Dallas 2005 Symposium

ROLE OF CAPILLARITY IN THE IMAGE FORMATION PROCESS,

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Prologue

Capillarity, Wetting phenomena, interfacial tensions, molecular adsorption and migration at polyphasic interfaces, dissolution and evaporation of salts or organic macromolecules, irreversible aggregation of amphiphilic micelles or colloid flocculation, Thermodynamics of molecular Diffusion within the actual gravitational field, are very widespread domestic phenomenons, although often unsuspected. They are formidably complex and one can pass decades studying and experimenting (as I did) without clearly understanding the exact way they proceed… in order to master their occurence and develop efficient physico-mathematical models.

This is actually a major problem for Humanity, since only 1/3 of the World Oil Reserves is recoverable under the present state of art, i.e. the remaining 2/3 are furiously trapped underground by Capillary forces. If we solve the Shroud enigma, then we are likely to receive more oil reserves…gratis pro Deo!

1- Introduction:

Let us look at the Shroud as at a beautiful "passion flower" **(figure 1):** Surely it is a miracle of the Providence: a devout person can see 3 nails, five hammers and a crown of thorns, but who can prevent a Scientist to see 3 stigma, 5 anthers with their filaments, stamina and petals, in order to determine the Taxonomical features of this flower, according to the Laws of Botany? I will endeavor to follow this last approach: using the common sense and the laws of nature to describe, as simply as possible, and approaching the challenge with the same eyes as our ancestors, this masterpiece of archeology.

2- Some historical descriptions:

- The tradition of an imprint “made without hands” first developed (IV° century) in the Byzantine empire with the legend of the Mandylion (the Christ wiped His face on a "mandyl" and sent it to cure the Edessa king Abgar), then in the Vatican (VIII° cy) when former pope, John VII officially honored the Veil of Veronica, the legendary woman who wiped with her veil, the brow of Christ (near the Golgotha), and found remaining an *imprint* of His face.

- Gregory the Referendarius, describing the arrival in Constantinople of the Edessa Image (August 15th, 944), noticed something which cannot be seen on the Mandylion: *blood and water from the side wound* . He added also a very important description: *"the Lord has been printed only by the sweats of agony on his face…which have flown as blood clots"…" It is those* (these sweats and tears) *which have decorated and colored His true IMPRINT"…"after, these corporal liquids having flown, His imprint has been embellished by drops of His own side…".*

-In 1201, Nicolas Mésaritès, curator of the collection of the Pharos's Relics (including the sepulchral clothes) said that: "…the linen of the Shroud defies the decomposition,

because it wrapped the mysterious naked corpse after the Passion". For this monk, it is of common sense that a shroud soaked with corporal liquids (sweat, blood, etc) enters into corruption rapidly.

-The document GG p 49-50 found by Ulysse Chevalier, and attributed to one of the Canons of Lirey, gives also a striking description: "*this Shroud of pure linen, which has enveloped the Corpse, bears an imprint so genuine that any attentive eye should see bruises still weeping and wounds slightly oozing".*

- When the Poor Clares, in Chambéry (1532), saw the reverse side of the Shroud (after removing the backing Holland cloth), they were struck by what they saw: *"we could see the wounds (of the front side) as if we watched through a glass-window*". These "wounds" including *"a large variety of blows*" made by *"different kind of scourge, such as rods with thorns twisted around, iron ropes*[1]… etc. This anticipates what will be discovered during the 2002 restoration (in Turin) and described more precisely hereafter.

By the way, it can be added that the Nuns noticed, on the Face side of the cloth: "*His nose, as the most prominent part of the face, is very marked…his beard partially pulled away out of contempt, and the blood had stuck the rest. Then we saw a long trace coming down the neck, which made us think that he had been bound with an iron chain during the capture in the Garden of Gethsemane, since the neck looks swollen in various points as if it had been pulled and shaken. The bruises and the scourge blows on the stomach are so thick that a pinhead-large zone free from blows could hardly be found. The scourge blows inter-crossed continuously and extended all along the body as far as the feet tips; a large blood clot marks the feet opening"*[1]*.*

Obviously they never made any distinction between the Body "bloody and stained" and a hypothetical "Body shade", projected image of the whole Body shape on the Cloth.

We must conclude that, from the first historical Shroud apparition up to Modern Times, the Shroud Observers were convinced that all the imprints were due to a natural transfer (mainly by direct contact) to the Shroud, of the corporal liquids (mainly sweats and blood) oozing and weeping from the tortured Body, staining internally the closely wrapped Shroud, that they soaked deeply up (and down) to its external face. It was not a supernatural object, but only the faithful witness of the Christ's Passion.

