IS THE *SHROUD OF TURIN* THE FIRST RECORDED PHOTOGRAPH?

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In this article I outline some of the more prodigious characteristics of the *Shroud of Lirey-Chambery-Turin*'s image and highlight the inadequacy of the various image formation theories postulated this century. A review is then given of some of the findings of a recently established body of evidence which strongly indicates that the image which appears on the *Shroud of Turin* was produced by means of a technique which (it is normally assumed), was only invented in the late eighteenth century, viz: negative photography. In the light of these findings I conjecture that our current understanding of the level of scientific and artistic knowledge (technology) available in the medieval period (especially c. 1280-1357 AD) is in need of a major overhaul.

Hierdie artikel bespreek sommige van die uitstaande kenmerke van die beeld op die *Grafkleed van Lirey-Chambery-Torino* en beklemtoon die ontoereikendheid van teorieë wat in hierdie eeu oor die vorming van die beeld gepostuleer is. 'n Oorsig word verskaf van resente getuienis wat suggereer dat die beeld op die grafkleed geproduseer is deur 'n tegniek wat (soos algemeen aanvaar) eers aan die einde van die agtiende eeu ontdek is, nl. negatiewe fotografie. In die lig hiervan word voorgestel dat huidige opvattings oor die vlak van wetenskaplike en artistieke kennis (tegnologie) in die Middeleeue (veral ca. 1280-1357) hersien moet word.

High above the altar of the *Royal Chapel of Turin Cathedral* reposes a linen cloth which is believed by some to be the actual burial cloth of Jesus Christ.[1] This historically unique relic, known popularly as the *Holy Shroud of Turin*, and which contains a highly naturalistic (albeit negative), two-fold image of a naked man has a pedigree stretching back to its first recorded exposition in Lirey in 1357 A.D. In this regard, carbon dating tests undertaken by the radiocarbon laboratories of Oxford, Tucson and Zurich in 1988 seem to support the interpretation that the *Shroud of Turin* was produced sometime between 1260 and 1357 (Damon 1989: 611-5).

In appearance, the *Shroud* is an ivory-coloured linen strip, woven in a herringbone twill which measures c. 1100 mm x 4300 mm. On this cloth can be seen a faint image (in pale sepia) of both the front and the back views of a naked and tortured man (See figures 1 and 2). This image is extremely subtle in the sense that it cannot be readily discerned by the human eye at close range. This fact is not easy for anyone to appreciate by merely viewing a reproduction of its appearance. In this regard, the enhanced black and white photographs included in this article are misleading. Indeed, most authorities who have had the privilege of seeing the *Shroud* at first-hand, confirm that the image is so faint that it is visually coherent only at a distance of some seven metres (Wilson 1978: 9). In addition to this, it is important to keep in mind that only since 1898 (when Secondo Pia took the first photographs of this relic) has it been possible for anyone to appreciate that the image has many of the characteristics of a modern day photographic negative, i.e. all highlights are depicted as shaded areas, and conversely, all dark and shaded areas are shown as highlights. For example, if the polarity of this image is reversed (e.g. by making a photographic negative of the *Shroud*) one can clearly see a positive, seemingly three-dimensional image of a man (See figures 3 and 4). This positive version of the *Shroud*'s image (contrary to its normal negative appearance) is highly naturalistic and detailed. Even so, correctly viewed, even the negative image, clearly shows what appears to be the imprint of a bearded man with shoulder length hair, his upper arms and legs lie straight. His forearms are bent at the elbow and cross over the pelvic area in such a manner that one wrist obscures the other. The hands show only four fingers as both thumbs are absent. The feet point downward. Except for the face and heart region, all parts of the body, both in the frontal and the dorsal image, are covered with small regularly spaced brown marks. (These latter marks are normally interpreted as being skin abrasions caused by scourging). The wrist (which is visible) contains what appears to be a nail wound, and 'blood' flows are clearly visible running the entire length of both forearms. Similar 'nail' wounds and 'blood' flows are visible on the feet.

On the side of the man's chest (in the front view) is a larger wound and associated 'blood' flow. This latter feature seems to be continued on the back view as a large 'blood' flow is visible across the man's back. The head of the man appears to be perforated in both the front and back views and a number of smaller 'blood' flows are visible – the most prominent being one in the shape of an inverted number '3' on the man's temple.

In addition, since 1532, the *Shroud*'s image has been marred and visually dominated by unsightly scorch marks caused by an accidental fire.

If it is to be accepted that the *Shroud* is, in fact, simply a painted/dyed/stained product of a medieval band of forgers, intent only on profit and gain, then why is our culture (with its highly sophisticated technology and expertise) still unable to explain its means of production, far less duplicate it? Also, (assuming as most people do, that this image was intended to be read as an imprint of Jesus Christ) why did its creators go to so much trouble over this relic when, conceivably, they could have quite easily satisfied the needs of the credulous with a production far less sophisticated than the *Shroud* actually is. Bearing this point in mind, why does this relic not contain the vestiges or stylistic minutiae characteristic of the culture that produced it? After all, if the carbon dating can be trusted, the image which appears on this seemingly unique relic was produced at a time when Christian art (although tending towards naturalism and humanism in certain centres such as Florence and Rome), was more normally characterised by the fairly rigid stylistic conventions as found in Byzantine, Italo-Byzantine, and Gothic images. Similarly, the authority of orthodox Christian teaching in the late thirteenth century would have ensured that Christ be depicted with the marks of the nails in the palm of his hands and with the marks of a crown of thorns. However, the *Shroud* not only shows Christ uncharacteristically naked, but with the marks of the nails in his wrists and with the marks of a 'helmet' rather than a 'crown' of thorns.

