Image Formation and the Shroud of Turin

by

Emily A. Craig, Ph.D., and Randall R. Bresee, Ph.D.

PREFACE: By Emily A. Craig, Ph.D.

The following reprint of our published paper addresses the details of how we produced a faint life size negative image of a man with no lines or brush strokes which affects only the uppermost fibrils of the cloth's fibers. Our paper also proves that our images are encoded with a wealth of accurate three-dimensional spatial information. With this drawing technique, one can also incorporate images of wounds, as well as blood evidence into the illustration. We primarily discuss the technical aspects of image formation and analysis, and conclude that a 13th or 14th century artist could have created the image on the Turin cloth. On the surface, this seems like the most logical and easily justified conclusion, but since the drawing technique is timeless, such an image could actually have been created centuries earlier. With this in mind, I present the added hypothesis that the image could just as conceivably be a type of deathbed documentary diagram. This is my personal opinion, and I think that our original testable hypothesis, as well as this new concept deserve serious consideration by other Shroud research scientists.

What if the image on the Shroud of Turin was created, not as a hoax but as a desperate effort to record the moment? In other words, a "portrait" of Christ. This of course, would not have been done as a portrait in the classical sense, but more on the order of a forensic medical illustration. With the technique we describe, the original portrait could have been created at the time of Christ's death, in the confines of the tomb, in a relatively short time. Final image transfer could have been accomplished at anytime thereafter - possibly even as late as the 1300's.

Most illustrators and photographers realize that when you dramatically alter the light source, you can dramatically alter the normal appearance of an object. If someone had tried to produce an illustration to document the postmortem appearance of Christ and the effects of his crucifixion, they would very likely be working in the abnormal environment of the tomb. Imagine a supine corpse in a dark tomb with the only illumination being from equally-placed, dim light sources (i.e. candles) on the floor. The appearance of the body would thus be totally reversed from that normally observed under normal lighting conditions. On the face, features such as the tip of the nose, the chin, and the forehead would appear to be the darkest. Other parts of the anterior surface of the body, such as the pectoral region and the extensor regions of the hands, forearms, and legs, would also appear uniformly dark rather than light. The same reversal of normal light and dark surfaces would be seen on the dorsum of the body once the corpse was turned over. With the idea that the image on the Shroud cloth is perhaps a type of deathbed portrait, it is then conceivable that the reverse topography, or so-called negative image, was not part of an elaborate hoax. It could simply have been an honest, straightforward rendering of what the illustrator observed and then duplicated in a loving, desperate attempt to document the event.

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ABSTRACT:

Both the first written historical record and modern radiocarbon analysis date the cloth known as the shroud of Turin to the 13th or 14th century. Interestingly, many people have remained convinced that the cloth was used as the burial shroud of Jesus and thus must be approximately 2000 years old. The primary reason usually cited for this belief is the inability of scientists to explain how a 13th or 14th century artist could have created the image on the cloth that is continuous tone, exhibits fine detail without brush strokes, is a negative image, and accurately represents an abundance of three-dimensional information. In this paper, we will show how the carbon dust drawing technique used by medical illustrators can be modified to produce images exhibiting numerous features of the Turin cloth. We compared images formed using the technique with image attributes reported for the Turin cloth and showed that the dust transfer technique is able to form images more similar to the Turin cloth than any previously described technique. Because tools, materials, and concepts required to use the drawing technique have been available for centuries, we concluded that a 13th or 14th century artist could have created the image on the cloth known as the shroud of Turin.

INTRODUCTION:

The cloth known as the shroud of Turin is an ivory-colored linen cloth measuring 4.3m by 1.1m and is believed by many people to have covered the body of Jesus of Nazareth when he was placed in a tomb nearly 2000 years ago. The cloth contains a yellow-colored, life-sized image of a man (Fig. 1) that faithfully reproduces the gospel accounts of the appearance of Jesus.

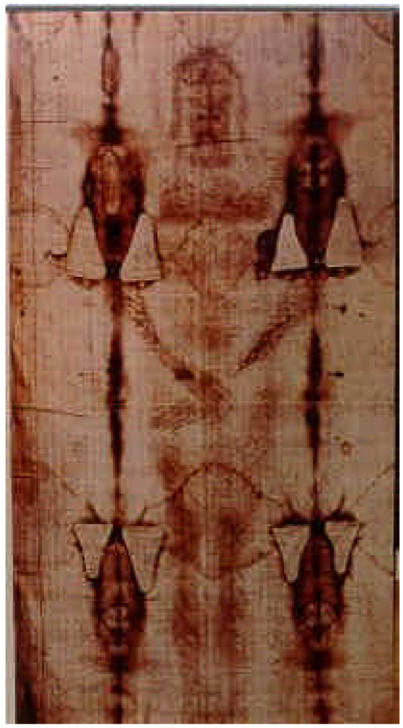

FIGURE 1:
The Shroud of Turin
(Published with permission from Vernon Miller).

The first recorded exhibit of the Turin cloth occurred in the early 1350's, and it has been enshrined in the Royal Chapel of Turin in Italy since 1578. The Shroud of Turin Research Project spent five days and nights analyzing the cloth in 1978. Although not unanimous, this group presented compelling evidence that the Turin cloth was in fact the burial shroud of Jesus. However, radiocarbon dating performed in 1988 concluded that the cloth originated between 1260 and 1390 A.D. [1] These dates agreed with the first recorded appearance of the cloth and cast serious doubt that the cloth existed nearly 2000 years ago. Interestingly, many people have remained convinced that the Turin cloth was the burial shroud of Jesus. The primary reason usually cited for this belief is the inability of scientists to explain how a 13th or 14th century artist could have created the image on the cloth.