3- Secondo Pia and his successors:

Usually, the negative of a photography looks quite blurred and unnatural. In 1898,

Secondo Pia discovered that, for the Shroud, it was exactly the contrary: the conclusion that the Shroud itself was a "true negative", despite all the liquids marks, was drawn by many, and progressively a large number of theories were proposed to explain the image formation by a kind of sophisticated imaging manufacture, or a

1) from the book: Le Saint Suaire de Chambery a Sainte-Claire-en-Ville (Avril-Mai 1534), par M. 1'Abbe Leon Bouchage, Chambery, Imprimerie C. Drivet, 1891 (Maurizio Marinelli translation).

"self projecting" transfer process. Almost all the defenders of the "imprint theory", mainly Loth, Vignon, Barnes, Legrand, de Gail, Fossati, Volckringer, were continuously challenged, during the first half of the XX° century by "modern scientists" who proposed more than a dozen of image formation process.

With the help of modern analytical tools, the first to propose to the Media (enthusiastic) a "full diagnostic", was the chemical expert McCrone: the image was a kind of paint, including iron oxide, cinnabar and gelatine. STURP's[1] Xray results, published in scientific peered Reviews, destroyed his fraudulent claims, and others of same value.

With the calamitous 14C datation, some proposed "projective" theories were transformed from "radiative" (electromagnetic waves, from heat to UV and Xray) to "nuclear" ones (proton and neutron from deuterium fission) [2], but of course none of them could explain the factual image properties: blood clots with associated serum, presence of corporal fluids (albumin, proteins, salts, etc…), the lack of fluorescence of the images, as if it was quenched by a film of organic compounds… which precisely makes the color (probably nanometric in some places).

In fact, most of these theories were proposed to satisfy a theological proposal: the beautiful image discovered by Pia could be due only to the "burst" of the Christ Resurrection. However, whatever is our Faith, we need to start from the simplest mechanisms taking into account the maximum of these common facts immediately identifiable on the Shroud.

4- Returning to Paul Vignon Natural School:

Reading Vignon's book[3] we are confronted everywhere with "imprints and soakings of corporal fluids": blood and serosities flowings, serum and lymph oozing out of clots and wounds, but also with contacts between the enveloping shroud (supposedly spiced with aloe powder) and all the prominent parts wetted by sweat (front and eyebrows, nose, moustache, beard, hair, chest, etc…); the unsolved problem (for Vignon) being the brown color of some parts which obviously could not have been contacted by the cloth: for these sparse areas Vignon imagined some distal actions of gaseous ammonia coming out of evolving sweats. His experiments, repeated by Rogers, were not very convincing with gazeous H-NH2 (rapid diffusion leading to blurred images).

1) STURP: Shroud of Turin Unit Research Project. A scientific US organization, authorized in 1978 to analyze during one week the Shroud on site. McCrone entered this Group by trickery and used their samples out of context.
2) From Professors J. Jackson (UV) and Fanti (Corona) to Father Rinaudo (virtual particles) these "advanced" theories are mainly devoted to match the Pia "projected" negative image.
3) Paul Vignon: Le Saint Suaire de Turin, 1902, et édition révisée de 1939, Masson Edts.
However, Rogers using heavier amines, improved the resolution of this image transfer mechanism[1], when the receiving cloth is above the R-NH2 emitting body. Unfortunately, his illness prior to his death has not left to him enough time to experiment the other way (the cloth being below). I suppose that the distances allowing a correct image transfer would have been found considerably reduced.

The first to implicate the sweat alone was Mgr Arthur Barnes, in 1934: the wedding veil of a new bride, carried only one time, folded and preserved during one century, exhibited clearly brownish marks at the contacts with the front, the nose, and the spot handed by the bride[2]…

Antoine Legrand[3] noticed that, rapidly after the death, a corpse dehydrates, losing large amounts of vapors, the composition of which is similar to that of usual sweat (more acidic claim some Forensics). Consequently, in 1934, he stained, with his own sweat, a white linen cloth[4]. The color intensity (brownish yellow, like that observed on the Shroud) was reached after about 3 years, concentrated mainly in the weft furrows of the weave (**figure 2**). So, Legrand's advise is that some parts of the body imprints on the Shroud were not visible when Saint John entered the Holy Sepulcher the Sunday morning, and become visible progressively after a longtime (much shorter than that is required for Volckringer's vegetal imprints).
This color seems very resistant: it cannot be removed by the repeated action of strong detergent products. Unfortunately Legrand didn't try the Diimide…but any body can do it. I have an experiment still undergoing.