In addition to these non-conformist, possibly heretical depictions of Christ, the image in the *Shroud* (as revealed by Pia's negative photographs) displays a degree of anatomical/medical/pathological knowledge that simply was not available to even a prominent medieval natural philosopher, let alone a medieval artist or forger of relics. Indeed, the depiction by the *Shroud* of such anatomical details as the reflex action of the thumb when an object is forced into the wrist at the *Place*

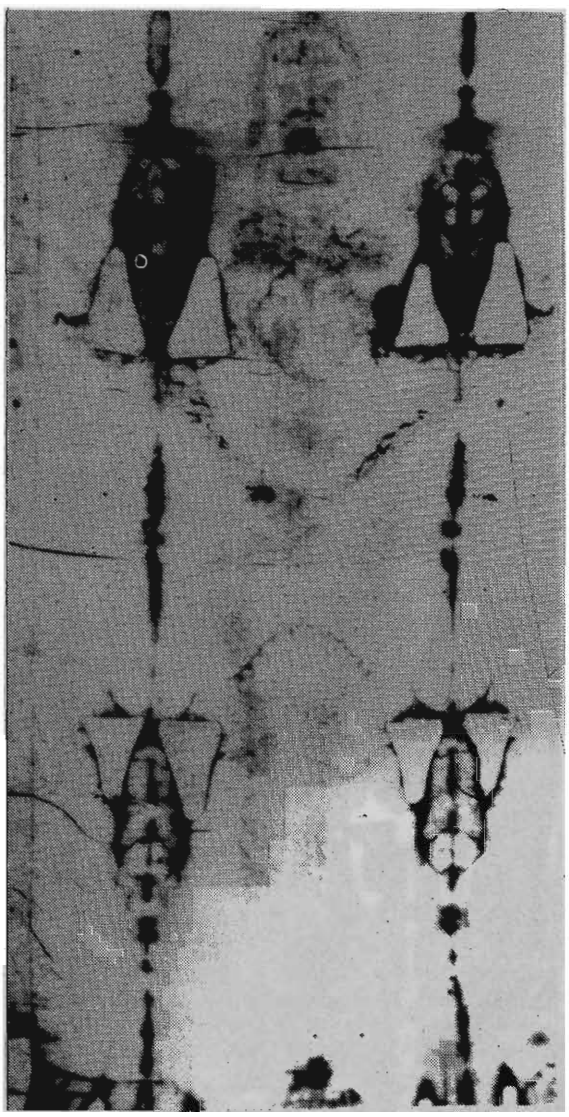

Figure 1: An enhanced photograph of the frontal image on the shroud of Turin

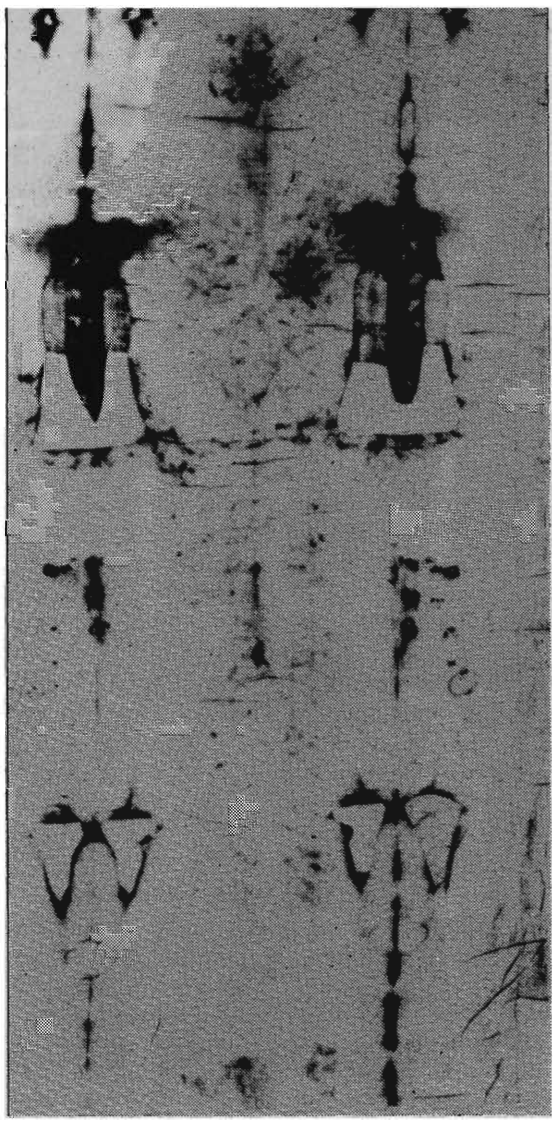

Figure 2: An enhanced photograph of the dorsal image on the shroud of Turin

of Destot was not documented until this century (by Barbet in the early 1930s). Barbet (1953:183) commented that "If these be the work of a forger, he must have been a supergenius as an anatomist, a physiologist and an artist, a genius of such unexcelled quality that he must have been made to order."

Barbet (1953:73) who started his investigations as a confirmed sceptic was so impressed with the anatomical accuracy of the *Shroud*'s image that he wrote: "I am a surgeon [...] and, as such, well-versed in anatomy which I taught for a long time; I lived for thirteen years in close contact with corpses, and have spent the whole of my career examining the anatomy of the living. The idea that an artist of the fourteenth century could have conceived, let alone painted or stained these negative images is sufficient to disgust any physiologist, any surgeon ... Please, do not even talk of it! This image is enough proof that nobody has touched the *Shroud* except the Crucified Himself."