When the cloth was photographed in 1898, the glass plate negative revealed a continuous-tone image of a man that was positive instead of the usual negative. This meant that the image on the cloth was negative rather than positive. When modern image analysis began in 1974, the negative image was found to contain an impressive amount of accurate three-dimensional spatial information. That is, body locations were represented substantially more accurately on the cloth than on typical paintings and photographs.[2] Other attributes reported for the image on the cloth are that it is barely discernible, it exhibits no apparent brush strokes, and it exhibits no evidence of layering (i.e., the image was applied all at once).

An important question that still remains to be answered is, "Did someone have the knowledge and capability in the 13th or 14th century to produce the image on the Turin cloth?" Scientists have offered numerous hypotheses about image formation on the cloth. An excellent summary of these hypotheses has been provided by Schwalbe and Rogers[3], so only a few details will be reiterated here.

Written evidence that the image on the cloth was painted by an artist dates to the 1300's.[4] Modern scientific analysis identified several types of colored particles on adhesive tapes used to remove substances from the surface of the cloth. In particular, iron oxide particles were found on all tapes from "blood" areas, two thirds of the tapes from "body" areas, and none of the tapes from nonimage areas of the cloth.[5] Tempera (made from collagen, egg albumen, or milk casein) accompanying the iron pigment was also identified and may have contributed to image formation by causing fiber discoloration.[6] This and other evidence led McCrone to conclude that the image on the Turin cloth could have been formed by an artist using an iron tempera paint applied as a dilute liquid suspension.

Several arguments opposing this hypothesis have been presented.[7] No evidence of capillary flow between fibers of the cloth has been reported. X-ray fluorescence did not detect substantial differences in iron concentration between image and nonimage areas of the cloth bulk. The yellow color of fibers was not extractable by solvents, as might be expected for collagen. Mass spectrometry, histological staining, and ultraviolet fluorescence failed to detect the presence of collagen in important image areas. Most importantly, experimental images formed with dilute tempera paint contained little accurate three-dimensional information.

McCrone's technique was modified by Nickell, who applied solid iron oxide to linen by rubbing over a bas relief.[8] However, the amount of three dimensional information produced by this method was substantially limited by the inherent qualities of bas relief sculpture. In addition, image distortion was introduced as a fabric draped over a three-dimensional sculpture was removed and flattened to two dimensions.

Several hypotheses that have been proposed attempt to explain image formation as involving oxidation and dehydration of cellulose to produce yellow-colored fibers. Of the many ways to achieve this change, the most likely mechanism has been proposed to involve transfer of a substance that either produces the image directly by oxidation/dehydration or acts of as a catalyst that sensitizes the cloth to image development later through another process such as heating.[9] Pellicori used this latent image process and replicated the color and chemical properties of the Turin image better than had other workers. He applied various uncolored substances to linen and heated the fabric. The substances catalyzed cellulose oxidation/dehydration, which produced colored fibers to form an image. Several problems with this process remain, however.[3] No sensitizing substance has been detected on the Turin cloth, although it has been recognized that a sensitizing agent substance may have been lost by washing, evaporation, or decomposition.[7] In addition, Pellicori's experiments failed to control the depth of penetration suitably. Most importantly, his process failed to produce accurate three-dimensional information, which is one of the most important attributes of the Turin cloth.

After much hard work, no hypothesis has been provided to identify a suitable mechanism of image formation on the Turin cloth. We will show in this report that the image on the cloth could have been formed by a simple drawing technique that uses technology available to 13th century artists. The technique may be implemented many ways to satisfy various image attributes reported for the Turin cloth. That is, the drawing medium may be iron oxide, iron oxide and collagen, or an uncolored sensitizing substance. Of particular importance is that images produced by this method are rich in three-dimensional detail.

THE DUST TRANSFER TECHNIQUE:

The technique of carbon dust drawing has long been used by medical illustrators to render images that reveal few brush strokes, contain fine detail, and exhibit photograph-like continuous transitions between light and dark. For this technique, dry powder (finely ground carbon or charcoal) is gently brushed onto a surface, using a soft artist's paintbrush. We modified this drawing technique several ways to obtain various image attributes.

We found that many substances besides carbon could be used for drawing. Nearly any material (colored or colorless) that can be ground into a fine dry powder is suitable. For example, increased permanence on linen fabric may be obtained by applying a mixture of a colored pigment and collagen and then dissolving the collagen with steam to bind pigment to the fibers.

To duplicate the characteristics of the image on the Turin cloth, a faint negative image had to be created in a way that revealed no brush strokes and accurately represented detailed three-dimensional structure. We dipped the tip of a clean, dry, soft artist's paintbrush into dry dust, gently tapped the brush to remove excess dust, and then drew the brush across a drawing surface in short, delicate strokes. The amount of dust applied with individual brush strokes was nearly indiscernible to the naked eye, but the brush strokes were repeated again and again from slightly different angles to build up dust in areas corresponding to the greatest numbers of brush strokes.

It is well known that the texture of a drawing surface affects the way pigment transfers from a brush. For example, brushing across the surface of woven fabric deposits much pigment perpendicular to yarns in a way that has been referred to as "snow-fencing". Another problem arises when pigment is applied as a liquid, because capillary action causes movement through the fabric unless the liquid is very viscous. We found that snow-fencing and pigment movement can be reduced by first applying dry pigment to a relatively smooth drawing surface and then mechanically transferring the pigment to the final textured material with gently rubbing. Figure 2 illustrates pigment transferred to a woven fabric in this manner with dry and liquid pigment transferred directly from a brush.

