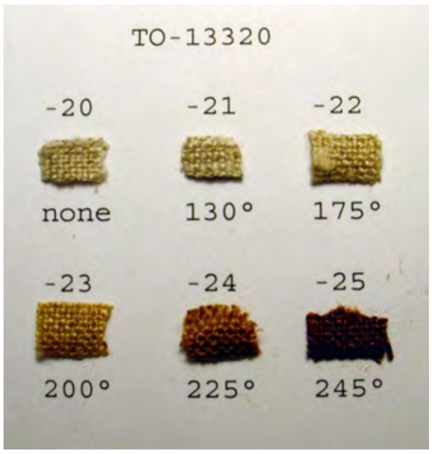

Figure 5. Appearance of six linen samples after heating for 75 minutes at indicated temperature.

The radiocarbon that remained after the heat treatments was measured and is shown in Figure 6; the extra points are for repeat measurements. The line at 133.77 pMC is the predicted value from Equation 4. If no points lie below this line, it indicates that only the radiocarbon produced from the nitrogen in the air diffused out of the sample and that the radiocarbon produced from the nitrogen within the linen did not leave the samples during heating at temperatures up to 245 ˚C for 75 minutes.

The diffusion rates for the heated samples were computed using the unheated sample as the reference. Two room temperature diffusion rates were determined from room temperature measurements at times of 114, 294 and 410 days after irradiation. The diffusion rates are plotted in an Arrhenius format in Figure 7. It is important to note that in computing the diffusion rates, the diffusion was not assumed to be linear because it is actually exponential.

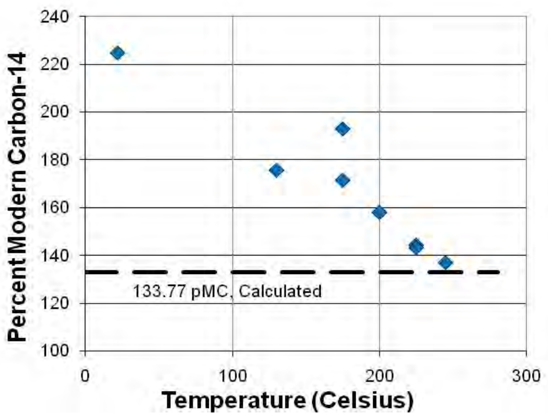

Figure 6. Measured radiocarbon remaining after 75 minute heat treatments between 130 and 245 ˚C.

Thus, more than two points are required to compute the exponential diffusion rate; the third point was the level to which the radiocarbon declined. The predicted value was 133.77±1.34 pMC; other values were also tried and the value of 133.4 pMC gave the lowest R^2 value in the Arrhenius plot. This further verifies the validity of Equation 4. It also verifies that only the radiocarbon produced from the nitrogen in the air diffused out of the sample and that the radiocarbon produced from the nitrogen in the linen remained in the sample at temperatures up to 245 ˚C for 75 minutes.

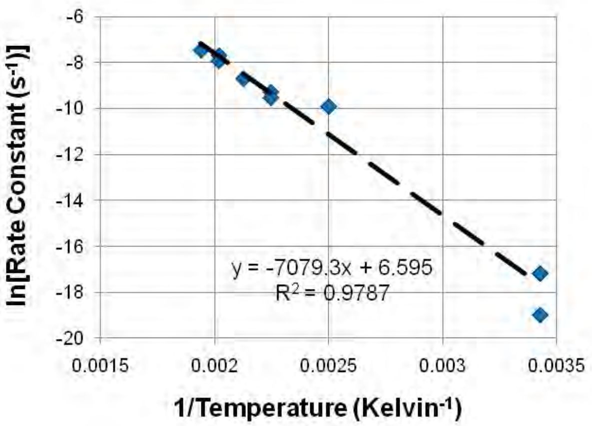

Figure 7. Least squares fit to Arrhenius plot of diffusion rates.

The Arrhenius plot provides the rate constants k(T) for the diffusion process for all temperatures, T, that lie on the straight line fit. The result is given in Equation 5.

$$k(T) = e^{6.595} \times e^{-7079.3/T} = 731.4\, e^{-7079.3/T} \qquad (5)$$

From Equation 5, the rate constant at room temperature (293 K) for diffusion of the radiocarbon produced from the nitrogen in the air is 2.34×10^{-8} sec^{-1}, or 0.74 yr^{--1}. Thus, after 6 years the fraction of this radiocarbon remaining in the linen will be $e^{-0.74\times6}$= 0.012, or 1.2%. This is very slow for diffusion of gases in polymers. The quantity 7079.3 in the exponent of Equation 5 corresponds to an activation energy of 58.9 kJ/mole, which is not an uncommon value for diffusion of carbon dioxide or other gases through amorphous polymers. However, the pre-exponential factor of 731.4 is very small for diffusion in fibrous polymers. The reason is probably because flax fibers are highly crystalline and diffusion is virtually zero through crystalline material. Thus, the diffusion most likely occurs along the labyrinth of amorphous material between the crystals that hold them together. This torturous path greatly slows the diffusion and could explain the very small pre-exponential factor.

TABLE 1.Description of Chemical Treatments Used

Type of Pretreatment	Chemical Pretreatment
Arizona A	0.5% HCl for 2 hours at room temperature (RT) 0.25% NaOH for 2 hours at RT Dilute acid wash
Arizona B	Commercial detergent (1.5% SDS) for 1 hour at RT Wash with distilled water 0.1% HCl for 1 hour at RT Commercial detergent (1.5% Triton X-100) for 1 hour at RT Soxhlet extraction with ethanol for 1 hour Wash with water for 1 hour at 70°
Oxford A	Petroleum ether for 1 hour at 40° 1M HCl for 2 hours at 80° 1M NaOH for 2 hours at 80° Dilute acid wash
Oxford B	Oxford A followed by 2.5% NaOCl (pH=3) for 30 min at RT
Zurich A	Ultrasonic wash in distilled water for 1 hour at RT
Zurich B	Zurich A followed by 0.5% HCl for2 hours at RT 0.25% NaOH for 2 hours at RT Dilute acid wash
Zurich C	Zurich A followed by 5% HCl for2 hours at 80° 2.5 % NaOH for 2 hours at RT Dilute acid wash

Effects of Chemical Pretreatments: Neutron-irradiated samples from both Regions 2 and 4 were subjected to chemical pretreatments like those used in the 1988 radiocarbon dating of the Turin Shroud. Table 1 describes the chemical treatments that were used to duplicate those used by Oxford, Zurich and Arizona. Figure 8 shows the results of the chemical treatments for samples in Regions 2 and 4. Not all pretreatments were performed on Region 2 samples because they were all consumed in the thermal treatments used to perform the Arrhenius analysis.