Anybody knows the beautiful imprints left by plant leaves kept during a long time inside of books. What it is not well known is that these imprints are made only during the vegetal dehydration and migration of its organic compounds onto the paper fibers (cellulose), even if some can still darken after the leaf retrieval. These marks are "negative", and more precisely "topology dependent" (i.e. the prominent parts are darker, and between two "ribs", halftone describes correctly the topology, which is not the case for a "normal" photographic negative). Clearly, there are both direct contact imprints and distal transfer of organic components, which produce a "distance dependent" color on the paper sheet.

In 1981, John A. De Salvo studied the vegetal imprints produced by Dr Jean Volckringer[5] and wrote[6]:
"In short, VOLCKRINGER's prints resemble the body image of the Shroud: the data of reflectance in the visible spectrum, of UV fluorescence, the details reproduction,

1) In order to explain and simulate the "superficiality" of the image, Rogers replaced Vignon's Aloe powder by starch, according to Pliny-the-Elder description (concerning flax weaving procedure in: The Natural History. Eds. John Bostock, M.D., F.R.S., H.T. Riley, Esq., B.A.).
2) in: Arthur Barnes, The Holy Shroud of Turin, London, 1934
3) Antoine Legrand: Le Linceul de Turin (Desclée De Brouwer, 1986).
4) A Palestine herringbone twill weave cloth, naturally bleached (not chemically).
5) Dr Jean Volckringer, member of the National Academy of Pharmacy: le Saint Suaire de Turin: Le problème des empreintes devant la Science, Ajaccio 1942.
6) In «SINDON», Review of the CENTRO INTERNAZIONALE DI SINDONOLOGIA di TURINO, December 1982, n°31, pp43-50: the Image formation process of the Shroud of Turin and its similarities with Volckringer patterns.

the facts that they are negative and that the image formation process takes place a long time after that the object was withdrawn (or deteriorated), are very similar. Finally, the more striking similarity consists in the fact that the image of the vegetal prints of J. VOLCKRINGER can be rebuilt in a 3D relief, by using the analyzer VP 8, as it is done for the image of the Shroud."

Figure 3 reproduces the 3D view of Scrofularia alpestris made by De Salvo.

The classical Analytical Chemistry has failed to uncover the structure of the compounds which make up these tiny colored marks. Today, the availability of new analytical tools gives hope to see this problem solved rapidly[1]. However, for the time being, it looks reasonable to suppose that these colored marks have the same origin as the brownish chemical compounds found by Rogers at the surface of the Shroud fibers with his polarized optical microscope (**Figure 4)**[2]**.** He anticipated that they were the results of series of Maillard's reactions[3] (as used to color ale), but failed to determine their exact composition because of the minuscule thickness of these "flakes".

This important discovery, allowed Rogers to propose in the same paper a series of processes which make possible the image formation with all known properties: reacting with starch residuals (left by evaporation after washing), heavy amines (evaporating from the Corpse) can produced colored compounds which stick on the closest fiber surfaces (either by contact or by gaseous diffusion) producing a "superficial" image. As a good (and honest) scientist Rogers always avoided to state something wrong and his proposal can be retained as good stack of evidences on which, the bunch of processes used by the Providence to produce such image, can be settled.

5- Relations between the Fabric and Corporal fluids:

The Shroud fabric has a beautiful side (the obverse) on which the warp yarn design makes a plateau (80% ot the total area) crossed by V shaped deep furrows occupied by transverse weft threads **(figure 5)**. The reverse side, on the contrary is flat and 80% of its surface is occupied by weft yarns. This topological principles will be useful to understands the fluids entrapment and their migration across the cloth. However these relations are complex and need to be sketched through contrasted pictures.