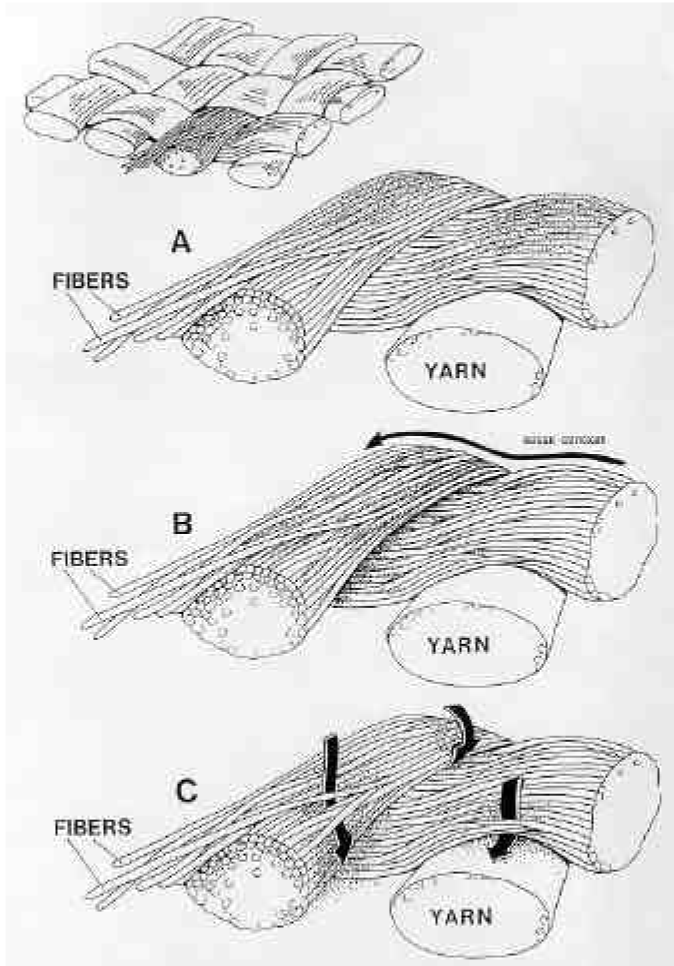

FIGURE 2: Illustration of colored woven fabric.
(A) Dry pigment transferred from a drawing using dust transfer technique.
(B) Dry pigment brushed directly onto the fabric.
(C) Wet pigment brushed directly onto the fabric.

Successful artists, illustrators and photographers translate the three-dimensional world into two-dimensional pictures by using shading and perspective. Although two-dimensional pictures often seem to represent the three-dimensional world accurately, the effects are achieved by light and dark areas that mimic highlights and shadows. Pictures created in this way generally do not duplicate the actual three-dimensional surfaces of the subject matter. This property can be observed when a photograph or other conventional picture is viewed as a three-dimensional surface and spatial relationships are seen to be confused and distorted.

We found that three-dimensional information could be accurately represented in a dust transfer drawing if the highs and lows of subject topography were simply correlated with dust buildup. Subject areas that are higher in relief are rendered with less dust buildup, and areas that are lower are rendered with more dust. A negative image can be produced simply by reversing this procedure to obtain a reverse topographical image. When this regimen is followed, an image can be easily drawn that accurately represents three-dimensional spatial information in either the traditional positive or negative view. A negative image produced by this process does not require complicated technology or knowledge of photography but simply involves conventional drawing along with artistic reversals of high and low. If an artist wanted to produce an image on cloth that looked as if it covered a human corpse, the reverse-topography drawing could be created easily to mimic cloth-to-body distance.

If the dust transfer technique described in this paper was used to create the image on the Turin cloth, a surface for creating the initial drawing must be identified. Almost any smooth, slightly porous surface available to 13th or 14th century artists might have been used. For example, the original drawing could have been rendered on vellum, a writing material prepared by soaking the skins of calves in pits.[10] It has been pointed out that residue from the soaking solution would be expected to remain on the skins and might have been transferred to the linen fibers of the Turin cloth, thus accounting for the traces of other chemicals documented in the Shroud of Turin Research Project study. Paper also could have been used as the original drawing surface, because it was readily available in long lengths. We used newsprint for our reproduction technique, because this coarse paper made from wood pulp has properties similar to, though not identical to, those of 13th or 14th century paper. [New notation added here in reference to *preface*: The original dust drawing could also have been done directly on cloth. However, only after t*ransfer* would it exhibit the physical attributes reported to be in the Turin cloth.]

If the image on the Turin cloth were created using the dust transfer technique, the only tools required for transfer of dust from the original drawing surface to linen cloth, would be a working surface and a flat piece of wood for rubbing. The images we created for this report were transferred by laying the initial newsprint drawing on a table, placing a piece of linen over the newsprint, and then pressing the linen against the newsprint by firm rubbing with the flat side of a wooden spoon.

EXPERIMENTAL RESULTS:

We compared attributes of images created using the dust drawing technique described herein to image attributes reported for the Turin cloth. We used various powdered substances to produce images. An example of an initial image drawn on newsprint using a mixture of iron oxide and collagen dust is shown in Fig. 3(a), and the corresponding image on linen fabric after transfer is shown in Fig. 3(b). As reported for the Turin image, the overall hue of the image was faint reddish-brown and was a negative view. This was more easily seen after the linen was photographed and the negative film was viewed, as shown in Fig. 3(c). The film revealed a life-like positive likeness of a person.