The consistently larger amount of radiocarbon in Region 2 samples than in the Region 4 samples requires explanation. It is a result of three things. (1) The Region 2 samples had a nitrogen content of about 720 ppm and Region 4 samples had about 566 ppm. (2) The Region 2 samples had more air surrounding them during radiation than did Region 4 samples and since radiocarbon is produced in the air during irradiation, more radiocarbon diffused into the Region 2 sample. (3) A longer time elapsed between irradiation and radiocarbon measurement for the Region 4 sample, allowing a greater amount of radiocarbon from the air to diffuse out again.

In the following these three things are incorporated into a simple correction which assumes all the radiocarbon produced in the air enters the linen. Since the nitrogen in the air and the nitrogen in the linen sample both receive the same neutron fluence, the radiocarbon produced in the air is equal to the radiocarbon produced in the linen times the ratio of the mass of nitrogen in the air surrounding the linen and the mass of nitrogen in the linen. This correction is simple, but it involves many steps. The correction is best described using Table 2because the table lists the Items used in the steps and also presents intermediate results that can be used for comparing the differences in the experiments conducted on Region 2 and Region 4 samples. Table 2 is for samples that received no chemical or thermal treatments because these treatments remove radiocarbon produced in the air, reducing the differences.

The Items 1 through 6 in Table 2 require no explanation. The discrepancies between calculated and measured values are shown as Item 7. The calculated radiocarbon for Region 2 is 90.83pMC smaller than measured, but the calculated radiocarbon for Region 4 is only 5.94 pMC smaller than measured. Items 8 through 16 are needed to compute the relative amounts of nitrogen in the air and the nitrogen in the sample. Looking at Item 16, the Region 2 sample was surrounded by 5.83 times more nitrogen than was contained in the sample, while this ratio is only 1.44 for the Region 4 sample. Thus, Item 17 shows the amount of radiocarbon produced in the air is much larger for Region 2 than it is for Region 4.

TABLE 2. Corrections to Account for Additional Radiocarbon Produced in Air Surrounding Sample

Item	Description	Unit	Symbol	Region 2	Region 4	Comment
1	Nitrogen content	ppm	f_N	720	566	Average in adjacent regions
2	Neutron fluence	$n\cdot cm^{-2}$	n_0	1.04×10^{14}	1.07×10^{14}	Measured
3	Radiocarbon increase	pMC	ΔpMC	26.77	21.66	Eq 4, using Items 1 and 2
4	Baseline radiocarbon	pMC	pMC_0	107	107	Measured
5	Calcuated total radiocarbon	pMC	pMC_c	133.77	128.66	Item 3 + Item 4
6	Measured radiocarbon	pMC	pMC_m	224.6	134.6	Measured
7	Uncorrected discrepancy	pMC	D_0	90.83	5.94	Item 6 - Item 5
8	Sample mass	g	m_s	0.51	12	Measured
9	Fiber mass density	$g\cdot cm^{-3}$	ρ_f	1.45	1.45	Measured
10	Fiber volume	cm^3	V_f	0.35	8.3	Item 8 ÷ Item 9
11	Container volume	cm^3	V_c	2.7	19	Measured
12	Air volume	cm^3	V_a	2.35	10.7	Item 11 - Item 10
13	Nitrogen content of air at STP	$g\cdot cm^{-3}$	ρ_{N_air}	9.11×10^{-4}	9.11×10^{-4}	Calculated from published data
14	Mass of nitrogen in air	mg	m_{N_air}	2.14	9.8	Item 12 × Item 13
15	Mass of nitrogen in sample	mg	m_{N_sample}	0.367	6.8	Item 1 × Item 8
16	Ratio of nitrogen masses (air/sample)		R	5.83	1.44	Item 14 ÷ Item 15
17	Radiocarbon produced in air	pMC	ΔpMC_{air}	156.01	31.09	Item 3 × Item 16
18	1st corrected radiocarbon	pMC	pMC_{cor1}	289.78	159.75	Item 5 + Item 17
19	1st corrected discrepancy	pMC	D_1	-65.18	-25.15	Item 6 - Item 18
20	Time from radiation to measurement	day	δt	114	395	Measured
21	Remaining radiocarbon from air	pMC	$\Delta pMC_{air}(\delta t)$	123.82	13.96	Eq 5, using Items 17 and 20
22	2nd corrected radiocarbon	pMC	pMC_{cor2}	257.59	142.62	Item 5 + Item 21
23	2nd corrected discrepancy	pMC	D_2	-32.99	-8.02	Item 6 - Item 22

Adding Item 17 to the original calculated radiocarbon, Item 5, produces the 1st corrected result that is now significantly larger than measured, as seen in Items 18 and 19.

Item 20 shows the large time delays between neutron irradiation and radiocarbon measurement. During this time delay, some of the radiocarbon produced in the air that entered the sample slowly diffused out again. Item 21 was obtained using Equation 5 to determine how much radiocarbon, Item 17, would remain after the time delay, Item 20. Adding this amount to the original calculated radiocarbon, Item 5, produces Items 21 and 22 that are significantly improved over Items 18 and 19, but still larger than measured.

A possible reason for the 2nd corrected calculated radiocarbon to be larger than the measured radiocarbon is that not all the radiocarbon produced in the air entered the sample as was originally assumed in this analysis. Neglected in this assumption is the possible loss of radiocarbon out of the containers used during irradiation. The Region 2 sample was in a polypropylene container containing four small 1 mm diameter holes open to the outside the air, which would allow the escape of radiocarbon, perhaps accounting for the -32.99 pMC discrepancy. The Region 2 sample, which has a discrepancy of only -8.02 pMC was irradiated in a tightly wrapped plastic film that was placed inside another container with the remaining volume filled with plastic foam, so it was less likely to lose as much radiocarbon through the container walls as was the Region 2 sample.

It must be pointed out that the nitrogen contents (Item 1) in Table 2 are not the nitrogen contents of the actual samples that were used, but are the averages of the nitrogen contents of samples in adjacent regions. Thus, exact agreements between calculated and measured values are not expected and good agreements may be fortuitous. Nevertheless, the corrections presented in Table 2explain why Region 2 samples had larger radiocarbon contents than Region 4 samples.

The lower bounds marked in Figure 8 are explained as follows. The smallest nitrogen concentration measured in Region 3, which surrounds Region 2, was 528 ppm. From this and the neutron fluence of that this linen received, Equation 4predicts that the pMC for Region 2 will not fall below 126.6±0.98pMC. If it falls below, then some radiocarbon that was produced within the linen is removed by the chemical treatment. Likewise, the smallest nitrogen concentration measured in Region 5, surrounding Region 4 and which received 1.07×10^{14}n·cm^{-2}, was 453 ppm; this results in a lower bound of 124.3±0.87 pMC for Region 4. Only one sample falls below its lower bound and that is the Region 4 sample that received the Zurich C treatment, which actually was not as harsh as the Oxford B treatment.