From the time of Pia's famous photographic discovery until today, many theories have been put forward to explain how this linen cloth could possibly possess such a miraculous image. In addition, four scientific commissions have been held this century, under whose auspices the *Shroud* has been subjected to a variety of scientific tests. Without a doubt, the most important of these investigations was held in 1978 when the *Shroud of Turin* Research Project (STURP) team compiled the most comprehensive set of data on this relic to date. STURP, which comprised specialists in computer technology, haematology, physics, organic chemistry, spectroscopy and X-ray analysis, was headed by John Jackson and Eric Jumper of the US Air Force Academy. One of the members of this team, Pellicori (1981: 39) states that: "Perhaps no work of art or archaeology

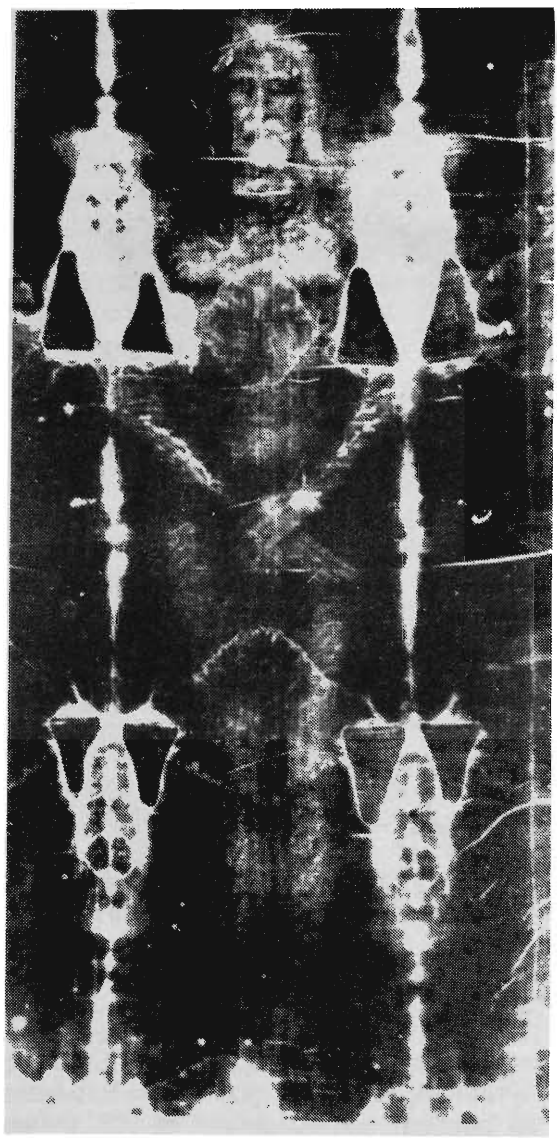

Figure 3: A negative photograph of the shroud of Turin showing the positive frontal image of a man

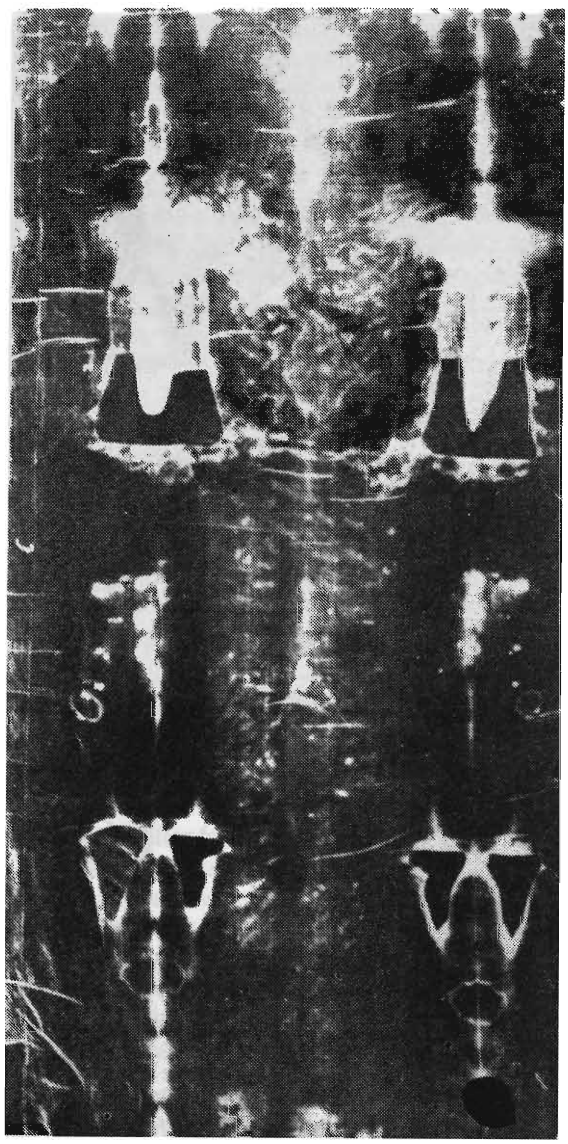

Figure 4: A negative photograph of the shroud of Turin showing the positive dorsal image of a man

has ever been so intensively studied as the shroud was about to be (1978). To probe the very atoms of the shroud's identity, a battery of the most sophisticated techniques available were brought to the task, many of them used in hair-splitting research on art forgeries and forensic problems."