Figure 6 shows an actual picture of the warp with its enlargement (upper right and left), and behind the small "sticks" (or rosary grains) described by Marion[4] as the

1) Except in Paris, where the protons accelerator ("Aglae") is openly "not available for devout studies" as it is claimed by its director.
2) Beautiful picture taken by Ray Rogers, and named by him "discontinuous yellow". The coating, fairly transparent and yellow, is visible on the upper edge of this flax fiber, but absent on the right lower edge: it is fragile, and peels off when stressed.
3)The Shroud of Turin: an amino-carbonyl reaction (Maillard reaction) may explain the image formation, by Raymond N. ROGERS & Anna ARNOLDI, in Melanoïdins, Ames JM editions, Office for official publications for European Communities, Luxembour 3003, pages 106-113.
4)André Marion: Nouvelles découvertes sur le Suaire de Turin, Albin Michel, 1997, pp 200, and figures 10 and 11. These sticks have a remarquable periodicity, while their size and intensity (grey scale) are variable.

encoding principles of the image. Well identified by the Fourier's Transform Test they are described as (entirely) responsible of the image (page 200). Surely not "entirely", because the warp is also colored, but probably at a level as high as 80%.

Figure 7 is an enlargement (x10) of an Enrié high resolution **photograph**[1], which allows to see the way in which blood marked on the fabric relief. One sees that

transferred blood is by no means cracked (or scaled, or chipped off) at those points where it appears still today very thick, making compact bridges between some prominent warp yarns, and filling all the weft furrows.
The overloaded character of the threads by the corporal product has been also verified by transparency (even trough the screen- fortunately regular- of the backing **cloth) 2**.

The mostly non-wetting character of the warp yarns (remaining white or slightly tinted) is apparent and predominant. The deep furrows of the weft, carry molded blood in a more regular way. However, viscosity and interfacial tensions make difficult the spreading of these blobs. One could suppose that the Shroud has been retired when these blobs were still humid, the dryer parts (near the fibers) being well attached by their contacts. The detailed problem of the various states of blood clots or stains is very complex and will not be discussed here.

The figure 8, taken during the 2002 restoration of the relic, shows very clearly that the quasi totality of the heavy blood clots, carried previously by the warp yarns has been erased. Only a a small crust (of about 1mm) stays on the terminal part of the flow, only colored traces remaining on most of these yarns). Now, are preserved only those bloody products which remain trapped in the furrows and holes of the weft.

The figure 9, shows at the weave level 2 important facts:
- on the warp face (left) le non wetting blood (clots on the warp plateau) has been probably erased (as on figure 8), and now the remaining "pieces" of blood are stuck on the weft threads at the bottom of the furrows (horizontal sticks, or "rosary grains" as previously described by Marion).
- on the weft side (right) we can see only some minute parts of these rosary grains which point through the weave meshes all around the warp yarns (mostly white). The blood has been filtered by the weave and the general color of the epsilon is now much lighter. The stain is now larger and the edges quite blurred.

My conclusion is that the blood, which has contacted the cloth, has been sucked (wetting forces greater than gravity) filtered, clotted, probably diluted by sweats, and has migrated by imbibition from the warp to the weft faces, but the weft yarns being statistically the principal "actors" of this movement (warp threads having more difficulties to be wetted).

1)Paul Vignon Turin Shroud (Masson editions, 1939) page 207
2)in Legrand (ibid) p 99: on Nov 14th 1973 it has been observed that the whole body image "was considerably reinforced" under transmitted light. This means that, in this area, blood and others corporal liquids are on both sides, probably enveloping completely the threads, and, at least for some of them, are occupying the mesh and furrows of the weave.
Staying always at the macroscopic scale, another important feature rise when we compare the ventral and the dorsal images (on the very precise warp face): most of the wounds reported on the dorsal image are much darker than those printed on the ventral one, but for the "body shape" it is exactly the contrary. My conclusion is that gravity acted differently in both cases: upwards it largely controls "sweat" evaporation (and has little action on imbibition forces), while downwards it favors the body weight and Newtonian liquids flows (and not vaporous transfers).

The obvious overall result is that the negative ventral image is much more precise and beautiful than the dorsal one…and the holy Face so extraordinary, while the "horse-tail" is quire blurred!

Now, if we look, at a larger scale, at the images seen on the whole Reverse side (**weft side)**[1], we can observe, with naked eyes, that the body appears more clearly on the ventral side: mainly the head, with its hair, eyebrows, nose, moustache, beard, etc. This means that Legrand's asumption was probably right: the Corpse could have lost large amounts of special "water" which could have condensed into the thread capillaries (starting from the Kelvin domain up to the Laplace one) of the weft **threads**[2]. By imbibition this condensed phase could have migrated (through normal van der Waals forces present on all cellulose crystal surfaces) by the weft across the cloth.

Although fainter and more discontinuous, body images can be seen also on the Back side: the head, the back (at the scapula level), the right sole and calf, and a lot of whip marks on chest and legs.