Effects of a Thermal Treatment followed by Chemical Pretreatments: Using some samples from the irradiated linen that was used in the chemical pretreatment experiments, similar experiments were conducted, but the samples were heated for 75 minutes at 175 ˚C prior to the chemical treatments. The temperature of 175 ˚C was chosen because Figure 4 shows that this heat treatment produces a small but noticeable color change, more than any color change that was observed on the samples used in the 1988 tests.

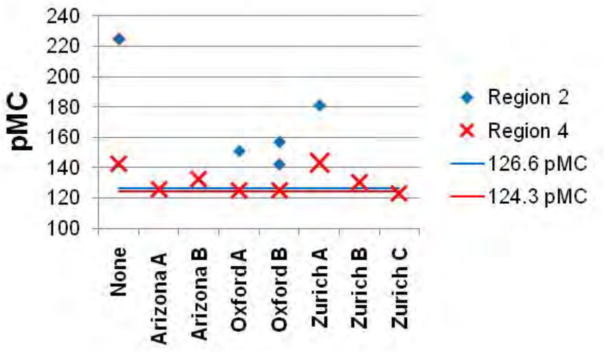

Figure 8. Percent Modern Carbon remaining in samples from Regions 2 and 4 after chemical treatments.

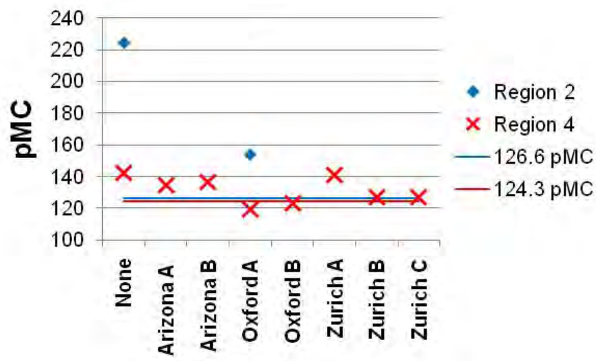

Figure 9. Percent Modern Carbon remaining in samples from Regions 2 and 4 after both thermal and chemical treatments.

Figure 9 shows the results of these experiments. Region 4 samples Oxford A and B fall slightly below the lower bound for this region, but this is attributed to a large variation in nitrogen content. As an example of the inconsistencies caused by variations in nitrogen contents, notice that Oxford A is lower than Oxford B even though Oxford B is a much harsher treatment. Comparing Figures 8 and 9, one might expect that samples both heat and chemically treated would have lower radiocarbon contents than those only chemically treated, but that is not true for all chemical treatments. This inconsistency is most likely caused by the variations in nitrogen content that occur throughout the linen. Within this error, it appears that no radiocarbon created within the flax fibers was removed by heat and chemical treatments.

Gradients of Nitrogen Inhomogeneity: While measurements of nitrogen concentrations at random locations in the linen confirmed that the nitrogen content is inhomogeneously distributed, it did not provide information on the spatial gradients of nitrogen variation and how this might affect the radiocarbon dating of closely-spaced samples. Therefore, closely-spaced samples were cut from 1 cm by 5 cm linen pieces obtained from Region 3 that surrounds Region 2, and Region 5 that surrounds Region 4, and their nitrogen contents were measured. Figure 10 shows how the samples were cut. The perimeters of the 1 cm×1 cm squares, which weighed 10 mg, were measured for nitrogen content. The centers, which weighed 15 mg, were retained if additional measurements were required.

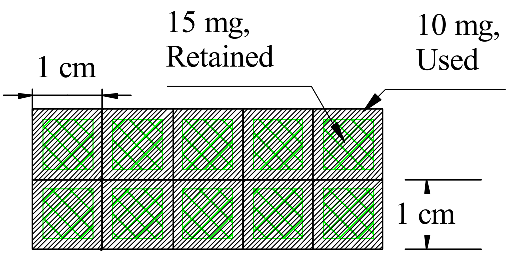

Figure 10. Squares of linen were cut for measuring gradients of nitrogen concentrations in Regions 3 and 5.

The results are plotted in Figures 11 through 14. Figure 11 shows the nitrogen weight fractions for samples in region 3 and Figure 12 shows how these samples would radiocarbon date in 1988 if irradiated in 33 AD with a neutron fluence of $8.3\times10^{13} n\cdot cm^{-2}$. Equations 3 and 4 were used to determine this neutron fluence to make the linen appear 1300 years younger if the nitrogen weight fraction was the average of all samples measured in this linen, namely, 569 ppm. The time period of 1300 years corresponds to the suspected age error in the 1988 radiocarbon dating of the Turin Shroud. Figures 13 and 14 are like Figures 11 and 12 except they are for samples taken from Region 5.

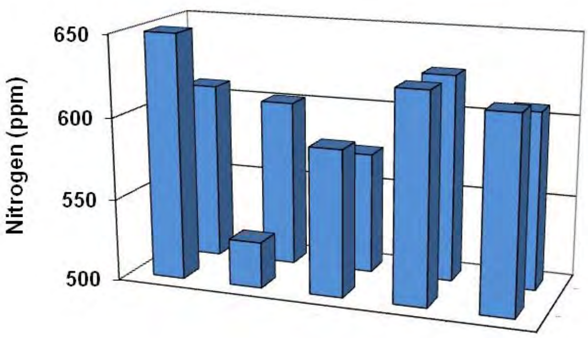

Figure 11. Measured nitrogen weight fractions in linen samples from Region 3. The bar locations correspond to the 1 cm spacing of the samples shown in Figure 10.

Figures 11 and 12 for Region 3 show nitrogen concentrations ranging between 528 and 653 ppm and the corresponding radiocarbon dates ranging between 1241 and 1502 AD instead of 33 AD. The gradients are as large as 125 ppm/cm and 261 years/cm.

Figures 13 and 14 for Region 5 show nitrogen concentrations ranging between 532 and 606 ppm and the corresponding radiocarbon dates ranging between 1241 and 1405 AD. The gradients are as large as 60 ppm/cm and 126 years/cm.

These gradients in radiocarbon dates calculated from the measured nitrogen concentrations in Regions 3 and 5 are comparable with the gradients of about 41 yr/cm observed for the 1988 radiocarbon results.

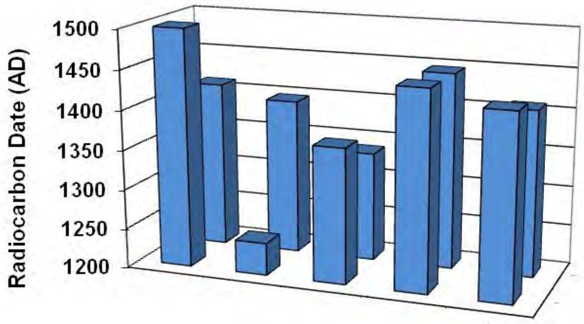

Figure 12. Calculated radiocarbon dates of the samples from Region 3 shown in Figure 11; see text.