Because collagen was reported[6] to be present as a thin coating on fibers of the Turin cloth, we held the linen fabric shown in Fig. 3(b) over a pan of boiling water to dissolve the collagen. It is possible that a similar steam process was part of the original image-formation process for the Turin cloth. It is also possible that steaming occurred accidentally at a later date. That is, the well known fire of 1532 was doused with water, which could have created steam to dissolve the collagen. It is also possible that collagen was not involved in image formation on the Turin cloth in any way but was present only as a contaminant. At any rate, we successfully created images, using iron oxide dust or iron oxide and collagen dust, either with or without steaming.

FIGURE 3: Image created with iron oxide/collagen dust.
(a) Initial image drawn on newsprint
(b) Image on linen fabric after transfer.

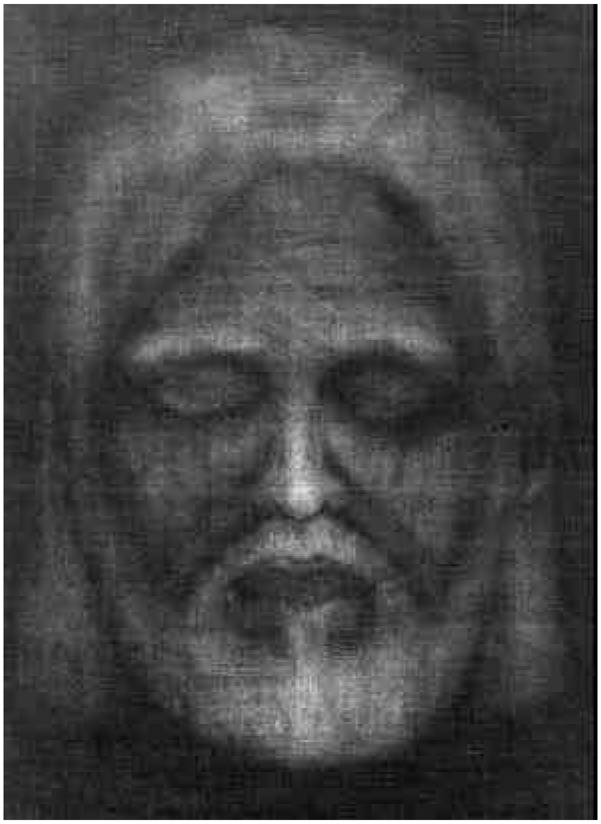

FIGURE 3: Image created with iron oxide/collagen dust.
(c) Photographic negative of the image on linen fabric.

Visible light microscopy was used to locate iron oxide and collagen dust on experimental fabrics. Fibers from image areas were removed from test fabrics and examined with brightfield illumination. Iron oxide dust was found to be dispersed relatively uniformly on the surfaces of individual linen fibers. Fibers were also stained with toluidine blue O, a stain that produces a blue color on contact with proteins. Stained specimens revealed that the distribution of collagen dust on most fibers on unsteamed fabrics was similar to that of iron oxide. For steamed fabrics, some of the collagen dust dissolved and formed a thin coating on the surface of fibers, which seemed to secure iron oxide dust onto individual fibers. In any case, iron oxide and collagen were present only on the most superficial fibers, as reported for the Turin cloth.

Electron microscopy was used to obtain more information about the location of iron oxide dust on the test fabrics. The secondary electron photomicrograph shown in Fig. 4, obtained from a strongly colored fabric area, revealed the topography of the woven fabric. A backscattered (BS) electron micrograph obtained from the same fabric area is also shown in Fig. 4. The BS electron micrograph, which was more sensitive to atoms of grater atomic number, shows the mainly carbonaceous fibers as dark and the iron as bright. The BS image shows that most fibers exhibited no evidence of iron oxide dust.

Even for the strongly colored area shown here, iron oxide is present only on the most superficial fibers of the fabrics, as reported for the Turin cloth.

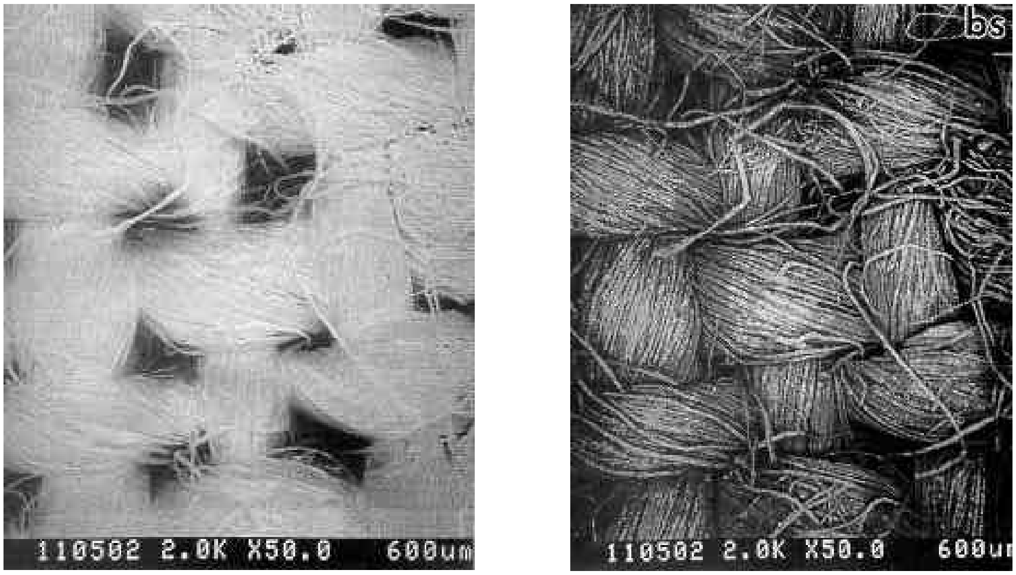

FIGURE 4: Scanning electron micrographs of strongly colored image on linen fabric created with iron oxide
(a) Secondary electron image. (b) Backscattered electron image

