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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.

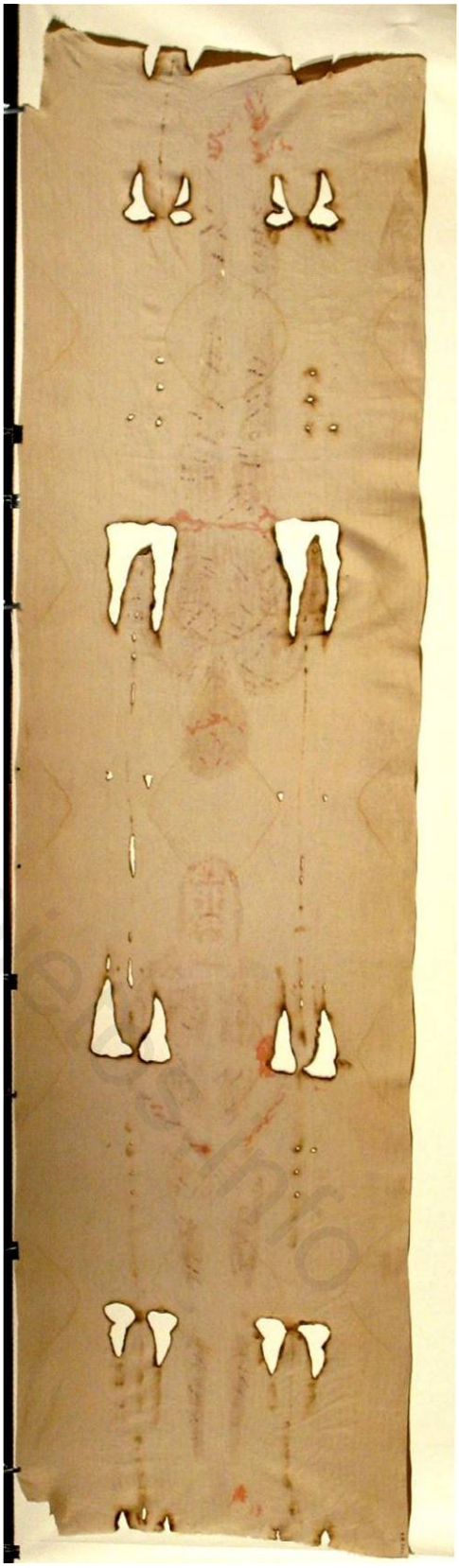

Figure 3. LG complete pseudo-shroud.

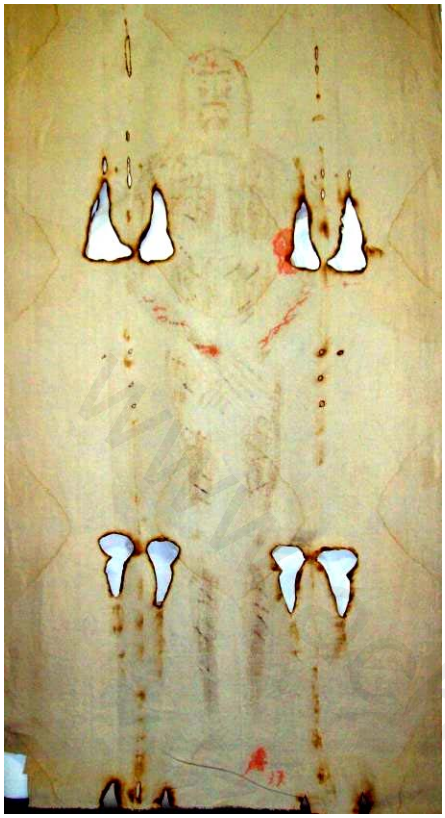

Figure 4. LG image. Front (positive).