The objective of this scientific arsenal, which included fluorescence, infrared radiometry, microchemical analysis, multispectral narrowband photography, optical microscopy, ultraviolet fluorescence photography, and visible, ultraviolet and infrared spectroscopy, was to investigate the *Shroud* as either a man-made (i.e., a painted/dyed) image or as a product of some (as yet unspecified) 'natural' origin. In addition, most tests were conducted in order to identify the elements present in both the image of Christ as well as those present in the 'blood' stains. In the latter case the scientists were especially keen to detect such trace elements as iron, potassium and phosphorous (the constituents of blood) (Pellicori 1981: 39).

The more important findings of the 1978 commission *vis à vis* the characteristics of the image as found on the *Shroud of Turin* have been listed in the same order as suggested by Stevenson & Habermas,(1981: 84-6) *viz*:

- **Superficiality**: The image is essentially a straw-yellow discolouration of the uppermost fibres of the linen threads of the *Shroud*'s fabric. This discolouration has not 'penetrated' the individual threads which make up the *Shroud* nor is the image visible on the underside of the *Shroud*.

Detailed: The *Shroud*'s image is so highly detailed that a number of medical experts (notably Barbet, Buckley and Willis) have been able to treat the image as they would the corpse of a deceased man (Barbet 1953 and Wilson 1978).

Thermally stable: The *Shroud*'s image was not affected by the heat of the 1532 fire. It is worth mentioning that the fire's temperature was high enough to melt the silver casket within which the *Shroud* was folded. Indeed, drops of molten silver set light to one of the corners of the folded linen.

No pigment: From the evidence of numerous tests it is quite certain that no pigment was applied to the *Shroud* and the image is not caused by pigment either.

Three-dimensional: The intensity of the image varies according to the distance of the body from the cloth. In other words features such as the nose, forehead and cheeks are more intense than areas such as the neck, ankles, and elbows. This correspondence between the body's high points and low points is so precise that Jackson and Jumper were able to produce a computer enhanced, three-dimensional replica from a photograph taken of the image in 1931.

- **Negative**: The image acts like a photographic negative which is as visually coherent as a positive photograph when its polarity is reversed.

- **Directionless**: Unlike hand-painted images (e.g., paintings) the image on the *Shroud* contains no 'directionality'. In other words the image could not have been produced by any technique which involved the use of brushwork.

- **Chemically stable**: The straw-yellow 'discoloration' which is the cause of the image on the *Shroud* cannot be easily dissolved, bleached, or altered by the application of bleaching agents.

- **Water stable**: The *Shroud* was doused with water to extinguish the fire in 1532. Although this has caused a water stain, the image itself does not appear to be affected.

Further the STURP researchers were in no doubt that those portions of the *Shroud* which 'contained' the image were not identical to the 'blood' areas. Allowing for errors (such as small misalignments of their apparatus and the varying thicknesses of the *Shroud*) it was found that the spectra definitely varied between 'blood' and 'non-blood' areas. Furthermore, the 'non-blood' areas were "qualitatively quite similar to one another" (Morris *et al*. 1980: 44).

In addition to these characteristics of the *Shroud*'s image, the researchers came up with fairly convincing evidence to support the notion that the stigmata ('blood' areas) and 'scourge' marks are formed from real blood. Although not absolutely conclusive, their more important findings cannot be ignored. For example, Pellicori undertook an experiment in which he compared the data of the reflectance spectra of several blood samples (four-day-old blood was used and in one case was artificially aged by baking) with *Shroud* 'blood', Pellicori discovered (as did Adler & Heller 1980) that there was a correlation in the spectrophotometry that indicated the *Shroud* blood to be *bona fide*. Pellicori (1980:1916) notes that "the absorption spectrum of a blood particle removed from the *Shroud* independently suggests that blood is present. Furthermore, the resemblance to blood as seen in the photomicrography of these areas is strong. The spectrum suggests denatured met-haemoglobin".

With the findings of the 1978 commission in mind, I would like to review the following image formation theories which have been propounded in the past century by numerous authorities and their respective untenability.

1. The image contained in the *Shroud* was produced by an artist who used either paint, dye, stain or a form of surface printing

Theories which support this kind of notion may be very quickly discounted, for even if an artist were able to apply some staining compound that contained a proportion of red ochre (as suggested by McCrone) (Stevenson & Habermas 1981: 105-7) the fibrils would be stained throughout, as is the case with the water stain caused by the Franciscan priests at Chambery when they doused the smouldering *Shroud* in 1532. However, this problem aside, one must also ask how an 'artist' could possibly view what he/she were painting/staining. As has been pointed out already, the image is so subtle as to be almost indiscernible from close range. This would imply that an artist would have to stand at least seven metres from the *Shroud* whilst he/she executed the 'forgery'.

Finally, the image has all the characteristics of a photographic negative, a fact that was only fully appreciated in 1898. How could anyone living in the thirteenth or fourteenth century (or even today for that matter) have managed to paint, dye or stain a photographically perfect negative image of a crucified man and, more importantly, why would they have bothered to have gone to such seemingly impossible lengths (assuming they had even understood these principles)? After all, an 'inferior' version (in negative or positive) would have sufficed, a fact borne out by the fact that both the *Shrouds of Besançon* and *Xabergas* (the latter still in existence) have been held in high esteem by their respective supporters for centuries. Indeed, both of these patently amateurish attempts at duplicating the *Shroud of Turin*'s image (Vignon 1902) have been revered for centuries as the genuine article.