Electron beam induced x-ray fluorescence spectra were obtained by scanning 300*m*m x 300*m*m areas of a test fabric. Figure 5 shows spectra obtained from fabric areas exhibiting high color (a), medium color (b), and scarcely discernible color (c). Spectrum (a) shows that the dominant peak from a highly colored fabric area is the iron K*a* line, although silicon (Si), sulphur (S), and calcium (Ca) lines also are present. Spectra from fabric areas exhibiting less color displayed a reduced iron peak intensity, as seen in Spectrum (b), wherein the iron peak intensity is reduced by a factor of ten or more, and Spectrum (c), wherein the iron peak is undetectable above spectral noise. This series shows that a correlation exists between image color density and the amount of iron detected by x-ray analysis. In addition, these data show that color is detectable by the eye even when the iron x-ray signal is too small to be detected by x-ray analysis over a 300*m*m x 300*m*m fabric area (Spectrum (c)).

Pellicori determined that iron oxide ($Fe_2 0_3$) could not be responsible for the image on the Turin cloth, because it would not be detectable by the human eye when present in concentrations <5*m*g / cm^2 (9). To compare our results to Pellicori's conclusion, we deposited 5*m*g / cm^2 chromium over a fabric area exhibiting medium color, using a precision coater equipped with a calibrated quartz-crystal thickness monitor. Chromium was chosen because it was located near iron in the periodic table and was resolved from it by the x-ray system. Spectrum (d) reproduces Spectrum (b) along with a spectrum from the same fabric area after chromium had been deposited. The replotted iron peak can be seen to be only 5-10% as high as the chromium peak when chromium existed as a concentration of 5*m*g / cm^2 on the same fabric area. Because color on this fabric area was detected by the human eye, we can conclude that iron oxide contributes significant visual color density to the fabric at a coverage level well below 5*m*g / cm^2, and probably as low as 0.5*m*g / cm^2. Because the coverage of iron oxide is very localized on a microscopic scale, one might expect that the sensitivity of the optical reflectance technique used by Pellicori was reduced compared with the case of uniform iron coverage, because his technique sampled a substantial fabric area.

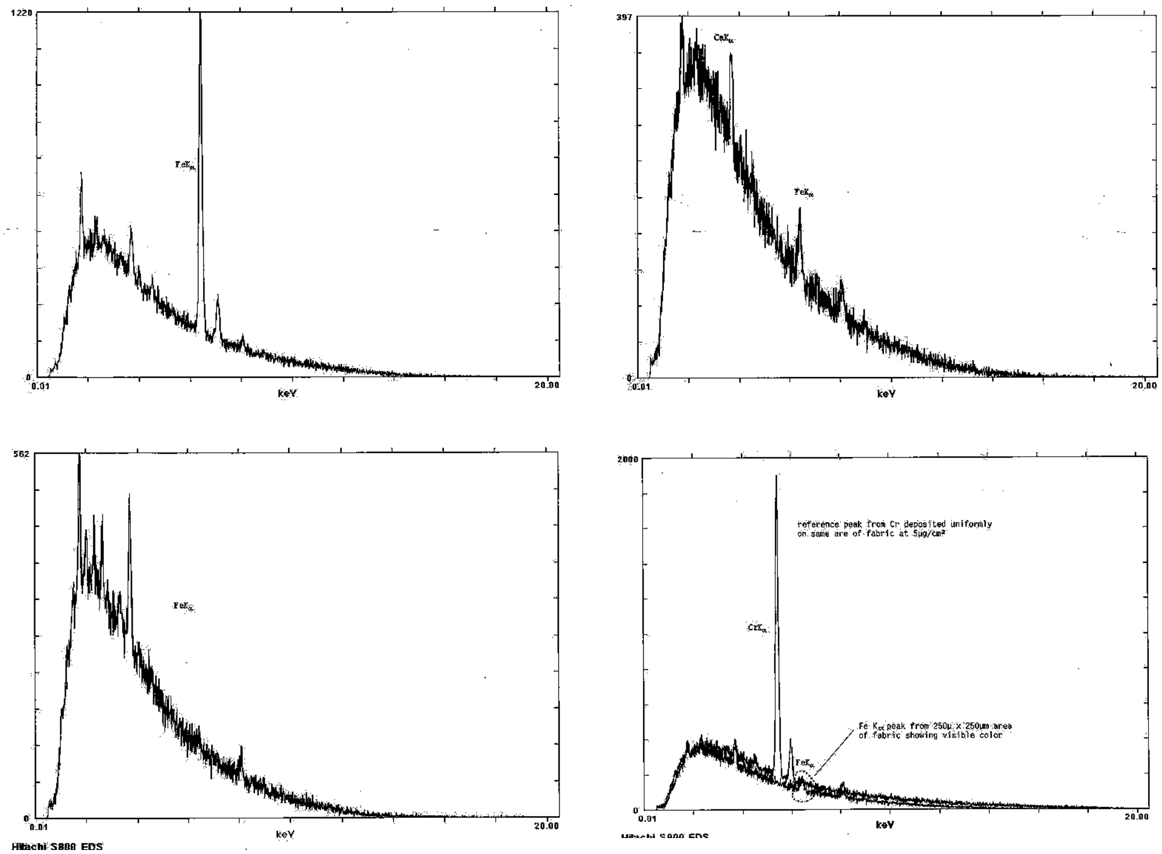

FIGURE 5

Electron beam induced x-ray fluorescence spectra from image areas created with iron oxide/collagen on a linen fabric (a). Area exhibiting high color (b). Area exhibiting medium color (c). Area exhibiting barely discernable color (d). Spectrum from medium color area plotted along with a spectrum from the same area after chromium deposition.