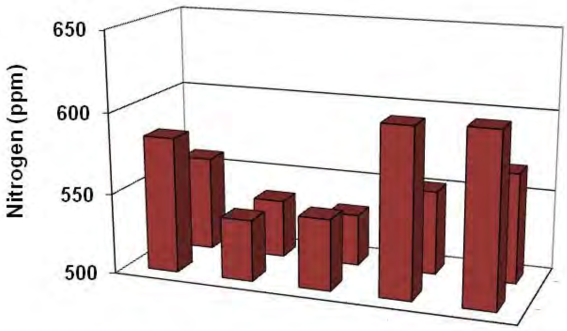

Figure 13. Measured nitrogen weight fractions in linen samples from Region 5. The bar locations correspond to the 1 cm spacing of the samples shown in Figure 10.

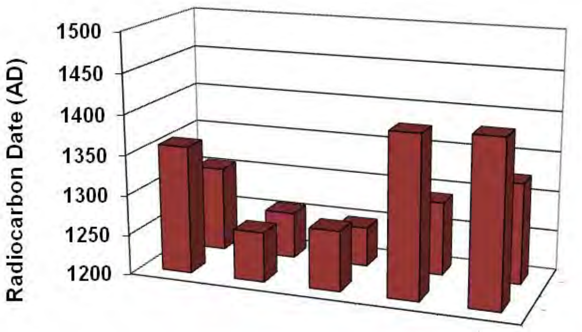

Figure 14. Calculated radiocarbon dates of the samples from Region 5 shown in Figure 13; see text.

4. CONCLUSION

Neutron irradiation of flax linen increases the radiocarbon content by two distinct modes. The first mode is by nuclear reactions with nitrogen indigenous to the flax. Within the uncertainties caused by variations in nitrogen content of the linen, the amount of radiocarbon produced by this mode can be calculated from the neutron fluence and the nitrogen content of the linen. Within these uncertainties, this radiocarbon was not removed by high temperatures or by the chemical cleaning treatments used in the 1988 tests. Thus, this radiocarbon acts as a contamination that is indistinguishable from the natural radiocarbon in the linen and it will act to reduce the radiocarbon age of the linen.

The second mode of generating radiocarbon is by nuclear reactions with the nitrogen in the air that surrounds the linen and then enters the linen. These experiments have shown that the amount of radiocarbon produced by this mode and which enters the linen can be estimated if the linen is of known volume, is in a closed container of known volume, and it remains there for a few days. Experiments were not conducted to determine how much radiocarbon produced by this mode enters the linen if the linen is not in a closed container or if it is removed from the container immediately after irradiation. The most important finding of this research concerning radiocarbon produced in the air surrounding the linen is that it is not permanently bound to the linen and 99% of it diffuses out in about six years at room temperature. Furthermore, virtually all of this radiocarbon can be removed in minutes by exposure to elevated temperatures or by the chemical cleaning treatments used in the 1988 tests. Thus, if the Turin Shroud received neutron irradiation, its carbon-14 content would increase, causing its radiocarbon age to be younger despite experiencing thermal heating greater than it received in the 1532 Chambery fire and by the pretreatment cleaning procedures employed in the 1988 tests. In addition, significant spatial variations of nitrogen were measured in the modern linen used in these experiments. Calculations showed that these variations would cause radiocarbon age gradients as large as 261 yr/cm if it received the neutron fluence needed to reduce its age by 1300 years. If the Turin Shroud had received neutron irradiation and the Shroud's natural variations of nitrogen content were similar to these found in the linen used in this study, these radiocarbon age gradients could explain Riani's [7] conclusions that the Shroud's radiocarbon dates were inhomogeneous.

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While we have many to thank for their support, we especially want to note the years of donations from Dick and Sandy Nieman and Pat and Patty Byrne. Several years ago Francis DeStefano literally gave all of his savings for these tests and experiments. Most of all, these tests and experiments would not have occurred without the dedication, determination and financial support of Paul and Mary Ernst and their friends in Boulder, Colorado. We would also like to thank Roelf Beukens of IsoTrace Laboratory for his suggestions and cooperation. Finally, we would like to thank the Referee for thoroughly examining all aspects of our paper and for making suggestions that improved its clarity and greatly strengthened our conclusions.

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12. Elemental analyses of CHO and N were made on three samples each weighing 1.5 g at Galbraith Laboratories in Knoxville, KY. Nitrogen concentrations on 42 samples each weighing 10 mg were made at Micro-Analysis, Wilmington DE.

13. Neutron irradiations were performed at the University of Missouri Research Reactor in Columbia MO.

14. Radiocarbon measurements, sample heat treatments and chemical treatments were performed at IsoTrace Radiocarbon Laboratory, Accelerator Mass Spectrometry Facility at the University of Toronto.

Two archaeometric methods for cellulosic textile finds using enzymatic test

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Abstract
A biosensoristic approach to the problem of dating cellulosic finds is reported. Two methods are proposed both based on the intramolecular modifications of the cellulose molecule resulting in increased degrees of carboxylation and of methylation with age. By calibration with referred samples it is possible to date unknown materials. The first method uses carboxylic group as immobilizing agent of enzyme molecules the amount of which is evaluated by the reaction catalysed by the enzyme. The second adopts a demethylating enzyme as focal component of the sensor measuring the concentration of a marker compound obtained by the methylation of a target molecule due to the methyl groups removed by the enzyme from the sampled cellulose.

Keywords: dating, enzyme, textiles, cellulosic finds, biosensor

1. INTRODUCTION

Our research consisted in designing, setting up and applying two methods for the scientific dating of textiles of archaeological and historical interest. The work must be considered as a possible future way of dating cellulosic finds, even if being at the present at a not complete assessment and definition.

The first method is based on an enzymatic biosensor, previously designed and applied by us to the dating of wood finds [1] and extended here to the case of cellulosic textiles. The principle of the method is that the number of carboxylic groups in cellulosic material increases with the passage of time, due especially to the intramolecular oxidation, so that it is proportional to age. As the presence of these groups allows an enzyme to be covalently bound to the cellulosic textile, it follows that the immobilised enzymatic activity is higher, as older is the sample. This activity can be evaluated by the analysis of the enzymatic reaction (for instance if enzyme is glucose oxidase the final product is gluconic acid to produce which oxygen is consumed).

The second method is based on SAMT (S-adenosylmethionine-transmethylase), an enzyme isolated from *Penicillium chrysogenum*. It was experimentally found that the alkylation degree of β-D-glucosidic monomers of cellulose (more particularly the presence of methyl and carboxyl groups in cellulosic textiles) increases with sample age. It was also observed that demethylation, catalysed by the SAMT enzyme, in the presence of SAM (S-adenosylmethionine), is more pronounced as older are the textiles. This process leads to the breakdown of SAM into adenosine and homocysteine. If the amount of adenosine generated by the reaction is determined, it is found to be proportional to the age of the sample.