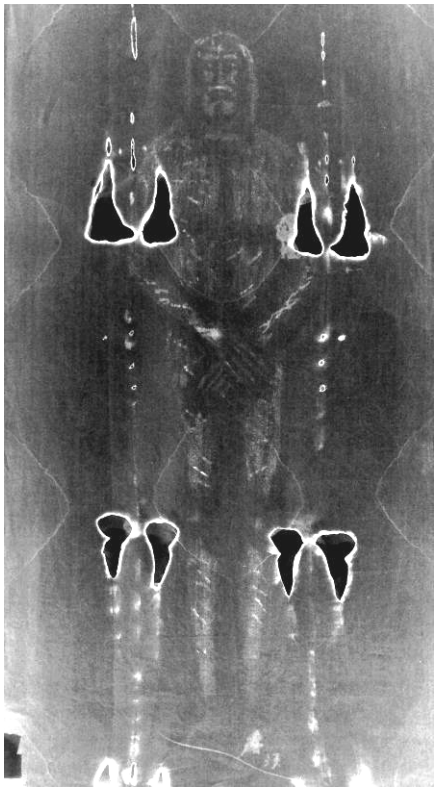

Figure 5. LG image. Front (negative).

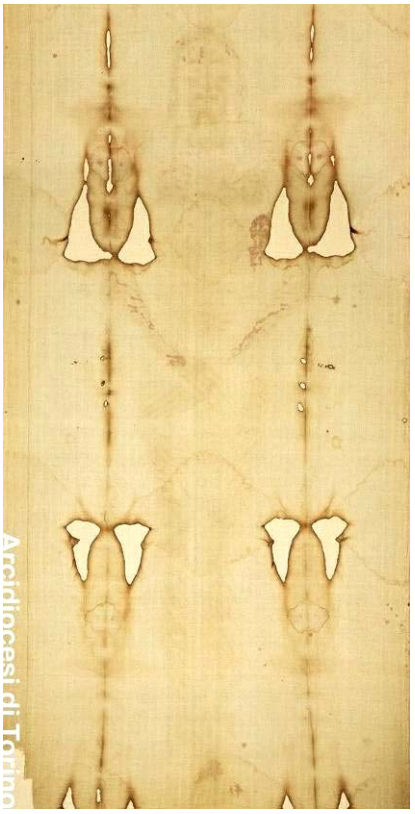

Figure 6. Turin Shroud. Front (positive).

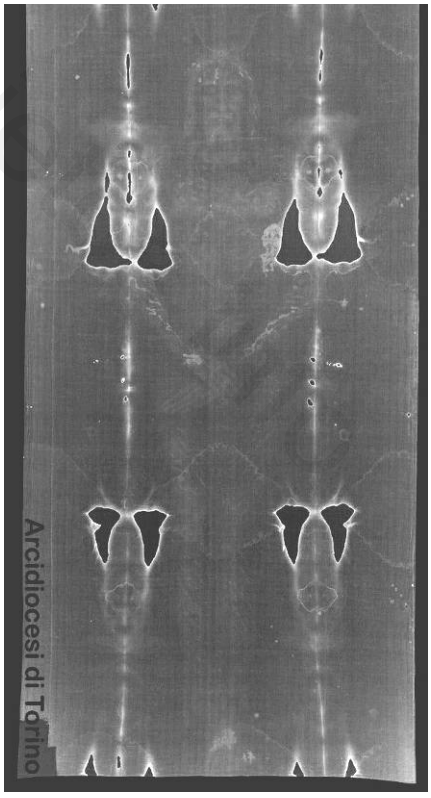

Figure 7. Turin Shroud. Front (negative).

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 (…)*".