These observations having been consolidated by new enhanced image processings (which have allowed a better separation of body stains from the noisy banding effects which affects all the cloth, mainly in the warp direction, but also in the **weft one**[3]**),** it is possible today to state that a real continuity does exist between the 2 faces of the Shroud, concerning the images properties and their formation.

For people who want to test the capillary properties of the Shroud, I propose the following enigma: there are 3 stains (with large concentric aureoles) on the left buttock (discovered by Professor Fanti in 2004). As they were important, they have migrated across the weave up (or down) from the warp side to the weft side. But, during this process, they have been reported on the right buttock by a simultaneous longitudinal folding. They imbibed this second spot and finally the residual fluids migrated and reached the weft side that they stained (very slightly). This is a good example of a contact/capillary process. There are a bunch of possible explanations, but I think that the final choice could be made only after the sampling and analysis of the center of one of these stains.

1)Giuseppe Ghiberti, Sindone, le immagini 2002, Shroud images (september 2002)
2)Here the capillaries are not necessarily "tubular": the pendular geometry of contiguous fibers could play the same role.
3)A first publication of these works has been done by Fanti and Maggiolo (2004), but large progresses have been made recently by Doumer (Bordeaux) and Castex (Pau) who are specialists in these treatments (Fourier's Transform, Deconvolution, Spectral widening…)

6- the myth of the "halftone" color:

As for the fabric/fluids interactions, the problem of relations between body and blood images (or others) and the "color" (often subjective) are complex: there are probably billons of colored fibers, in body image areas as well as outside these areas, with coloration (appearance) depending on the magnification, the local intensity, and the concentration of colored products. Most of the observers, who analyzed fiber characteristics, were reliable scientists: i.e. we can rely on the precise facts they

noticed…but not necessarily on their drawn conclusions which depend essentially of their personal formation and experience.

Today the "body image color" (as opposed to a supposed simple "blood image") is understood as the mixing of yellow fibers (all of the same straw yellow intensity) with white fibers (halftone model[1]), the local concentration of which gives, for a human eye, the local color. Here again, the reality needs to be sketched through contrasted pictures in order to be clearly understood.

Figure 10 shows threads without image:
On this excellent photo made by Mark Evans in 1978 we see white lustrous fibers. This appearance is given by the magnification. Normally, the naked eye catching a concentration of fibers greater, they would look yellowish. Rogers think that their color is given by a thin coating of polysaccharides more chemically-sensitive than the bulk cellulose of the fiber walls. For him, the mechanism responsible of the color is the same as the "discontinuous yellow" shown hereabove. Probably this film could be also removed, revealing also the true original fiber color (white), as white as after the bleaching treatment.

Figure 11, is described by Rogers as the more important microphoto giving the "secret of the image color". It comes from the nose, and exhibits bands of color (kind of colored striations), continuous along the fibers, but discontinuous between strands, and even between two contiguous fibers. These two last first remarks underline the roles of capillarity (for the first) and wettabilty (for the **second)[2].**

In 1978, Rogers obtained the permission to "use a dissecting needle to remove fibers, looking directly through the microscope at the image area". He observed that the color was only on the top of the weave (no more than 3 fibers deep into the thread, or 40 microns).

1) In fact, Rogers was the first to question this model of "areal density of monochromatic dots" proposed by Pellicori, suggesting a more "natural" one based on colors intensities.
2)Surprisingly, some STURP scientists stated: "the image fibers do not show any sign of capillary flow of a colored or reactive liquid "(Evans 1978; Pellicori 1981). On the contrary, most of Evans pictures show striated image areas on fibers, which seem to run along the fibers from some point to an ending point. "That implies some sort of fiber directional mechanism like capillarity, and simultaneously some sort of starting and quenching mechanisms" (R. Schneider, 2004).

Now, from what has been said before, we can conclude that the color (in the image area of the obverse side) is a thin coating around the 2 or 3 upmost fibers of the thread. It is fragile and can be removed, for example by means of sticky tape. It could have been applied by fluids contact or by capillary condensation. Its distribution along the fibers must have obeyed to wetting laws, which could lead on flax to "stains without smears".

Figure 12, summarizes most of the conclusions previously obtained: the colors are different, underlining different origins (coatings made of aggregation of various organic compounds), their striation follows the fibers, dirt and foreign particles are stuck at the top of the threads (some are little blood crusts). Probably, with a good microscope, we could see on this print of the heel the entire history of the Passion.