2. The image contained in the *Shroud* was produced by the actions of a paint/dye/blood/sweat covered corpse, body or statue coming into direct contact with the linen cloth

There are four main hypotheses for this category of image-formation theory. The image

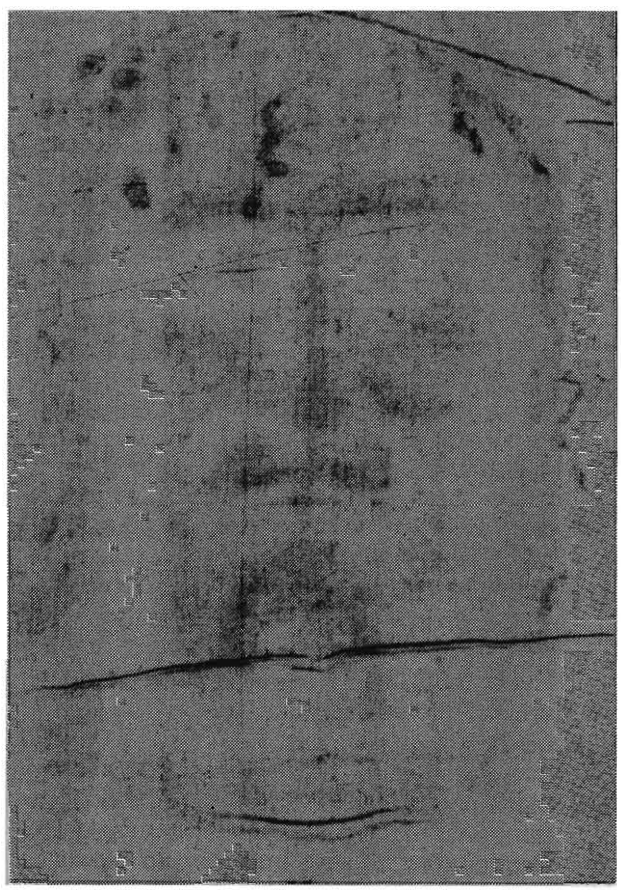

Figure 5: Enhanced photograph of teh Shroud of Turin: detail of the head

Figure 6: Negative photograph of the Shroud of Turin: detail of the head (positive version – compare Figure 8)

of the man on the *Shroud* is a natural chemical reaction between the *Shroud* and a corpse; a man-made impression caused by covering a red-ochre stained corpse with the *Shroud*; a man-made impression caused by covering a chemically-treated corpse, statue or a heated metal statue with the *Shroud*; a man-made impression caused by covering a heated metal relief sculpture with the *Shroud*.

All of these theories (with the exception of the last one) can be safely excluded for one major reason, namely that if the *Shroud* came into contact with all areas of the hypothetical corpse/body/statue that appear in the actual image, then that image should be grossly distorted.[2]

The last possibility – the image is a man-made impression caused by covering a heated metal low-relief sculpture with the *Shroud* – (although logically acceptable) is highly speculative. Not only would the style of such a relief sculpture (which would have to have been akin to a modern photographic plate) be totally unknown to 14th-century artists, its production (even if possible) would have been far more of a technical *tour de force* than the *Shroud* itself. Indeed, this two-dimensional metal plate would have to have contained the three-dimensional data which the *Shroud*'s image actually contains.

3. The image contained in the *Shroud* was produced by the actions of a chemical process Vignon termed *vaporography*.

It is supposed that someone spread an unguent on the *Shroud* (such as myrrh and aloes) 'thus rendering it sensitive to the action of organic emanations from the body' (Vignon 1902:164); a corpse, still covered in a layer of uric acid-rich 'morbid sweat' (the latter produced naturally by the body as a result of a highly stressful death) was laid out naked on the *Shroud* and then covered by the same; the urea, starting to ferment, produced carbonate of ammonia. The resultant ammoniacal vapours rose upwards and oxidized the aloes, thus producing a negative image (similar to the kind produced by zinc vapours on a photographic plate).

Vignon's 'vaporographic' theory has to be excluded for at least three reasons:

- The cloth of the *Shroud* (laid upon the cadaver) would not have suspended itself horizontally (literally in the air) in order to maintain a two-dimensional surface. The latter factor would be an absolute prerequisite to obtaining a vapour induced and still visually coherent three-dimensional image. Any distortion of the cloth's surface (including bodily contact) would have resulted in a distortion of the final image.
- The pressure of the body reposing on the *Shroud* would have produced a dorsal image quite unlike the carefully modulated image that in fact exists on this section of the *Shroud*. In other words the image of the buttocks, calves and ankles show no signs of having been compressed.
- Vaporographic images are caused by chemical changes that would be evident throughout the fibrils of the *Shroud*. The image on the *Shroud* is in fact visible only on the outer surface of the fibrils.

It is because of these and other seeming paradoxes, that most sindonologists have alluded in different ways to the suggestion that the *Shroud* could almost be a photograph taken of an actual victim of a crucifixion but for the annoying little fact that photography was not invented until c. 1800-1851. In this regard the following statement by Ostler (1988: 56) is typical of the feelings of many modern researchers: "The dating dispute may be settled, but the shroud remains as mysterious as ever, reason: it bears an inexplicable life-size image of a crucified body, which is uncannily accurate and looks just like a photographic negative – occurring centuries before photography was invented."

Despite this overwhelming evidence to the contrary most researchers are still prepared to concede that this relic is nothing more than a painted/dyed forgery, one which was produced for the sole purpose of deceiving the Catholic world of the late thirteenth century.[3] However, if this is the case, then why does this image defy our repeated attempts to decipher the methods and techniques which were most assuredly employed during its manufacture? Surely, the answer to this problem must lie in the fact that this artifact was produced by some technique that is either completely unknown to us or is known, but not normally associated with the level of technology believed to have been available before 1357 (See Forbes 1964, Grant 1977, Hoefer 1866, Sarton 1947, Thorndike 1923a, 1923b, 1934a, and 1934b).