Next, the accuracy of the three-dimensional information in experimental drawings was assessed. The head and face of a life-sized manikin were drawn on newsprint as a negative image with iron oxide/collagen, using the technique described above. The manikin was also photographed. Both images (drawing and photograph) were illuminated with diffuse light and then imaged with a video camera, which in turn was interfaced with a personal computer. Computer images of the photograph and drawing were acquired as positive images (to facilitate interpretation later) and stored on the frame grabber with 512 x 512 spatial resolution (262,144 pixels) and 8-bit gray level resolution (256 gray levels). The accuracy of three-dimensional information in each image was assessed both qualitatively and quantitatively.

An attempt was made to assess the accuracy of three-dimensional information in the photograph and drawing quantitatively as follows: Thirty-three facial features (e.g. tip of nose) were located on each of the original digitized images, and the pixel gray level was recorded at each location. Then, each of the same 33 features was located on the manikin ant the height of each feature was measured from a plane behind the manikin. If structural information were accurately represented in an image of the manikin, a plot of feature gray level (in the image) versus feature height (on the manikin) would be expected to correlate in some way. Figure 6 shows these plots for the photograph and for the dust drawing, along with the best fit linear regression line for each data set. Little correlation between the photograph's gray levels and feature height measurements was observed ($R^2 = 0.19$). This result indicated that feature height was not represented accurately by gray level in the photograph of the manikin. A stronger correlation was observed for the drawing ($R^2 = 0.59$), indicating that feature height was more accurately represented by gray level in the drawing of the manikin.

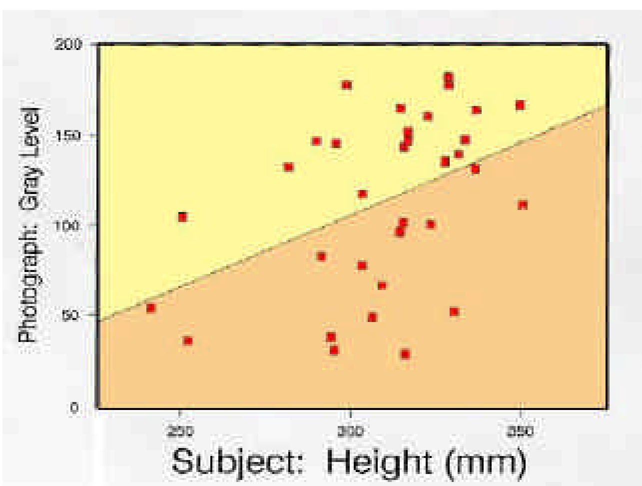

FIGURE 6 (a)
Feature gray level (in the image) versus height (on manikin) from the photograph.

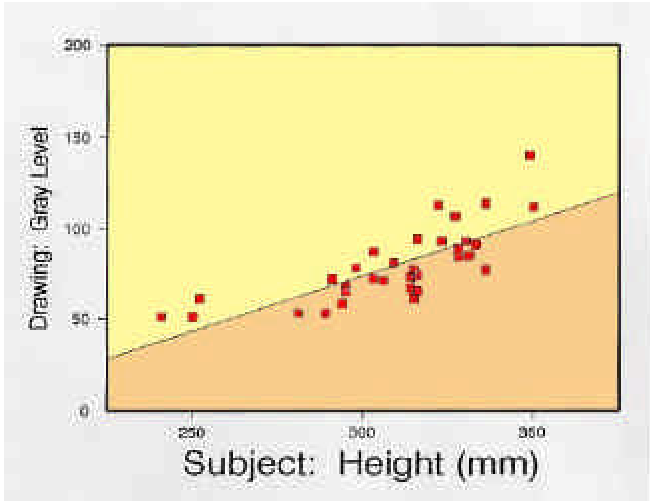

FIGURE 6 (b)
Feature gray level (in the image) versus height (on manikin)
from the dust drawing using iron oxide/collagen.

To assess three-dimensional information qualitatively, we prepared three-dimensional surface plots from digitized images of both the photograph and the drawing. Commercially available software for technical graphing and data analysis (AXUM by Trimetrix, 444 NE Ravenna Blvd. Seattle, WA) was used for both data reduction and plotting. First, pixels were deleted to provide a square array of 480 x 480 pixels. Then successive pairs of pixel columns were averaged row-by-row, and successive pairs of pixel rows were averaged column-by-column. This operation smoothed the data and reduced the data set to a 240 x 240 array (57,600 pixels). Then even-numbered pixel columns and even-numbered pixel rows were deleted to reduce the data set again by a factor of four to achieve a 120 x 120 pixel array.

Using the reduced data set, three-dimensional surface plots were prepared by plotting image gray level at each pixel location. These plots allowed us to determine qualitatively if image gray level represented subject height. Plots are shown in Fig. 7 for the manikin's head. The gray level information of the photograph can be seen to have confused and distorted the three-dimensional spatial relationships of the manikin. The dust transfer drawing, on the other hand, represented the manikin's three-dimensional structure substantially more accurately.