CONCLUSION:

Of course, the Shroud being an marvelous archeological legacy made to Humanity, the most important relic for Christians, the most important conclusion that we can draw from this study, is surely the fact that it is like the Life, terribly complex and fragile, and that we must insist on obtaining from the Christian Authorities all the guarantees that "the blood will not continue to disappear on the wrist" (as shown by figure 8).

Concerning the scientific understanding of the Body image, the photography of the Reverse side (with the help of a breakthrough on the image processing techniques) has definitively enhanced all the Research Programs towards less theoretical speculations and more realistic applications, specially concerning the intimate properties of linen fibers which received all these precious materials.
Le role of capillarity in the image formation process is one of them. After having seen the extraordinary picture made by Mark Evans (figure 13), I think that the onus is on those who propose "radiative" theories to demonstrate that such image is not due to the wetting and condensation of corporal fluids on and in the weave of the Shroud.

Acknowlegments:

I wish to recognize the lamented Raymond Rogers (with honor to the memory of a famous Man of Science) and Barrie Schwortz, for their immense help and receptiveness in putting their invaluable data and personal time, spontaneously available, to explain what they have actually done and obtained in the past, and to comment, with an admirable honesty, all the undergoing works.

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Figure 1
Courtesy of Coucoumania

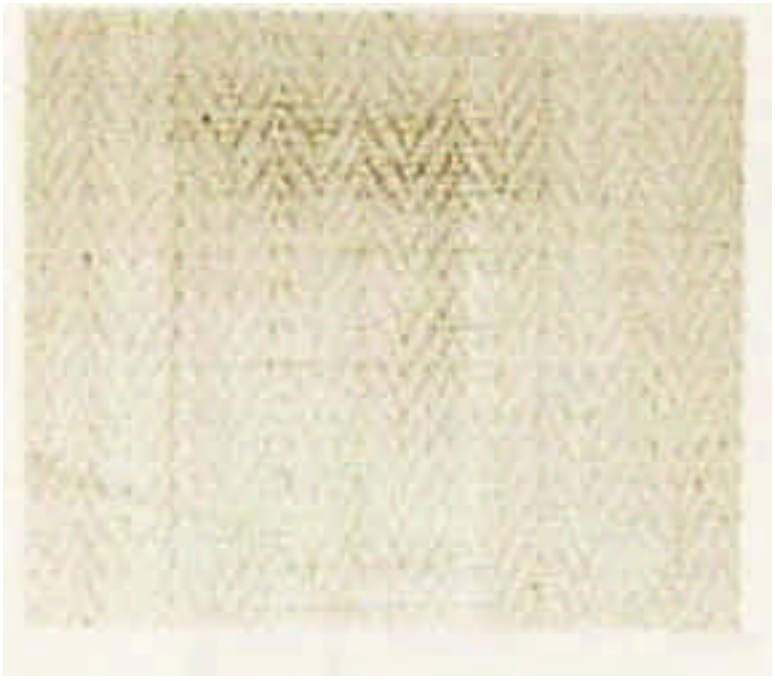

Figure 2
© Desclee De Brouwer (Legrand 1938)

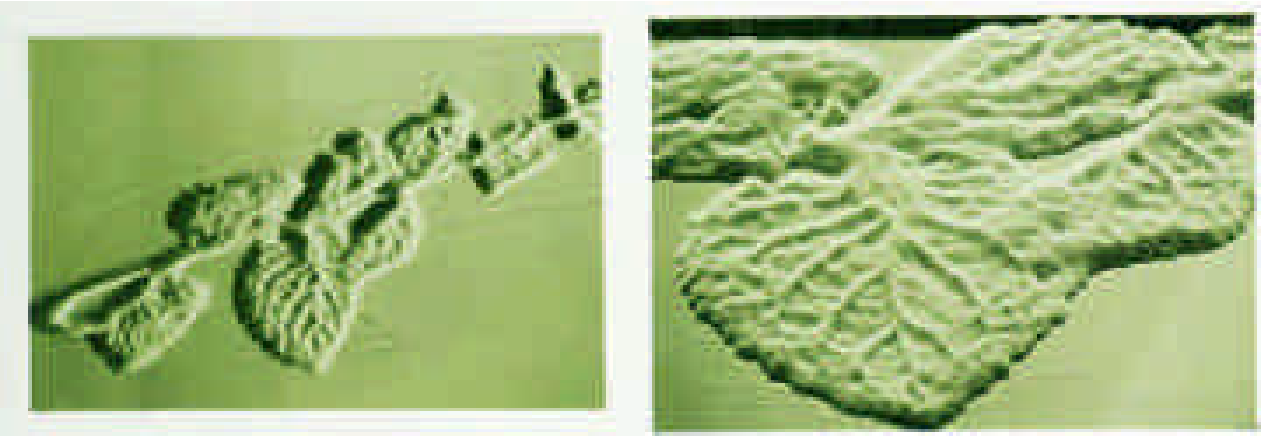

Figure 3
© Editions Eveche d'Ajaccio (Volkringer-Salvo 1983)