It is accepted by all that in every way the *Shroud* acts as a negative photographic plate. However, surprisingly, no-one to date has seriously suggested that the *Shroud* could have been produced photographically. This is undoubtedly because such an outlandish notion would threaten our comfortable paradigm concerning the history, development and 'progress' of art and science. Indeed, it is accepted that the workings of such apparatus as the *camera obscura* were well known by Renais-

sance times, but the actual process which we call photography (i.e., the art of producing stable records of the images of nature through the action of light on light sensitive materials) was only in its infancy five centuries after the *Shroud* came to the attention of the western world. In this regard, Thomas Wedgwood (1771-1805) and Sir Humphry Davy (1778-1829) are on record as having produced the first photographically related images, in the form of silhouettes and negative images of botanical specimens (i.e., contact copies of leaves) on both white paper and leather moistened with a silver nitrate solution before 1802. However they could not fix their images, which had to be kept in a dark room and could only be viewed by candle light.

Figure 7: An enhanced photograph of a negative image of a man's head, produced with silver nitrate and ammonia

William Henry Fox Talbot (1800 -1877), like the other early pioneers of photography, first employed silver nitrate as a suitable light-sensitive chemical for his investigations. At first his products were simple negative images, but he went on to perfect a negative-positive process and is consequently accredited with being the discoverer of photography.

However, if we remove the phenomenon of the *Shroud of Turin* from the paradigm of contemporary scientific and historical opinion it becomes patent for those with eyes to see that the image on the *Shroud* is a type of photographic negative, but like the early silver nitrate negative images produced by the 'known' pioneers of photography, the *Shroud* displays a number of features that would necessarily classify it as a very primitive form of photography. If my argument is acceptable thus far, we have at the very least a provisional theory which would explain how the image on the *Shroud* was produced – a solution which seems bombastic and speculative only once it is placed within the context of our present-day understanding of medieval cultures and their respective levels of technology. In addition, if it could be proved that our present understanding of certain aspects of medieval technology was inaccurate, it would not only help to solve the mystery concerning the *Shroud*'s method of production but, perhaps more importantly, would force us to re-evaluate the kind of knowledge available c. 1200-1357.

For the past three years I have been conducting research which, is looking very seriously at the possibility that a form of photography was the cause of the image on the *Shroud*. It has been discovered that a person

can very easily make a permanent photographic negative image on linen which utilises chemicals and substances which, collectively,

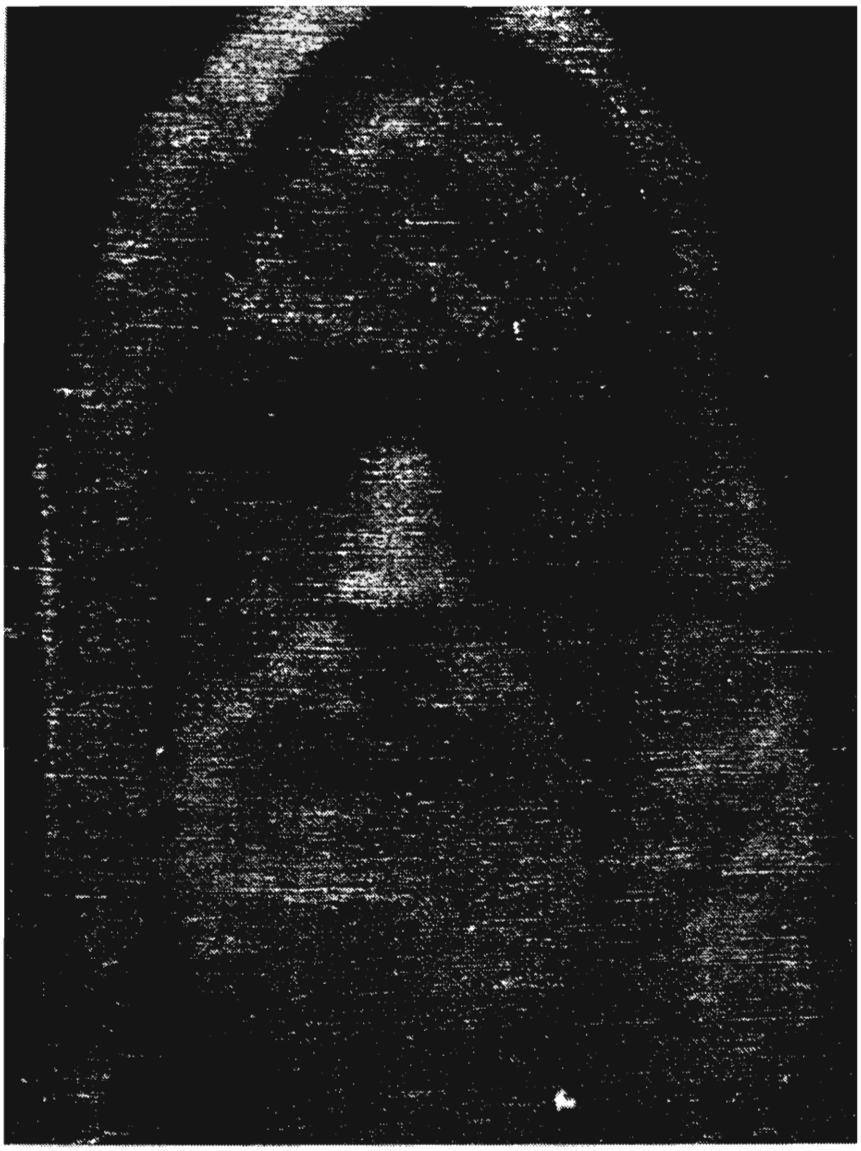

Figure 8: A negative photograph of the image produced with silver nitrate and ammonia

were known to have existed at least by 1280, viz:

silver nitrate (in solution),[4]
ammonia (in solution),
linen cloth (which naturally contains cellulose, hemicellulose, lignin, pectin etc.,
natural quartz (optical quality) magnifying glass or bi-convex lens.