2. SAMPLES

The cellulosic textile samples consisted of linen and rope, dating respectively to the 8th, 14th and 16th centuries, kindly supplied by Moscow University, Turkish Museums and private collections, together with linen samples from more recent periods (20th and 21st century).

3. METHODS

3.1 Biosensor method

The method is based on the correlation between cellulose carboxylation, which progresses with time, and the ability to bonding between the carboxyl groups produced and an enzyme. Quantities of enzyme bonded may be evaluated by the electrode's response to oxygen, whenever the enzyme, as in this case, belongs to the oxidase group. To achieve this, an enzyme [2], glucose oxidase, which catalyses the reaction:

$$C_6H_{12}O_6 + O_2 + H_2O \xrightarrow{\text{glucose oxidase}} C_6H_{12}O_7 + H_2O_2 \quad (1)$$

is immobilized on the cellulosic material being tested.

Therefore, if glucose is added in excess to the solution in which the electrode containing the cellulose sample with the immobilized enzyme is dipped, reaction (1) will take place.

The O_2 variation with the time (that means O_2 consumption rate) due to reaction 1 detected by the transducer (Clark electrode), is proportional to the immobilised enzyme activity, which itself correlates with the number of carboxyl groups on the cellulosic material and thus with its age.

To this purpose, 8 mm disks were cut out of the linen samples. These disks were then weighed and placed in small beakers, where they were subjected to enzymatic immobilization treatment using carbodiimmide [3].

The cellulose sample with the immobilized glucose oxidase was then sandwiched between the gas-permeable membrane of the Clark electrode and nylon netting which was then secured to the electrode cap using a rubber O-ring. After assembly, the biosensor was connected to the power supply and the measuring device and was then ready for use. It was then immersed in a beaker containing 10 mL of acetate buffer 0.1 mol/L at a pH = 5.1. The electrode was allowed to be stabilized for about 10 min in these conditions till to constant signal; this state was indicated by a plateau on the recorder. A micropipette was then used to add 1.0 mL of glucose 1 mol/L, that is, a strong excess of substrate. The addition of substrate led to a diminution of the dissolved oxygen concentration as a result of reaction (1). As soon as the glucose was added a chronometer was started and amounts of oxygen (in ppm, i.e. parts per million) were recorded every 10 sec. At the same time, a recorder connected to the potentiometer plotted the corresponding curve. The signal was then allowed to reach a stationary state, for which a time of about 8 min was necessary.

Using pre-referenced samples and plotting the oxygen consumption rate (due to the enzymatic reaction) versus the sample age, it was possible to record a calibration curve for which the age of unknown samples can be determined.

3.2 SAMT method

It is known that the structure of ancient textiles contains chemically modified β-D-glucose residues. In particular, it was found that cellulose alkylation increases with textile age [4].The method used to date the cellulosic material consists in allowing the previously washed and air dried sample to react with a solution containing the enzyme SAMT (S-adenosylmethionine-transmethylase), which catalyses the demethylation reaction in presence of SAM (S-adenosylmethionine) and THFA (tetraidropholic acid), a cofactor that, by forming a complex, THFA-CH_3, facilitates the subsequent demethylation of the cellulose. The older the ancient textile the more methyl groups it contains.

Therefore, in presence of the enzyme SAMT and under these reaction conditions, the textile sample is demethylated, that is, the SAM ↔ SAH equilibrium is shifted towards the SAH (S-adenosylhomocysteine) [5]. The latter is then broken down into adenosine and homocysteine.

$$\text{cellulosic material} \xrightarrow{\text{SAMT+SAM+THFA}}$$

$$\text{demethylated cellulosic material + adenosine + homocysteine}$$

The amount of adenosine thus released will be higher for the older textiles and lower for the younger ones. The adenosine released is determined either by the thin layer chromatography (TLC), using ammonia/acetic acid /acetone/ n-butanol/chloroform (3:2:5:4:1) (v/v) as eluent and densitometric measurement (TLC-UV at λ = 254 nm) or better by the high – performance liquid chromatography (HPLC), which allows amounts of nmol order to be measured [4]. Therefore, using referenced, that is, dated samples, it was possible to plot an archeometric curve showing the quantity of adenosine released, expressed in (μmol/g of dry material) 10^{-3}, versus the age of the sample expressed in years.

The operating conditions used for the HPLC measurements are shown in table 1.

TABLE 1. Conditions of HPLC analysis of adenosine

Analytes	Adenosine (ADO), SAM and SAH
Column	Supelcosil LCI8 (25 cm x 4.5 mm)
Mobile phase	20% MeOH, 80% solution: 20 mmol/L sodium phosphate buffer (pH=5.5), 1mmol/L EDTA, 3% MeOH
Flow rate	1 mL/min
Detection	UV λ = 254 nm

4. RESULTS AND DISCUSSION

Results obtained with the biosensor method

By applying the (glucose oxidase) biosensor to textile cellulosic materials experimental values were obtained that allowed to construct the archeometric curve shown in fig. 1.

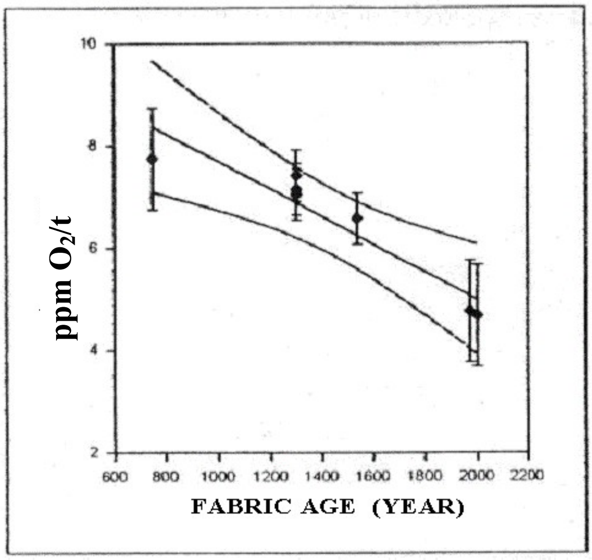

Figure 1 Archeometric curve for the biosensor method. Equation and confidence limits:
Y = (-0.0027 ± 0.0004) X + (10.4 ± 0.7);
Y = mg/L of O_2/t
X = year $r^2 = 0.8868$; t = 8.77; (1 –a) = 0.95

Results obtained with the SAMT method

Using dated samples and the SAMT method, experimental values were obtained which could be used to construct an archeometric curve, as shown in fig. 2.

Really, we performed two curves in two different laboratories of our Department.