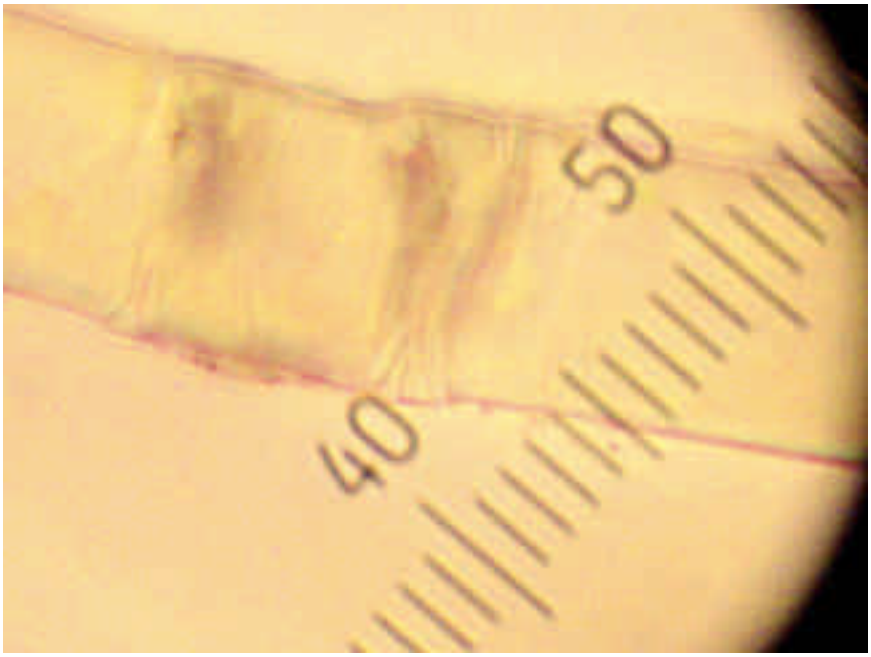

Figure 4
© 2004 Ray Rogers

Figure 5
Courtesy of CIELT (Alonso)