It has been found that if any three-dimensional object (including a deceased human subject)[5] is set up in front of a *camera obscura* and is illuminated by direct sunlight over a period of a few days,[6] that a negative purple-brown image will form on linen cloth which has been impregnated with silver nitrate in solution. In addition, this image may be 'fixed' simply by soaking the cloth in a mild solution of ammonia. During this process the image turns to faint straw-yellow. This image is in the negative and only forms on the upper fibrils of the linen material. In other words, no image is visible on the reverse side of the cloth. This image is extremely subtle and (like the images formed inside a *camera obscura* when either a pinhole aperture or a small aperture with a fixed lens is employed) is not easily discernable at close range. In addition, the image is not a 'snapshot' of a particular moment in time (as is the case with most modern photographs). Rather, it is the record of the passing of many days. This means that those parts of the body which have literally received more sun (such as the bridge of the nose, cheeks, eye brows etc) are registered more intensely on the cloth than those areas which were further away (such as the neck, sides of the head etc) or received less radiation (such as the sides of the nose).

Although an image may be focused onto a piece of linen cloth by means of a simple bi-convex lens and this image (viewed at the correct distance) is clearly visible with the naked eye (inside the *camera obscura*) it was discovered that, in actual fact, the visible spectrum had no discernable affect on the silver-nitrate solution at all. Rather, it was the action of ultraviolet radiation (specifically 320-190 nm) that actually formed the image over a period of many hours. In this regard a glass lens is quite useless for this technique, since glass absorbs ultraviolet light whereas quartz will not.

It was also discovered that if the subject (to be 'photographed') was painted white the image formation would take place in considerably less time. In short, increased reflectivity of the surface of the subject ensured that higher concentrations of ultraviolet radiation would enter the *camera obscura*. In many ways the images that were achieved had all the characteristics of a severe suntan and were uncannily similar to the image on the *Shroud of Turin* (Cf. figures 4,5,6 and 7). I am certain that if a human subject could be found who has the identical physiognomy to the unfortunate man who died sometime before 1357 and whose negative image is now contained in the *Shroud*, that for all intents and purposes an identical image could be achieved today. *Stigmata* and other 'blood' areas on the *Shroud* were most probably daubed on by brush in real blood (with or without a slight addition of red ochre) after the negative body image had been achieved (this latter image needing two separate exposures to obtain the frontal and dorsal views of the suspended corpse).

In the light of these findings (no pun intended), it would seem that we have no choice but to accept that the *Shroud of Lirey-Chambery-Turin* (irrespective of its actual origin, and regardless of who may have produced it) is, in itself, sufficient evidence that someone had access to a form of photographic technology sometime before 1357. If this view can be supported by another non-destructive test on the *Shroud* which specifically addresses the photographic hypothesis, then the implications would have far reaching affects on our present understanding of the history and development of art, science and technology during the medieval period.

NOTES

1. Views expressed in this article are based on research currently being undertaken through the Department of Fine Art, University of Durban-Westville, Republic of South Africa.
2. Vignon (as early as 1902) undertook a series of experiments to prove this point. He had a tautly held cloth placed over a face smeared with red chalk and carefully attempted to produce a *Shroud*-like image. His results were grotesque, noses were flattened and spread out, faces were too wide.
3. This seemingly casual disregard for the overwhelming evidence which proves that the *Shroud* is not a painting is perhaps best reflected by the attitude of Professor Edward Hall (Oxford) who flippantly explained to a British Museum press conference that 'There was a multi-million-pound business in making forgeries during the fourteenth century. Someone just got a bit of linen, faked it up and flogged it' (Wilson 1991:12).
4. A number of formulae have been experimented with, but until the present research (in its entirety) has been completed, no figures will be released.
5. Casts (taken from life) were used for most tests.
6. The length of exposure varies according to the exact formula of the light-sensitive reagent, the exact diameter of the aperture and the relative condition of the weather. However, there is no doubt that a minimum period of eight hours exposure would be required to achieve a *Shroud*-like image. In other words, two complete days would be the absolute minimum time needed to produce both a frontal and dorsal image.

SELECTED BIBLIOGRAPHY

Accetta, J.S. & Baumgart, J.S. 1980. Infrared reflectance spectroscopy and thermographic investigations of the Shroud of Turin. *Applied Optics*, 19(12):1921-9.

Adler, A.D. & Heller, J.H. 1980. Blood on the Shroud of Turin. *Applied Optics*, 19(16): 2742-4.

Barbet, P. 1953. *A doctor at Calvary*. Dublin: Doubleday.

Beck, H.C. 1928. Early magnifying glasses. *Antiquaries Journal*, 8: 327-30.

Bellet, C.F. 1902a. Le Suaire de Turin: son image positive. Extrait de *L'Universite Catholique*. Paris: Alphonse Picard et fils.

Camille, M. 1990. *The Gothic idol: ideology and image-making in medieval art*. Cambridge: Cambridge University Press.