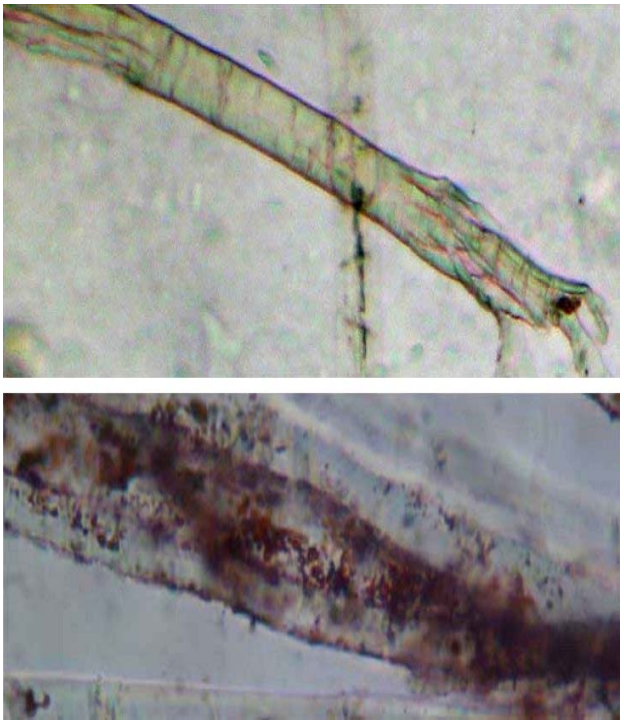

Figure 9. Comparison of the color distribution at fiber level. Top: colored fiber of the TS (STURP sample 1-EB), G. Fanti. Bottom: dry pigment distribution on a linen fiber, [11].

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.

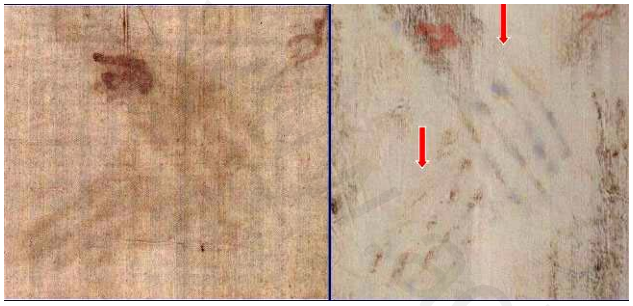

Figure 10. Close-up of the LG image (right) showing that it has no fuzzy border and is not continuous contrary to the TS image (left).

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.

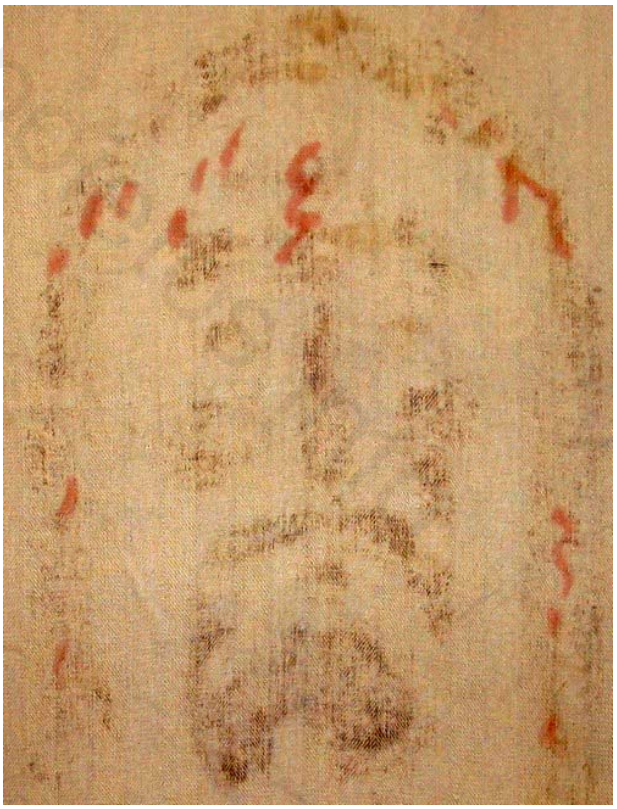

Figure 12. Face of LG second experiment.

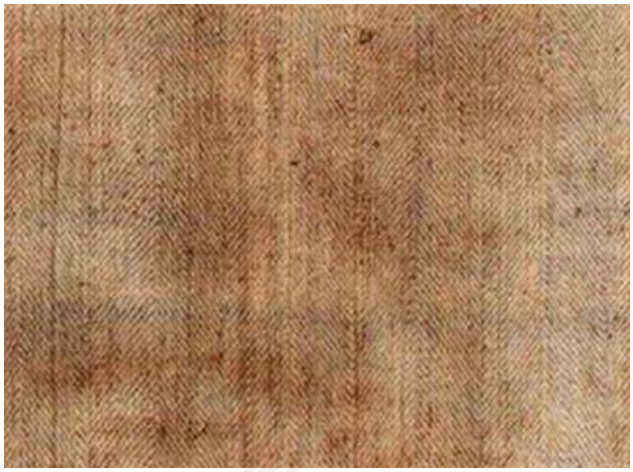

Figure 13. Close-up of the TS face (contrast enhanced).