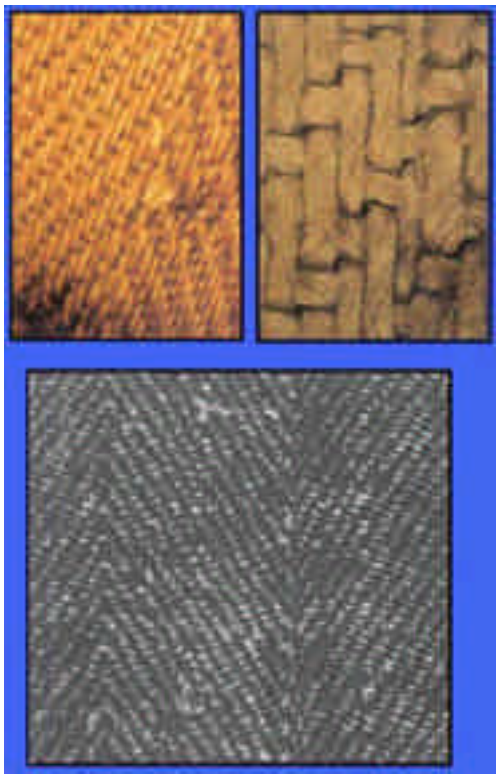

Figure 6
Courtesy of A. Marion

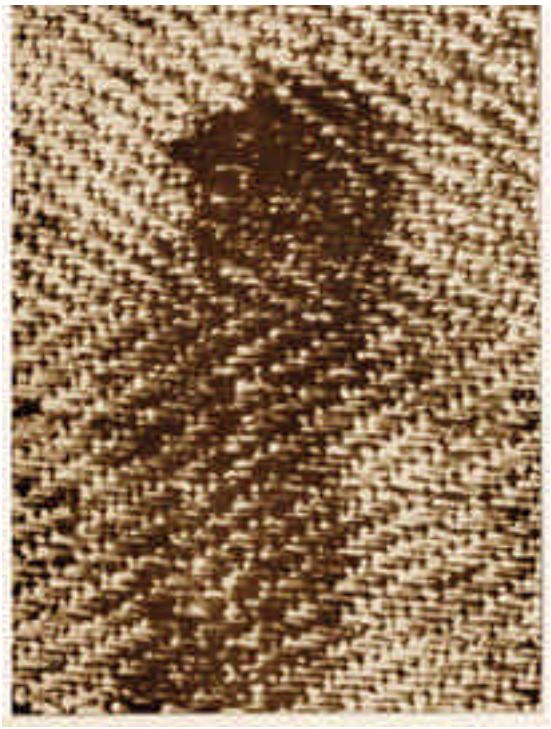

Figure 7
© 1931 E. Enrie

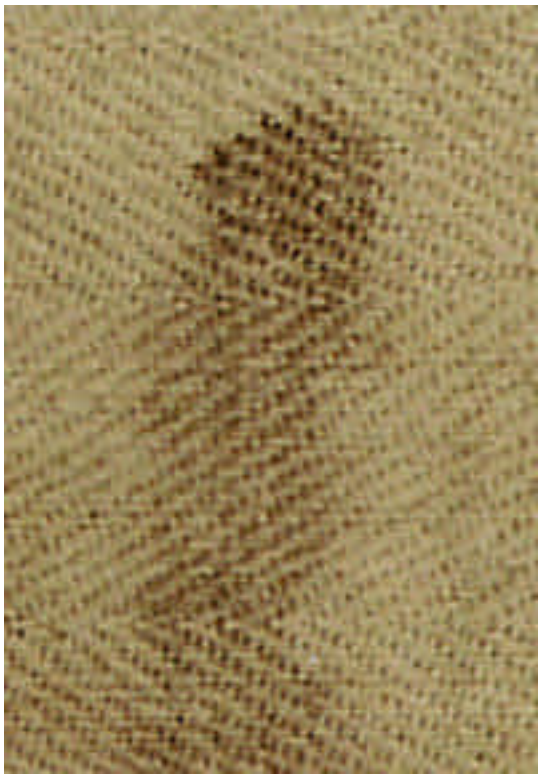

Figure 8
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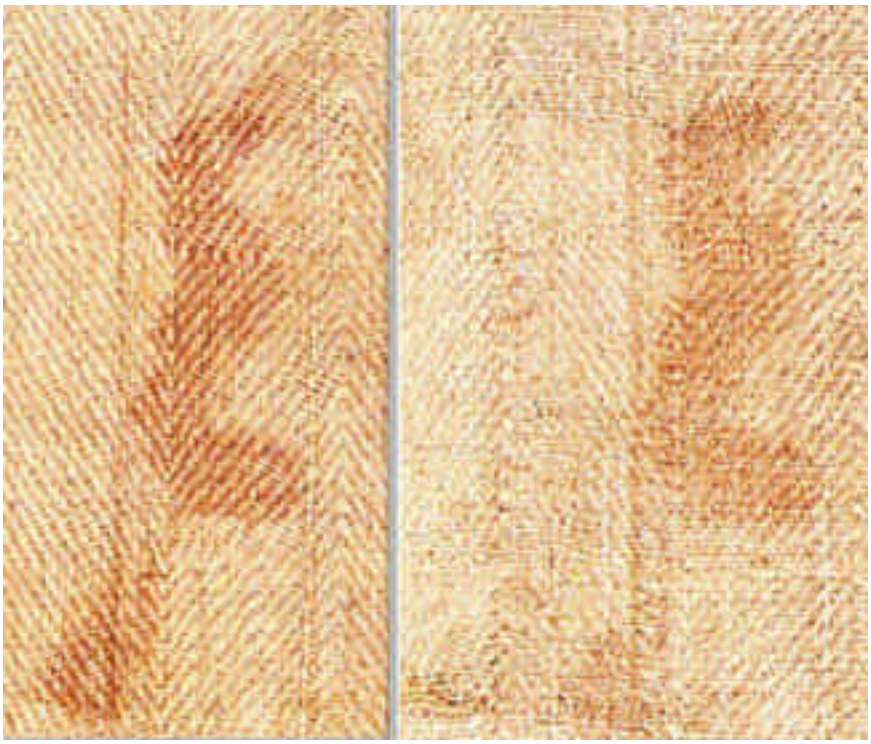

Figure 9
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Figure 10
© 1978 Mark Evans

Figure 11

Figure 12

Figure 13