Cohen, I.B. 1953. Camera obscura. *Encyclopedia Britannica*, 4: 658-60.

Culliton, B.J. 1978. The mystery of the Shroud of Turin challenges 20th-century science. *Science*, 201: 235-9.

Chevalier, U. 1902a. *Le Saint Suaire de Turin*. Paris: Editions de l'Art et l'Autel.

Chevalier, U. 1902b. Le Saint Suaire de Turin: histoire d'une relique. Extrait des *Etudes Historiques et Religieses du diocese de Bayonne*. Paris: Alphonse Picard.

Chevalier, U. 1903. *Autour des origines du Suaire de Lirey: avec documents inedits*. Paris: Alphonse Picard et fils.

Crombie, A.C. 1971. *Robert Grosseteste and the origins of experimental science, 1100-1700*. 3rd ed. Oxford: Clarendon Press.

Damon, P.E. [*et al.*]. 1989. Radiocarbon dating of the Shroud of Turin. *Nature*, 337(6208), 16 February: 611-5.

De Bourgade la Dardye, E. 1902. *Le linceul de Turin et les actions photogeniques*. Paris: Edition de la Revue Scientifique.

De Gourgues, A.J.D. 1868. *Le Saint Suaire*. Perigueux: [*s.n.*].

Forbes, R.J. 1964. *Studies in ancient technology*. Vol.8. Leiden: E.J. Brill.

Geary, P.J. 1978. *Furta sacra: thefts of relics in the central Middle Ages*. Princeton: Princeton University Press.

Gilbert, R. & Gilbert, M.M. 1980. Ultraviolet-visible reflectance and fluorescence spectra of the Shroud of Turin. *Applied Optics*, 19(12): 1930-6.

Grant, E. 1977. *Physical science in the Middle Ages*. Cambridge: Cambridge University Press.

Hoefer, F. 1866. *Histoire de la chimie*. 2^{me} ed. Paris: Libraire de Fermin Didot freres, fils et Cie.

Jordan, F.I.& Wall, E.J. (eds.) 1976. *Photographic facts and formulas*. New York: Amphoto.

Judica, G. 1937. *Il colpo di lancia al cuore di Cristo*. Milano: La Medicina Italiana.

Lindberg, D.C. 1968. The theory of pinhole images from antiquity to the thirteenth century. *Archive for History of Exact Sciences*, 5: 154-76.

Lindberg, D.C. 1970a. The theory of pinhole images in the fourteenth century. *Archive for History of Exact Sciences*, 6: 299-325.

Lindberg, D.C. 1970b. A reconsideration of Roger Bacon's theory of pinhole images. *Archive for History of Exact Sciences*, 6: 214-23.

Morris, R.A, Schwalbe, L.A. & London, J.R. 1980. X-ray fluorescence investigation of the Shroud of Turin. *X-ray Spectrometry*, 9(2): 40-47.

Newhall, B. (ed.) 1982. *The history of photography*. New York: Museum of Modern Art.

O'Gorman, P.W. 1940. The Holy Shroud of Jesus Christ: new discovery of the cause of the impression. *Ecclesiastical Review*, Philadelphia. [sp].

Ostler, N. 1988. Debunking the Shroud of Turin. *Time*, 24 October: 56.

Pellicori, S.F. 1980. Spectral properties of the Shroud of Turin. *Applied Optics*, 19(12): 1913-20.

Pellicori, S.F. & Evans, S.M. 1981. The Shroud of Turin through the microscope. *Archaeology*, 34(1): 34-43.

Plane, R.A. & Sienko, M.J. 1966. *Chemistry: principles and properties*. New York: McGraw-Hill.

Sarton, G. 1947. *Introduction to the history of science*. Vol. 3: *Science and learning in the fourteenth century*. Baltimore: Williams and Wilkins.

Schmidt, J.A. 1698. *I.n.f. sudaria Christi.* Helmstadt: Georg Wolfgangi Hammii.

The New Encyclopedia Britannica, 1986. Shroud of Turin. 12: 55.

Singer, C. [*et al.*] (eds.) 1956. *A history of technology. Vol.2: the mediterranean civilizations and the Middle Ages. c 700 B.C. to c 1500 A.D.* Oxford: The Clarendon Press.

Stevenson, K.E. & Habermas, G.R. 1981. *Verdict on the Shroud: Evidence for the death and resurrection of Jesus Christ*. Michigan: Servant.

Testi, G. 1950. *Dizionario di alchimia e di chimica antiquaria*. Roma: Casa Editrice Mediterranea.

Thorndike, L. 1923a. 1923b. 1934a. 1934b. *A history of magic and experimental science during the first thirteen centries of our era*. Vol. 1-4. New York: Macmillan & Columbia University Press.

Vignon, P. 1902. *The Shroud of Christ.* Westminster: Archibald Constable.

Vignon, P. 1939. *Le Saint Suaire de Turin devant la science, l'archeologie, l'histoire, l'iconographie, la logique*. Paris: [*s.n.*].

Waterhouse, J. 1910. Camera obscura history. *Encyclopedia Britannica*, 11th ed. 5: 105-71.

Weaver, K.F. 1980. Science seeks to solve... the mystery of the Shroud. *National Geographic*, 157(6): 730-52.

Wilcox, R. 1978. *Shroud*. New York: Bantam.

Wilson, I. 1978. *The Turin Shroud*. London: Victor Gollancz.

Wilson, I. 1991. *Holy faces, secret places: the quest for Jesus' true likeness*. London: Doubleday.