The Image on the Shroud of Turin: Clues from the Volckringer and Russell Effects

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Two phenomena suggest that the image is initiated by hydrogen peroxide evolved from bacteria coating the body, and then developed over decades by the autocatalytic 'yellowing reaction' of cellulose.

Introduction

It is not proposed to discuss the general appearance and history of the Shroud of Turin, for it is considered that readers will already be familiar with these aspects. They will also know that:

- There is an unresolved discrepancy between the pictorial and anatomical details of the image – which are remarkably concordant with Gospel accounts of the crucifixion – and the C-14 age of a sample of the fabric which gave a date of AD 1260-1390.

- Independently of the age and origin, no scientifically agreed theory of image formation has yet been formulated, much less confirmed experimentally.

It is proposed to discuss only the second problem, that of image formation.

Characteristics of the image

It is helpful to first list those characteristics that must be explained by any acceptable hypothesis of image creation:

a) The Shroud exhibits full-size frontal and dorsal images of a naked man. This in itself renders difficult mechanisms more suited to a model.

b) Both images are in negative, becoming much more realistic when viewed as contrast-enhanced photographic positives.

c) The images are not silhouettes: there is modelling and detail within both the frontal and dorsal views. Thus, the latter exhibits marks of severe scourging with what appears to be a Roman flagrum. Hair and beard are registered in both views.

d) Microscopic examination has shown the image to be made up of yellow-brown oxidized fibrils on one side of the fine linen cloth (1). There is no pigment (e.g. iron oxide) beyond adventitious grains, or detectable brush marks. No modern artist has succeeded in painting convincingly in negative.

e) There are no gross distortions or anomalies (such as registration of ears alongside the eyes) that might conceivably result from close-wrapping of a shroud around a corpse for a period of time.

f) Instead, we see a strong directionality, more or less at right angles to the facial plane.

g) It has been claimed (2) that the intensity of an image element on the Shroud is inversely related to its distance from the body.

Photographic mechanisms

We are accustomed to making and seeing photographic portraits of people (although not full-size!) so it is understandable that two groups of investigators (3,4) have independently proposed silver- or chromate-based photographic mechanisms for the origin of the image. However, apart from being several centuries before the accepted invention of photography, there are enormous technical and optical problems to be overcome (5). Added to which, neither silver nor chromium could be detected on the Shroud by X-ray fluorescence analysis (6).

The main advantage of photographic theories is that directionality is achieved through the medium of a lens. The lens of any camera selects photons reflected from any given area of an object, and directs them to a corresponding element of the real image. The intensity of this image therefore depends on the brightness of the object rather than its distance.

'Radiation'

Some suggestions have involved a vague 'burst of radiation' – presumably IR, light, X- or gamma radiation. How this is collimated, modulated or selectively absorbed to give an image rather than an overall burn or smudge has not been made clear.

'Vaporographic' theories

It was long ago proposed by Vignon (7) that a volatile chemical substance (ammonia?) was released by bacterial decomposition of sweat coating the tortured body of the Man in the Shroud.

Assuming the corpse was laid horizontally on its back, he suggested these vapours might ascend short distances until, contacting the fibres of the Shroud, they reacted with impregnated aloes to produce an insoluble dark coating. Problems are:

i) There is no sign of such an organic coating today.

ii) If the reactive chemical is considered to rise vertically to produce good resolution, then it cannot at the same time diffuse laterally to result in dilution and a less intense area of image. Instead, it would surely produce a silhouette! For this reason I proposed (8) the short-lived radical 'singlet oxygen' as the active species initiating a latent image on the linen thread.

iii) Both 'ammonia' and 'singlet oxygen' hypotheses experience difficulty with the dorsal view, where the body was presumably in close contact with the cloth of the Shroud. Why is there not a solid silhouette?

iv) The good representation of hair on both frontal and dorsal views must not be ignored. Hair is dead: there are no dying epidermal cells to release singlet oxygen.