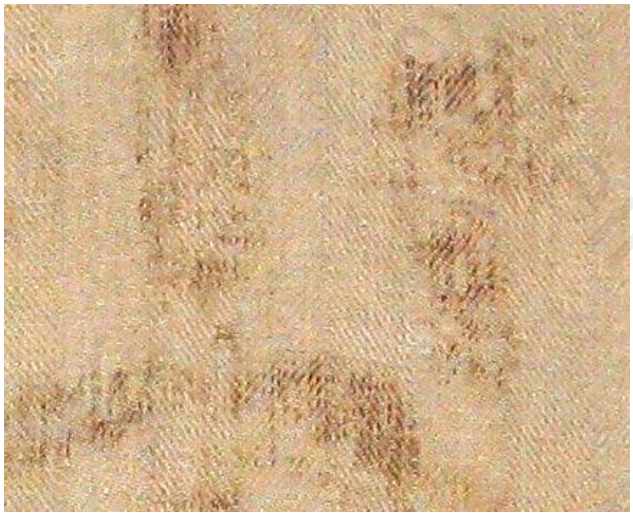

Figure14. LG face: close-up of the same area as in Fig.13.

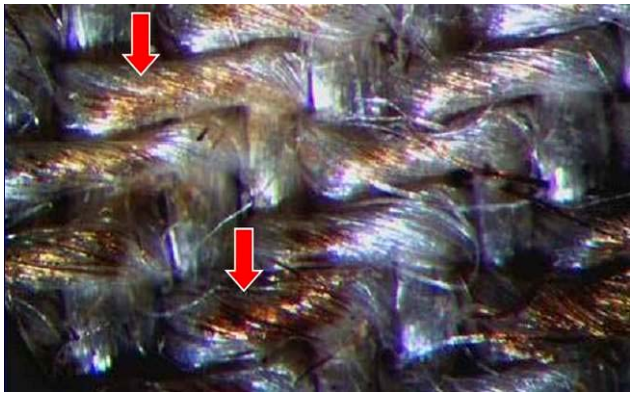

Figure 15. LG image showing the characteristics of the color at thread level (arrows indicate areas with very different hues).

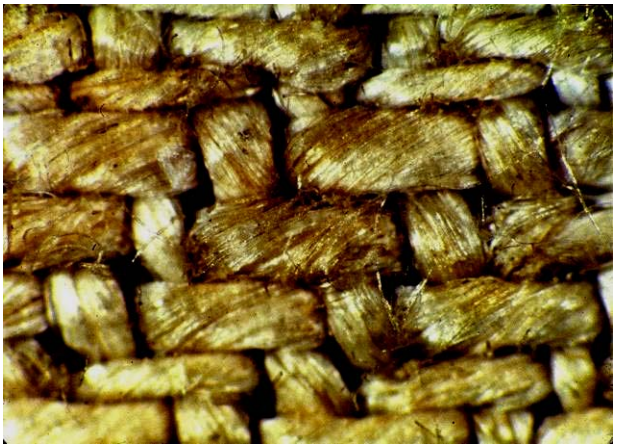

Figure 16. TS image (M. Evans) - Foot area. Contrast enhanced.

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.

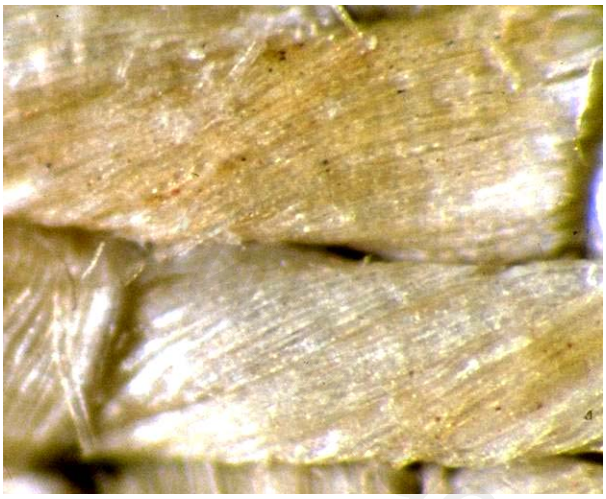

Figure 18. Typical TS image color distribution (high magnification).