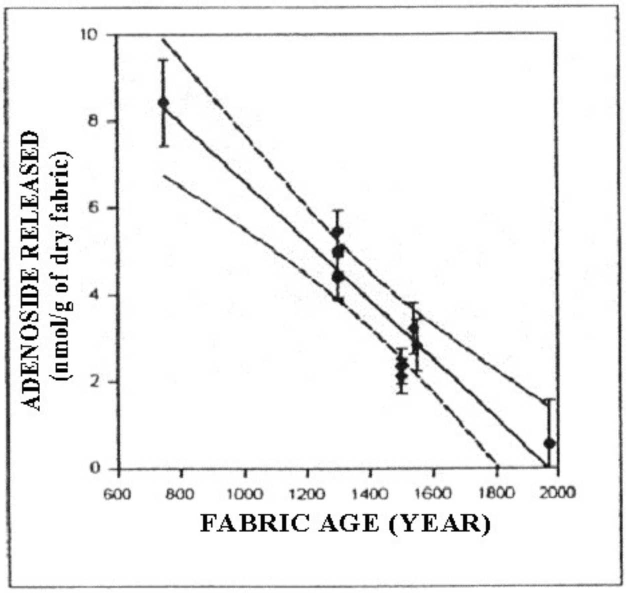

Figure 2 Archeometric curve of SAMT method. Equation and confidence limits:
$Y = (-0.00687 \pm 0.0007) X + (13.5 \pm 1.0)$;
Y = nmol/g of adenosine;
X = year $r^2 = 0.9222$; $t = 14.37$; $(1 - a) = 0.95$

The two curves show fairly good agreement. The slope of the two straight lines are very similar. The r values is slightly higher in the case of the curve obtained by more homogeneous samples. We have also evidance that a positive effect on r is obtained with a purer SAMT enzyme.

It must however be added that sample,T3, colored green deviates from the line. In the hope of identifying the reason for this, photographs were taken under the electron microscope; by comparing this image with that one of the SEM photomicrograph obtained for a sample which instead gave positive result, it seems likely to hypotheses that former is covered by a layer of some unknown substance. Further studies are under way to clarify whether this is the reason for the apparent blocking of the SAMT-catalyzed reaction. In any case, the results confirm the proportionality between the quantity of adenosine released and sample age, which allows ancient textiles to be dated on the basis of the cellulosic material they contain.

5. CONCLUSION

By an original and innovative method based on the enzymatic reaction catalysed by SAMT an archeometric curve was obtained. It can be used to date amount less then normal of ancient textiles of unknown age on the basis of the adenosine released during the reaction. With a reproducibility of about 85%. Also in the case of the biosensor method an archeometric curve was recorded for archaeological textiles which can be used to evaluate unknown ages with a precision of about 90%. Comparison of the sensitivity of the two methods in terms of variation of mole number to be revealed per year shows that the SAMT method is about one hundred thousand times less sensitive than the other. The first method is also faster, simpler and cheaper than the first one, and can be used on smaller amounts of sample.

ACKNOWLEDGMENTS

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A critical review of the radiocarbon dating of the Shroud of Turin. ANOVA - a useful method to evaluate sets of high precision AMS radiocarbon measurements

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Abstract
A review of the radiocarbon literature illustrates limitations the AMS method shows when dating bones and all kind of living plants like flax, mainly composed out of cellulose. A number of old and recent radiocarbon dating results, made on linen and wood, are compared.

Keywords: AMS Statistics, Chi² test, IEM-EEM, ANOVA.

1. INTRODUCTION

In 1989, Nature [1] published the report on the radiocarbon dating of the Shroud of Turin, by the laboratories of Oxford, Arizona and Zurich. Claimed was of mediaeval date for the Shroud with a least 95% confidence.

I then published a small booklet [2], with a complete statistical analysis, including Chi², IEM-EEM and a small ANOVA [3] tests; showing that the claimed 95 % confidence was not supported by a statistical test.
Today ANOVA is accepted by NIST [4].

When I conducted some heating experiments on inducing ^{14}C enrichment, I received an official dating report from the Oxford radiocarbon laboratory. I was surprised to read the following caveat:
"One should bear in mind that these measurements have been made on organic material and that this cannot be regarded as a guarantee of the article date of manufacture. It should be noted that the undetected presence of any contaminant may affect any radiocarbon result."

A caveat in contrast with the more stringent requirements imposed for industrial laboratories. In that context, a precision in part per million is mandatory.

2. AMS MEASUREMENTS

Until 1977, radiocarbon measurements were made by counting the number of ^{14}C decays over a long period. The development of AMS with real ^{14}C isotope counting was a revolution. One became able to almost completely separate nitrogen and carbon isotopes. In 1986, a Zurich AMS test run with 14 standard samples, showed a counting error of 0.3% and an overall error of ~ 1 %. The conclusion of that study was: "One should improve the count rate and reduce contamination by at least a factor 2" [5]. So, the need to improve the precision of AMS measurements has been known for some time.

Scott, analyzing the 1990 International Collaborative Programme [6] concluded: "*It seems reasonable to consider that a laboratory performs adequately if it has no systematic bias and assesses its internal and external variability adequately. IEM & EEM should not significantly different from 1. In total, only 15 out of 58 laboratories did meet these 3 basic criteria*".

Today in its website, the AMS laboratory of the University of Arizona at Tucson [7] claims an error as low as 0.2%, a high level of precision in RC year terms. They note that when results are in doubt, measurements are repeated and the AMS equipment tuned or even shut-down for repair.

This level of precision and accuracy has changed over time. In 1990-1992, Arizona obtained ~ 85% correct measurements. By 2000, they improved to about 92% but this still means nearly one failure out of ten measurements. May one wonder about the failure rate in 1988?

It should also be noted the need for a statistical analysis of the ^{14}C count, due to some unpredictable spontaneous reactions:

$$^{14}N + n = {}^{14}C + p \ \ \& \ \ {}^{14}C => {}^{14}N + b + 160 \text{ keV}$$

Analysing char and root fractions from grain and pollen samples, NIST researchers [8] noted significant differences in the ^{14}C content of different fractions taken from the same sample. Analysis of SRM 1649a NIST reference material showed an elemental ^{14}C

char/soot ratio of 2.75. The biomass is about 38% and contains a mixture of about 13% aromatic components. Because such a high biomass carbon fraction is very important, there must be a significant missing carbon component in this material.

Most important, it was noted that cellulose (such as the linen of the Shroud) is an excellent candidate for easy contamination!

Recent "molecular analysis" of individual amino acids from crude collagen and gelatine fractions from the Dent Mammoth [8], shows ^{14}C counts between 4,000 and 2,500 (8,000 ~ 11,000 BP).

In *Radiocarbon* n° 40 (1996), the same author noted: "*In the nearby future modern ^{14}C techniques will eventually lead to the application of a **real** isotopic mass balance, using actual **true** ^{14}C counting*".

As recommended by Polach [9], ^{14}C count values are more appropriate in analysis than using "RC ages" which are log-normally distributed. An example of this effect is as follows.

A RC age of 795 ± 65 years represents an uncertainty range of 65/795 or ± 8.2%.