'Semi-Contact' mechanisms

The front view of the Man in the Shroud has usually been the primary consideration, but it now seems to me that the back view might furnish better evidence on mechanism. Here we have close contact between linen cloth and the body producing a pale negative image, but within this silhouette there are subtle variations in intensity. Areas of non-contact (e.g. behind the knees) are comparable in tint with the background, whilst areas of greater contact pressure (back of the head, shoulder blades, the sole of one foot) are slightly darker than average. The linear lacerations are darkest of all, as if they are the source of enhanced amounts of the active agent. It appears that varying *concentrations* of the initiating agent are responsible for variations in intensity.

This picture appears consistent with the corpse being laid face-up on one end of the Shroud, the latter spread out like a tablecloth upon a firm horizontal surface. The sides of the body, ears etc. do not contact the fabric, and so do not leave an image. The other half of the linen was then brought up and over the front of the body, being allowed to rest upon elevated areas such as nose, chest, hands and knees. It is not pressed down or tucked in. The absence of contact at the sides, it is suggested, results in the orthogonal view with which we are familiar. There is some 'action at a distance', but this must fall off very rapidly. Two phenomena may be cited in support of this hypothesis, and both provide further clues.

Volckringer patterns

Botanical collections normally include specimens of leaves and flowers pressed between absorbent white paper. Examination of older material will usually disclose a few sheets bearing faint brownish images behind (and sometimes on top of) the plant remains (Fig.1). Volckringer (9) and DeSalvo (10) have drawn attention to these markings, pointing out such resemblances to the image on the Shroud as their negative characteristics and increased realism on conversion to high-contrast photographic positives taken through a blue filter. More recently, Danin and Whanger (11) have claimed to discern faint images of certain flowers native to the Holy Land on background areas of the Shroud.

The classic Volckringer patterns offer evidence that:

a) Cellulose – common to both paper and linen – needs no additional photosensitive ions or dyestuffs to register an image.

b) Contact –or at least very close proximity – is required. A well-defined negative image of three-dimensional botanical material is produced, with very little blurring.

c) Considerable periods (decades) may be required for the image to become visible. It appears to undergo a slow 'development' with time.

d) Only a minor proportion of pressed botanical specimens give rise to Volckringer images, even when the mounting papers are identical. Some further factor seems important.

In spite of comparatively ready availability, no direct research appears to have been done on the nature of the agent responsible for these surface degradation products of cellulose, although DeSalvo suggested lactic acid. It is also not established whether cheaper papers (including a proportion of lignins) are more sensitive than very pure cellulose of the 'filter paper' type.

However, there does seem to be a connection with the 'yellowing reaction' that affects drawings and watercolours exposed to daylight. Here the discoloration appears to be initiated by UV light (12). For this reason galleries restrict the illumination of valuable artifacts to weak artificial light. Cheaper papers containing a proportion of wood pulp are notoriously liable to yellowing (e.g. newspapers and the edges of paperbacks.)

The Russell effect

Unmodified cellulose, in the form of paper or cloth, *can* then register an image of plant remains under certain conditions, but the process is so slow that experimental research is difficult. What is required is a medium that will give rise to a latent image after an exposure of only a few hours in total darkness. The Russell effect provides such a phenomenon.

In the early days of photography it was found that ordinary silver bromide/gelatine emulsions were sensitive to other influences besides light. Thus, the black paper with which glass plates were wrapped, the enclosing cardboard boxes, or metal fittings on the plateholders, were liable to produce marks and fogging even though light was rigorously excluded. The phenomenon was investigated by several workers in the 1890s, but the number of publications by W.J.Russell from 1897 onwards resulted in it becoming linked with his name. He demonstrated (13, 14) that vegetable material such as fresh and dried leaves, flowers, paper, card and wood induced latent images of themselves if placed for a few hours in the dark directly upon the photographic emulsions of the time. Some makes of plateholders provided evidence that the apparently quite different group of metals (e.g. copper, brass and zinc) were also active (15). Conventional development was required to make these latent images visible, followed by fixing with thiosulphate to enable the plates to be preserved and examined in daylight.