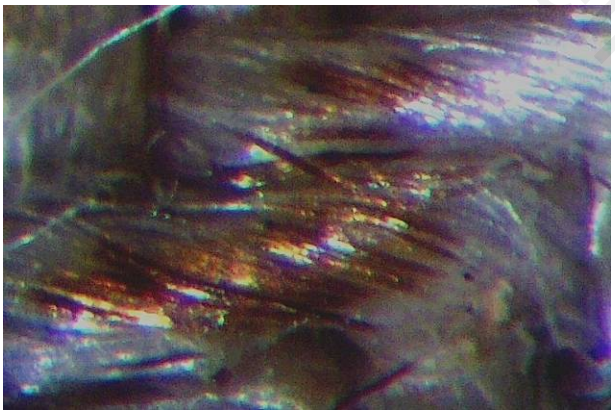

Figure 19. Typical LG image color distribution (high magnification).

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.

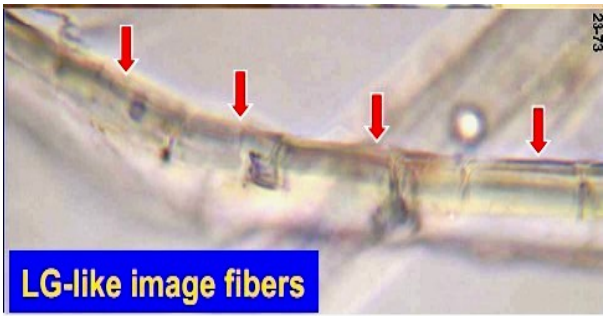

Figure 20. The color is only found on one side of the surface (arrows) in experiments similar to LG second hypothesis.

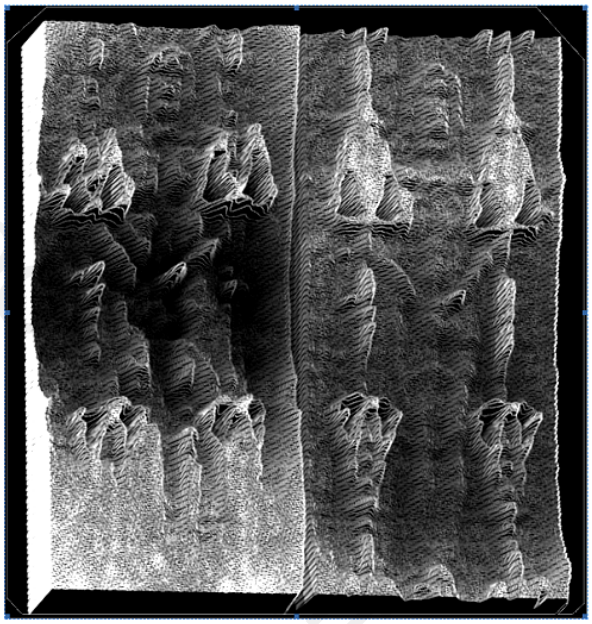

Figure 21. 3-D comparison of the whole front image (left: LG, right: TS), © K.Propp.

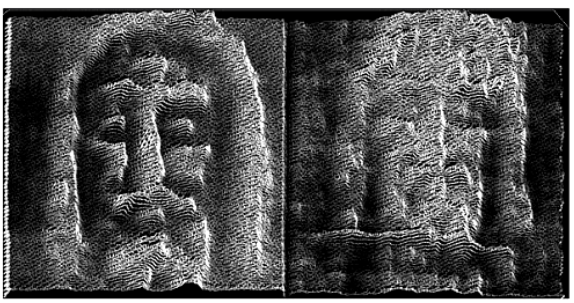

Figure 22. 3-D comparison of the faces (left: LG, right: TS). © K.Propp.

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

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