The equivalent ^{14}C data produces a count of 8629 ± 68 which represents an error of 68/8267 = 0.82%. Likewise, 795+65 = 860; 860/8267 = 0.104015; exp(0.104015) = 1.1096; 9,500/1.1096 = 8,561.5 ^{14}C counts

795-65 = 730; 730/8,267 = 0.088292; exp(0.088292) = 1.0923; 9,500/1.0923 = 8,697.2 ^{14}C counts.

Mean date = 8629 +/- 68.

From this it is apparent that relatively small changes in ^{14}C count can translate into large changes in reported radiocarbon dates.

3. COMPARISON OF A SET OF DATES, REPORTED BY POLACH AND THE DATES REPORTED FOR THE SHROUD

To illustrate how to evaluate radiocarbon data, Wilson and Ward [9] used data for three independent measures of a single piece of wood, given by Polach [9]. From this we can conclude that there is no evidence to reject the null hypothesis the three samples observations are consistent.

Using these three samples with a calculated χ^2 value is a useful way to compare the *Nature* [1] data reported in Table 2 for the Shroud. Here we apply the same methodology as above to evaluate the hypothesis that the measurements are consistent.

As showed previously, one should correct Table 2 as follows (see the full analysis on www.shroud.com, paper by Van Haelst):

Comparison between the Polach samples and data given in Nature.

Polach		Nature Table 2		Nature following Table 1	
Sample a	4330 ± 190	Arizona	646 ± 31	Arizona:	646 ± 17
Sample b	4560 ± 210	Oxford	750 ± 30	Oxford:	749 ± 31
Sample c	4940 ± 300	Zurich	676 ± 24	Zurich:	676 ±24
Mean:	4525 ± 128	Mean	689 ±16	Mean	672 ± 13
Chi² :	2.99 < 5.99	Chi²	6.35 > 5.99	Chi²	8.56 > 5.99
p = 0.24		p = 0.042		p = 0.012	

Thus, in both published and corrected cases, there is no reason to accept the null hypothesis that the observations are consistent and provide 95% confidence. However, for the Shroud measurements the radiocarbon researchers rejected this conclusion. One laboratory even questioned the statistical method used by the British Museum. According to Prof. Ramsey, Director of Oxford RC Laboratory, the measurements for the Shroud obtained in 1988 were within the acceptable error range of the AMS facilities of that time. He noted that he did not wish to spend his time recalculating data statistics [10].

Dr. Hedges (Oxford) and Prof. Jull (Arizona) agreed that there is indeed a "small" statistical problem, the Oxford dates being different from the two other laboratories [10, 11]. Unfortunately, none of them answered the question: "How did you obtain the claimed 95% confidence?"

Another recent example of a possible erroneous radiocarbon result is the dating of the "Seamless Cloth" [12], the type of garment mentioned in the Gospel of John (19:23). The cloth kept in Argenteuil, thought to be the Seamless Cloth, was twice radiocarbon dated by Gif-sur-Yvette and later in a totally blind evaluation by ETH Zurich. See below for the dating results.

Seamless Cloth dating results:

Gif A 40100: 1450 ± 40	Gif A 40101: 1510 ± 40	ETH 30402: 1260 ± 40
Error weighted Mean: 1407 ± 23	χ^2 : 21.2917 > 5.66	p-value =0.0000

Thus, the hypothesis that the measurements are homogeneous and the means equal is rejected and the dating results are shown to be not conclusive.

Also the analytic details related to the Acid-Alkali-Acid cleaning are noticeable:

	Carbon	**Oxygen**	**Aluminium**	**Sulphur**	**Calcium**	**Iron**
Before	56	43	3	9	31	2
After	54	29	15	14	10	0

(height of the peaks in mm on the graphs.)
A loss in Carbon, Oxygen, Calcium and Iron. A gain in Aluminium and Sulphur.
A loss of about 1/3 in weight, probably indicating some heavy contamination.

It is clear from these two examples that there are apparent difficulties in reliably dating old fabric using standard radiocarbon dating precleaning techniques.

Today in AMS single run, one measures with repetition between 6 ~ 20 pure carbon targets prepared from the same sample, together with a number of standard and blank samples. The pure carbon is mixed with a graphite carrier. These pellets (targets) are placed on a turning wheel, to be measured one after another using sophisticated AMS equipment. Measured are also a number of standard samples and blanks. The targets are bombarded with high energy beams. Separation of ^{12}C, ^{13}C and ^{14}C isotopes is almost complete while care is taken to avoid crater formation in the targets.

Note that ^{14}C is counted, while the other isotopes are "frequency current" measurements. In Arizona the laboratory uses "coulomb/second" measurements. The measured ratio $^{14}C/^{13}C$ is about 18 times the natural ratio [7]. In practice, AMS measurements still are of variable precision. Therefore one needs corrections, taking in account a possible instrumental "drift".

Each laboratory uses a specific method to correct variable counts, taking into account the correction factors for the measured ratio $^{14}C/^{13}C$ and ^{14}C count and as a result, for this reason, "raw" count data cannot be used in statistical analysis. Several runs such as this are made to create a set of measurements with their standard errors. For instance, for the 1988 Shroud dating, Arizona made eight independent runs [10]. Each single AMS measurement is the combination of at least 6 observations per run.

Applying a classic analysis of variance (ANOVA) taking in account only the counted ^{14}C particles, allows to determine whether the measurement differences noted are due to chance or to the fact that the differences between the runs are indeed too large. By chance alone, the F statistic should be ~ 1.00. Errors are assumed to be due to chance or to experimental uncertainty.

4. ANOVA

In 1986, the British Museum applied an Analysis of Variance on the 12 individual measurements supplied by the laboratories, to determine the t_d value for 2 - 9 degrees of freedom [1]. They found that the errors based on the scatter should be multiplied by a factor 2.56 to more appropriately represent the variability in the data.

In the English version of a small booklet published in 1989 [2] I already employed ANOVA. Analysing the 12 mean data in Table 2 of the *Nature* paper [1], I concluded: "*The calculated F value 4.7 is larger than 4.2, the critical F value for 2-9 degrees of freedom*." With results like these, one should not draw any conclusions but ask for more and better measurements. Further, other researchers have also used ANOVA to analyse Table 2 and came to the same conclusion [13].

The accuracy of the ANOVA method can be impacted by differing numbers of measurements per group, large deviations from the normal distribution and inequalities in the variances of each of the groups being evaluated. Being sure these factors are accounted for, ANOVA provides a useful means of evaluating comparative measurements.

Using ^{14}C count means much tedious calculation work, but is readily made manageable by using an Excel worksheet or by using any of the modern commercially-available statistical packages.

In this study the laboratory data given in Table 1 will be analysed by ANOVA, taking into account the observation that each single date is the results of multiple measurements. The errors based on quoted errors and in percent are used.

5. MODELLING

Let suppose there are three runs, each counting 10 ***standard*** samples (targets) with a number of blanks, measured under the same conditions, in the same AMS machine.