Russell believed the phenomenon to be due to the release of traces of hydrogen peroxide (16), and this was accepted by his contemporaries and later workers (e.g., 17,18,19) on the evidence of sensitive colorimetric reagents. The well-respected photographic chemists Sheppard and Wightman (20) found that 1.2×10^{-8} g/cm^2 of hydrogen peroxide would produce a photographic latent image. Reviews of the phenomenon have been published by Keenan (21) and Bullock (22). However, it was not established that hydrogen peroxide was the sole reagent – other volatile oxidizing agents might additionally be involved (23) – so modern analysis would be invaluable. Nevertheless, initiation by evolution of the volatile oxidizing agent hydrogen peroxide (24) will be accepted as a working hypothesis. This substance could also be responsible for Russell-type images induced by metals, although there has been some controversy over the possibility of exoelectron emission (25). Relevance to the claims (26, 27) that small copper coins have also left their imprints on the Shroud will be apparent.

The main thing is that the enormous sensitivity and amplification associated with the silver halide/gelatine/development process (up to 100 million times (28)) appears to offer a comparatively rapid means of investigating Shroud-like semi-contact images induced in the dark.

Elimination of the Russell effect

There is, however, a contemporary problem. Manufacturers of photographic emulsions understandably did not welcome their products being spoilt by their packaging, so sought to eliminate sensitivity to anything other than radiation. How they did this has never been disclosed, but so well did they succeed that emulsions produced from the 1930s onwards did not show the Russell effect, and the phenomenon was even omitted from standard textbooks of photographic science.

A brief resuscitation

However, for a decade or so following 1975 it was possible to investigate and utilize the Russell effect. This is because R.P.Clifford, of the Kodak Research Laboratory, published in that year the information that Kodaline Reproduction Film 2566, if bathed in dilute aqueous ammonia and dried, showed the phenomenon (29). Ammonia 'hypersensitization' of fast b&w films was employed by an earlier generation of astrophotographers in search of ultimate sensitivity to faint light sources, but was unsuitable for general application since the treated films fogged in a day or two even if stored in complete darkness. Bathing in aqueous ammonia certainly puts silver halide grains into an unstable and exquisitely sensitive condition, and in the case of Kodaline 2566 this included 'Russell' sensitivity. (The untreated film did not show this property.)

In the 1980s Daniels (30,31,32) was therefore able to propose the Russell effect as a tool for monitoring and assessing methods of conservation, and in 1984 I was able to check on certain aspects relevant to the Turin Shroud (see below). Unfortunately, Kodaline 2566 had been withdrawn from the Kodak catalogue by 1990, and contemporary b&w films remain inert even after bathing in ammonia. Nowadays, there appears no alternative to making one's own emulsion and coating plates in the manner of the pioneers (33,34). The resulting simple emulsions will be blue sensitive and slow by current standards, but should show the Russell effect. It might also be possible to coat the emulsion on fabric, to provide a porous support.

Confirmation of the Russell effect

Working by the light of a distant and diffused Kodak 1A safelight, and wearing vinyl gloves throughout, Kodak 2566 cut film was divided into 12 x 9 cm pieces, loaded into a photographic tank, and washed with cold tap water. It was then activated by pouring in chilled ammonia solution (containing 10 ml of 0.880 ammonia per litre) and agitating gently for 5 minutes before washing thoroughly once again with cold tap water. Holding each piece of film with plastic tweezers, it was rinsed with cold 90% ethanol and then hung in a current of cool filtered air for 10 minutes. Activated films were then placed emulsion-side up in new polystyrene boxes preparatory to placing samples upon them. A standard exposure time of 24 hours was employed, the boxes being held for that period within an opaque X-ray tank and further enveloped by black plastic bags. Development was in Kodalith and fixing in Amfix, followed by thorough washing and drying in a dust-free atmosphere. Some examples of the results obtained are as follows:

Fig.2 Fingerprint

The result of accidental brief contact.

Fig.3 Filter paper and ground glass.

Glass discs cleaned with chromic acid protected the emulsion from a light general fogging, but quadrants of filter paper taken straight from the box gave a strong reaction. Only if a hardened paper was washed in boiling distilled water followed by redistilled alcohol just before use was it inert (centre).

Fig.4 Softwood

A small block of pine placed directly on the emulsion gave the upper picture. Supporting another piece on slips of cleaned glass 0.74 mm thick resulted in the lower picture: it is of much lower definition, but demonstrates that actual *contact* is not essential for the production of an image.