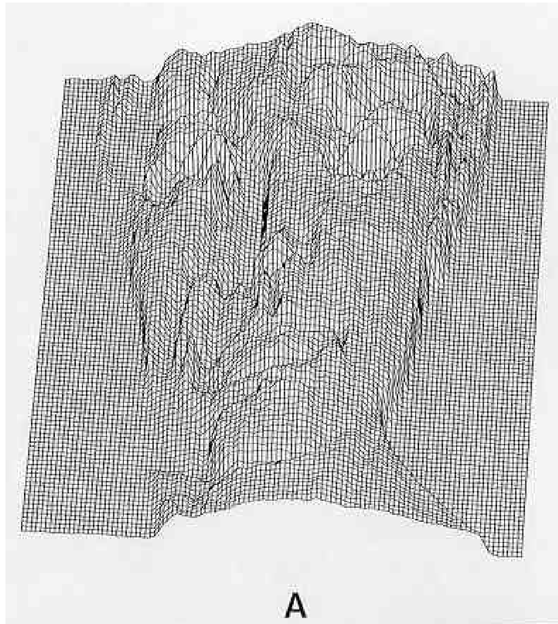

FIGURE 7 (a)
Surface plots from the photograph

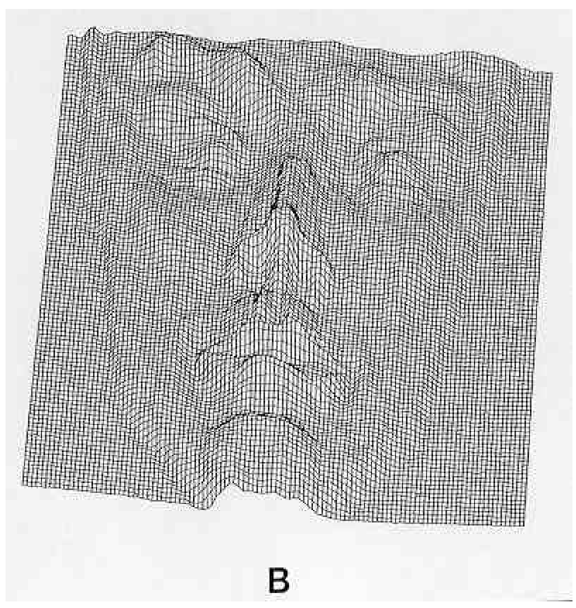

FIGURE 7 (b)
Surface plots from the drawing using iron oxide/collagen

When dust drawn images were transferred from newsprint to fabric, three-dimensional information on the fabric became slightly less clear. This result is shown in Fig. 8, where three-dimensional surface plots are provided for an image drawn on newsprint (Fig. 8 (a)) and after transfer of this image to linen fabric (Fig. 8 (b)). Image deterioration after transfer occurred because the image signal intensity decreased (not all pigment transferred to the fabric) and because the image noise increased (fabric structure contributed more visual noise than paper). Figure 8 shows that the final image on fabric still accurately represented a substantial amount of three-dimensional information, however. These results indicate that the dust drawing technique provides a simple way to accurately represent an impressive amount of three-dimensional information.

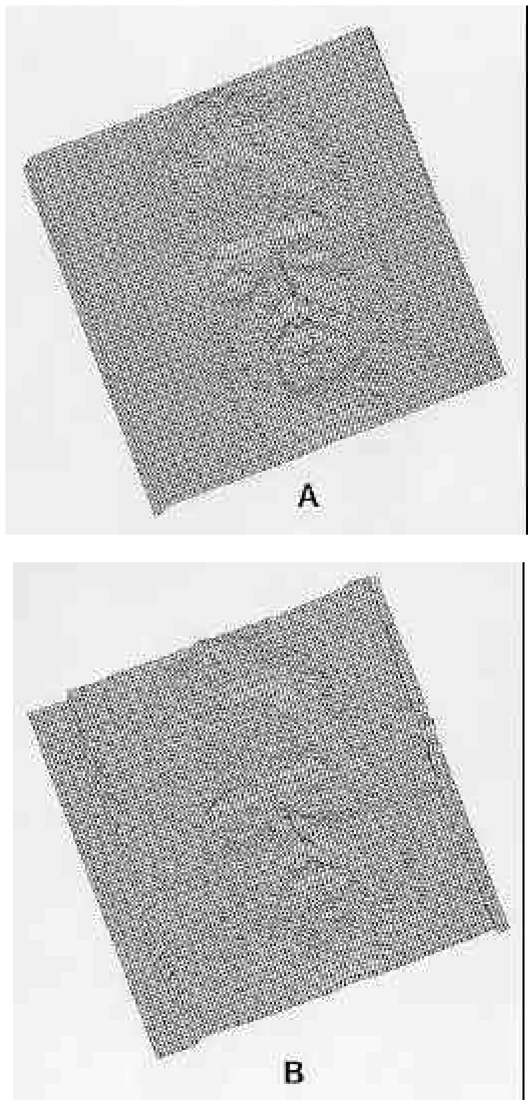

FIGURE 8 (a)
Surface plots of figure 3(a), the original drawing on newsprint and 3(b), the original drawing on fabric, after transfer from newsprint.