To simplify calculations, we assume that the exact number of ^{14}C counts for each standard sample totals 30,000 with the measurements normally distributed ± 0.3% around the mean for each run. In our example, the total number of ^{14}C count is equal to 10,030 + 10,000 + 9,970 = 30,000.

With the above assumptions we observe that:

Run A	Run B	Run C
987	984	981
993	990	987
997	994	991
999	996	993
1002	999	996
1004	1001	998
1007	1004	1001
1009	1006	1003
1013	1010	1007
1019	1016	1013

We then use one-way ANOVA to evaluate the null hypothesis that the mean value of each of the runs is equal.

ANOVA: Single Factor
SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	S.D.
Run A	10	10030	1003	718	8.93
Run B	10	10000	1000	718	8.93
Run C	10	9970	997	718	8.93

ANOVA

Source of Variation	***SS***	***Df***	***MS***	***F***	***P-value***
Between Runs	180	2	90	1.02297	**0.3730**
Residual error	2375.44	27	87.98		
Total	2555.44	29			

Conclusion: the hypothesis that the mean value of each of the runs is the same is accepted.

A practical example

In the past, I received a breakout of the original measurements provided by the University of Arizona's Tucson radiocarbon dating facility to the British Museum as a part of the 1988 radiocarbon dating experiment [10]. These data (originally reported laboratory measurements) are:

1988 Radiocarbon dating experiment: original measurements with quoted error of measurement at 1 σ level.
Shroud of Turin samples

Laboratory	Measurement (RCYBP)	Error
	606	**+/- 41**
	574	**+/- 45**
	753	**+/- 51**
Arizona	**632**	**+/- 49**

	676	**+/- 59**
	540	**+/- 57**
	701	**+/- 47**
	701	**+/- 47**
	733	**+/- 61**
	722	**+/- 65**
Zurich	**635**	**+/- 57**
	639	**+/- 45**
	679	**+/- 51**
	795	**+/- 65**
Oxford	**730**	**+/- 45**
	745	**+/- 55**

The Arizona data were combined into four measurements that are the dates reported in the *Nature* paper [1]:

Original data:			Combined: (Van Haelst Acts CIELT Rome 1993 p 216)
Session A	606 ± 41	574-+45	591± 30
Session B	753 ± 51	632-+49	690 ± 35
Session C	540 ± 57	676-+59	606 ± 41
Session D	701 ± 47	701-+47	701 ± 47
Mean	646 ± 17		646 ± 17 (*Nature:* 647 ± 31) [1]

Unfortunately, the *Nature* paper never mentioned the combination of the eight observations into four observations and, as a result, the statistical analysis reported was somewhat misleading.

Because no information was provided by the laboratories, I was obliged to recalculate the number of ^{14}C atoms detected. I used this calculation to simulate a distribution of observations that make up each of the runs and test the hypothesis that the runs means are the same.

Let us assume the following characteristics: counting error = 0.3%, with eight runs each using 10 targets as shown in the following example:

Run A	**Run B**	**Run C**	**Normally Distributed Run D**	**Run E**	**Run F**	**Run G**	**Run H**
8539	8592	8591	8617	8664	8691	8725	8750
8589	8642	8641	8668	8714	8742	8776	8802
8618	8672	8671	8698	8745	8773	8806	8832
8642	8696	8695	8722	8769	8797	8831	8857
8664	8718	8717	8744	8791	8818	8852	8878
8684	8738	8737	8764	8811	8840	8874	8900
8706	8760	8759	8786	8833	8861	8895	8921
8730	8784	8783	8810	8857	8885	8920	8946
8759	8814	8813	8840	8888	8916	8950	8976
8809	8864	8863	8891	8938	8967	9001	9028

ANOVA: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Run A	10	86740	8674	6619.368
Run B	10	87280	8728	6702.043
Run C	10	87270	8727	6700.507
Run D	10	87540	8754	6742.032
Run E	10	88010	8801	6814.622
Run F	10	88290	8829	6858.051
Run G	10	88630	8863	6910.973
Run H	10	88890	8889	6951.580

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*
Between Runs	389,588.8	7	55,655.54	8.1998	0.0000
Residual error	488,692.6	72	6,787.40		
Total	878,281.3	79			

We reject the hypothesis that the means of each of these runs are equal and accept the hypothesis that one or more of the means is statistically different.

Detection of possible outliers using the method given by Burr [7]

Ratio: Count A/((Total – A)/7) = 8899/((70273 – 8899)/7) = 1.015
The same calculations for B, C, D, E, F, G and H.
All counts about 2σ away from the mean may be possible outliers.
Sum: 8899 8863 8829 8801 8754 8727 8727 8673 = 70273/8= 8784
Ratio 1.015 1.01 1.006 1.002 0.996 0.993 0.993 0.986 = 8.001/8 = 1.00125

The dates 8899 (= 540 yr) and 8673 (= 753 yr) are borderline results.

Interestingly, Christen, [15] analysing the Shroud data as given in [1] and using Bayesian statistics, came to the same conclusion: the dates 591 (Arizona) and 795 (Oxford) are possible outliers.

It should be noted that by simply discarding one outlier the Shroud data are more consistent.

Applying the IEM-EEM criteria, as proposed by Scott, leads to the same conclusion [6].

For Oxford and Arizona the External Error Multipliers are 1.45 and 1.5

ANOVA Analysis of the Shroud RC data, reconverted to ^{14}C count, based on the quoted errors.

	Targets	DF	Between	Residual	F ratio	97.5%	
Ox	18	2-15	13900/2 = 6950	46459/15 = 3097	6950/3097	= 2.2 < 5 =	OK
Ar	24	3-20	57492/3 = 19164	24563/20 =1227	19164/1227	= 15.6 > 4 =	FAILS
Zu	30	4-25	49603/4 = 12401	73815/25 = 2953	12401/2953	= 4.2 > 3.5 =	????
Mean	72	11-60	247390/11 = 22490	160312/60 = 2672	22490/2672	= 8.4 > 2.3	FAILS

Enlarging the errors for Zurich and Arizona, in order to obtain the critical F values, is not sufficient to obtain the critical F value for the combined 12 data.

6. CONCLUSION

The radiocarbon dating of cellulose-based textiles need to be approached very carefully since textiles appear to present experimental limitations which can result in non-homogeneous measurements.

Concerning the Shroud dating, the Arizona F value is out of range and should not be used in further calculations and certainly not in drawing conclusions supporting a 95% confidence.

The Zurich F value is a borderline case. In theory, the combination of 12 data is meaningless.

As stated by Burr, et. al. [7], one should verify the tuning the equipment and the effectiveness of the AAA cleaning methods before drawing any conclusions.

The different data for $-\delta^{13}C$: Oxford: 0.027, Arizona 0.025, Zurich 0.0251, given in Table 1 of Nature [1] indicate a further need to examine the homogeneity and the chemical composition of the twelve sub-samples.

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