Fig.5 Fossil fish

A fossil fish embedded in a matrix of limestone gave this result.

Fig.6 Copper coin

A 1p coin placed directly on the activated emulsion resulted in an image containing identifiable lettering and a distorted view of the Queen's head.

Not illustrated. Linseed and other essential oils.

Impregnated into cleaned filter paper quadrants, these gave rise to large dark smudges spreading out from the supports. Printing ink was very active.

The above results confirm the claims made by Russell and other researchers in the early decades of the 20th century that photographic emulsions can give images in total darkness if exposed to a range of organic materials or to some metals. Contact gave the best definition, but volatility of the inducing agent was indicated by haloes around very active samples and the poor images induced by samples supported a short distance above the emulsion (Fig.4).

The inducing agent will be provisionally accepted to be hydrogen peroxide at very low concentrations. That this substance is a product of plant growth was demonstrated by Usher and Priestley as long ago as 1906 (35), and it has also been recognized to be involved in the aerial oxidation of ‘drying’ oils such as linseed (36). More recently, hydrogen peroxide has been identified as a product of dismutation and other reactions of reactive oxygen intermediates (37).

Application to the Shroud of Turin

The skin does secrete oils, and that a human finger will produce a Russell image is apparent from Fig.2. Dried bloodstains were found to be active when the Russell effect was being intensively researched (38), but as circulating or fresh blood contains catalases that decompose hydrogen peroxide I am inclined to attribute the Shroud image to bacteria always present on the skin (39). In particular, as pointed out by Vignon, a tortured and crucified body must be soaked in sweat, providing an ideal culture medium for proliferation of the normal biota.

In 1922/23 McLeod and Gordon demonstrated that many genera of bacteria did not produce catalases, and released hydrogen peroxide as a normal concomitant of their growth (40,41). Peroxide formation from such a source would account for the otherwise anomalous production of a good image by the hair and beard of the Man in the Shroud (8).

In September 1984 I placed sheets of activated Kodaline 2566 film above open Petri dishes containing various bacterial cultures inoculated on nutrient agar, and stored the assemblies in total darkness at room temperature for 24 hours. *Staphylococcus epidermidis* gave a positive result, but *Bacillus subtilis* (a common soil microorganism) did not (Fig.7). It was subsequently discovered that Frankland (stimulated by Russell’s publications) had done much the same thing in 1898 (42,43).

Conclusions

The formation of Volckringer patterns demonstrates that, under certain conditions, cellulose in contact with plant material can register negative images of the latter without any addition of recognized photosensitive ions such as silver. These images appear to take decades to become visible, following ‘development’ of an originally latent image by an autocatalytic free-radical process analogous to the ‘yellowing reaction’ of drawings and other works of art. Identification of the original initiating reagent has not yet been reliably accomplished, but hydrogen peroxide is believed to participate in the yellowing reaction.

The Russell effect is the induction of latent images upon activated photographic emulsions in total darkness, by contact with (or close proximity to) a whole range of organic materials or certain metals such as copper. Only a few hours are required, the great amplification associated with conventional development enabling the detection of very small quantities of the initiating reagent. Russell believed this to be the slightly volatile compound hydrogen peroxide, and this was accepted by almost all his contemporaries and subsequent workers.

It has been shown that some species of bacteria can evolve traces of hydrogen peroxide, and can give rise to a 'Russell' image. These species of catalase-deficient organisms include members of the normal skin biota. It is therefore suggested that the evolution of traces of hydrogen peroxide from enhanced numbers of bacteria flourishing on the skin and hair of the Man in the Shroud initiated a latent image on the contact side of a linen cloth draped over the supine body. The 'yellowing reaction' due to autocatalytic oxidation by atmospheric oxygen 'developed' this latent image over a period measured in decades.

Further research

The practical work carried out in 1984 had to be fitted in as circumstances allowed, and it is a matter of regret that the research could not be followed-up in later years due to the withdrawal of Kodaline 2566 film. In particular, one would like to see some tests on animal material such as a mouse or small fish, as well as modern methods being applied to the definitive analysis of the substance(s) initiating the Volckringer and Russell effects.

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