As discussed previously, several hypotheses have attempted to explain image formation on the Turin cloth by incorporating oxidation and dehydration of cellulose to produce yellow fibers. Pellicori replicated the color and some properties of the Turin cloth by applying substances directly to fabric and then heating the fabric to induce oxidation / dehydration of the linen fibers. The applied substance catalyzed this process so that more intense yellow color appeared where the substance had been applied. We attempted to use the dust drawing technique for image formation, using nearly colorless aloe powder, which would be expected to form an image on linen by catalyzing oxidation / dehydration rather than by direct coloration. The image of a human face was drawn on paper with the aloe powder, then transferred from paper to linen fabric, and the fabric was heated in an oven at 200^0F for approximately 5 hours to induce oxidation / dehydration of the linen.

Figure 9 shows a three-dimensional surface plot of the face on linen fabric using aloe dust. This figure shows that the dust drawing technique can represent three-dimensional structure accurately when image color is produced by oxidation / dehydration, using a nearly colorless sensitizing substance. However, the three-dimensional structure of the subject when drawn with aloe (Fig. 9) can be seen to be less accurate than when the drawing is made using iron oxide. (Fig. 8(b)). This resulted simply because it was more difficult for us to draw using a nearly colorless substance than when using a strongly colored substance. However, a professional artist may not be as limited as we were in this regard. When Fig. 8(b) and Fig. 9 are compared, Fig. 9 can be seen to exhibit more visual "noise" than Fig. 8(b). This apparently occurred because the image was more faint and because the texture of the linen fabric increased as the fabric was heated. As discussed previously, one would expect modern investigators to have detected aloe on the Turin cloth if it had been used to produce the image, but it is possible that it was lost by washing or decomposition. It is also possible that a colorless sensitizing substance, such as powdered boric acid, was used but has escaped detection by modern analysis.

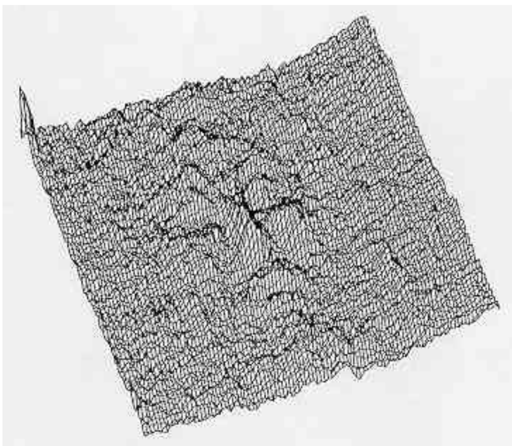

FIGURE 9:
Surface plot of image on fabric created with aloe powder.

DISCUSSION:

The experimental results we report in this paper show that important image features of the Turin cloth can be satisfied with a dust drawing process. The technique of dust drawing has a long history. The caves at Lascaux, France, contain magnificent drawings of animals that were created during prehistoric times with a dust drawing technique that may have been similar to the technique we report in this paper. The process was described as follows: "For drawing, he (the artist) used chunks of red and yellow ocher, and for painting he ground these same ochers into powder that he blew onto the walls or mixed with some medium, perhaps animal fat, before applying." [11]

Religious events have inspired artists as subject matter and are said to have influenced the actual artistic process. Many works produced during the Middle Ages were said to include direct divine intervention, "To Medieval minds, imbued with the conception of God as the 'great artificer,' legends about art miraculously wrought were especially appealing."[12] Fanciful accounts of divine intervention during the creation of artistic works revealed a deep respect for art but provided little information about the actual artistic process. The production of art during the Middle Ages was vast, but little is known of its creation. However, the 12th century work of Theophilus, *De diversis artibus*, and the 14th or 15th century work of Cennino d'Andrea Cennini, *Il libro dell'arte*, revealed step-by-step procedures for artists of that period. [12] Cennini's handbook includes instruction for grinding pigment into powder, brushing charcoal with feathers, and burnishing an image onto cloth. His handbook contains chapters containing specific instructions on "how to paint a dead man" and "how to paint wounds".[13]

These considerations indicate that the inspiration, knowledge, and tools necessary for an artist to create the image on the Turin cloth were probably available during the 12th and 13th centuries, although the specific combinations of individual techniques we used in our dust drawing technique may not have been described. It is clearly possible that an artist created the image on the Turin cloth. Of course, radiocarbon dating also supports this hypothesis, because this analytical technique determined that the Turin cloth originated between 1260 and 1390 A.D.

The hypothesis that an artist could have created the image on the Turin cloth also finds support in historical accounts of the burial shroud of Jesus. Historians have counted more than 40 copies of the shroud during the 14th - 16th centuries and point to the likelihood that other copies were made earlier.[4] It is fairly well established that the Turin cloth was brought from the Crusades to France by Goeffrey de Charney during the time copies were produced. Therefore it is conceivable that the Turin cloth could be a copy of the original burial shroud of Jesus.

CONCLUSION:

The conventional carbon-dust drawing technique was modified to produce faint continuous-tone images that contained an abundance of accurate three-dimensional information, exhibited no evidence of brush strokes, and were topographically reversed into negative images. This accomplishment motivated us to compare attributes of images formed using our technique with image attributes reported for the shroud of Turin, a linen cloth believed by some to be the burial shroud of Jesus of Nazareth. Macroscopic, microscopic, and image analyses were performed to show that an image could be created on fabric with physical properties and image features similar to those reported for the body image on the Turin cloth. However, it is impossible to satisfy simultaneously all observations reported for the Turin image, because many reported observations conflict! Because the inspiration, concepts, materials, and tools necessary to implement the drawing technique we describe have been available for centuries, we conclude that a 13th or 14th century artist could have created the image on the Turin cloth.

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