APPENDIX · THE PHOTOGRAPHY

In 1917 The Svedberg and Ivar Nordlund made an examination of the Codex Argenteus to investigate the possibility of making a legible reproduction of the manuscript by photographic means. An account of these experiments is published in Uppsala Universitets Årsskrift 1918, Matematik och Naturvetenskap 1. The examination was of the five leaves numbered 23, 24, 25, 62 and 63. They all belong to the Gospel of St. Mark, and were chosen among those which had been at some time torn off (Uppström's »decem folia rediviva»). Even though the material of the examination was somewhat onesidedly selected, we have without hesitation been able to base a general plan of reproduction upon the results of the above mentioned investigation; for those leaves exhibit all the typical damages of the manuscript, such as the discoloration and falling off of the silver, the falling off of the gold and the penetration of the ink from one side of the leaf to the other. Furthermore Svedberg and Nordlund, as the preface of their investigation shows, had directed most of their attention towards the overcoming of the difficulties caused by these damages. The list of the methods tried by the authors, some of which were original to them, is so complete that it is difficult at the present moment to suggest any further additions of importance.

In addition to a spectro-photometric examination of the Codex, their work embraced the following photographic investigations:

1. The photographing of the manuscript with monochromatic light of the following wavelengths: 860—740 μμ infra-red, 725—650 μμ red, 577—579 μμ yellow, 546 μμ green, 436 μμ blue-violet, 405 μμ violet, 366 μμ »glass ultraviolet» and 313 μμ »quartz ultra-violet».

2. The photographing with Röntgen-rays and α- and β-rays of radium, partly by transradiation and partly by secondary rays.

3. Fluorescence photographing, that is the illumination of the manuscript with ultra-violet light and photographing by means of the fluorescence so produced.

4. The photographing with oscillatory electrical discharges.

No single one of the methods they tried can, however, satisfactorily solve all the difficulties. But two of them have proved to be decidedly superior to the rest. These are the photographing with reflected ultra-violet light of the wavelength 366 μμ and fluorescence photographing, in which the fluorescence is excited with the same wave-length, 366 μμ. Moreover, since these two methods complement one another in certain respects, it has been considered suitable to give a reproduction of each page of the Codex by both these methods. The former method, which from now on will be referred to as the ultra-violet method, makes use of the relatively high reflective power of silver for light of the wave-length 366 μμ; and this reflective power remains to a certain degree even in discoloured silver. The method gives a photograph in which the silver writing appears light on a dark background, but the more the parchment has become faded and the silver discoloured, the more the contrast disappears. Gold also, if it has preserved well, is reproduced on the photograph with much the same appearance but with weaker contrast. Since the wave-lengths which are more suitable for the reproduction of the gold, namely 577—579 μμ and 313 μμ, are decidedly less suitable for the reproduction of the silver, their use is out of the question. The writing which has penetrated from the reverse side of the leaf appears as dark shadows on the photograph and can therefore be easily distinguished from the text under examination. It is also of some interest that the structure of the parchment, too, is revealed in the photograph. With regard to the presentation of the original appearance of the manuscript the ultra-violet method is superior to any of the others.

The fluorescence method, originally worked out by Kögel[1], gave the best results in Svedberg and Nordlund's investigation when the leaf was illuminated with light of the wave-length 366 μμ. (The wave-length 313 μμ, Röntgen-rays and the β- and γ-rays of radium were also tried.) When illuminated in this way the parchment shines with a bluish light, while the writing appears dark. The photograph, when taken by the aid only of the fluorescence, thus presents the text as dark against a light background. It is of great advantage that the discoloration of the silver and the parchment do not have any influence on the resulting photograph and that the traces left behind by the silver which has fallen off are in some cases likewise capable of diminishing the fluorescence of the parchment, so that the writing still stands out on the photograph with sufficient contrast. Notes in ordinary ink are also reproduced distinctly, and this is sometimes of interest. The disadvantages of this method, however, are that the gold which has fallen off is badly reproduced and that the silver which has penetrated from the reverse side appears so well contrasted that it often masks the text examined.

It is evident that these two methods have a common imperfection in the reproduction of the gold in the text. One plan to insert this part of the text on the ultra-violet plate by means of two exposures, the first using a gold filter and with only the gold writing exposed, the second a general exposure with the ultra-violet filter, had to be abandoned. The retouching of the plate which was then necessary introduced a factor which tended to make the photograph no longer a faithful reproduction of the original manuscript. Instead it was thought necessary to complete the work by making a supplementary collection of photographs. And in this collection are reproduced on a smaller scale those pages, of which the ultra-violet and the fluorescence methods together give indistinct and illegible photographs.

Three methods of photography have been used for this supplementary collection: photography with a yellow filter, with secondary Röntgen-rays and with oblique illumination. Photography with a yellow filter was the first to be tried and this proved to be effective in many cases, especially where the gold of the text was to be made more distinct. Oblique illumination was only used in a few cases, chiefly for those leaves from which the metal of the writing had almost completely vanished and only feeble indentions in the parchment remained. Photography with secondary Röntgen-rays turned out to be the most fruitful. This method, invented by Svedberg and Nordlund, was recommended by them as being superior to the others in so far as the reproduction of traces of gold was concerned. It was also found that this method was of value in many cases for making the silver of the text more distinct. With this method it should be noted that it is chiefly the noble metals, gold and silver, which occur in the manuscript that are photographically active, and that the more metal we have on the parchment the better is the result obtained. But the colour of the writing, the colour and structure of the parchment and also the notes written in ordinary ink are inactive. Spots on the manuscript act in a disturbing manner only if they contain such metals as gold and silver or if they cover the writing enough to cause the radiation from it to be partially or completely absorbed. Penetrated writing has no appreciable disturbing effect since the parchment generally cuts off completely the radiation from the text on the reverse side of the leaf. Consequently photography with secondary Röntgen-radiation

[1] Photographische Korrespondenz, Jahrg. 52 (1915), p. 205.

is superior to a certain extent to the ultra-violet and fluorescence methods for the reconstruction of the original text. But the reasons which have already been given for the choice of these two as the principal methods have nevertheless been found to be the strongest.

The photographs which form the basis of this work on the Codex Argenteus were taken in the Upsala University Library with a camera built specially for the purpose by Messrs. A. W. Penrose and Co., Ltd., London. Certain alterations had to be made in the methods used by Svedberg and Nordlund in their investigations, partly because of the special object of this reproduction and partly because of the fact that new technical devices had been invented since those investigations were carried out. It is a great advantage that the manuscript has been detached from its binding, for now the leaves are free and can be easily handled. Consequently it was possible to press the leaves out, and this in its turn led to a sharpening of the resulting photograph. The copy-board of the camera was displaced by a specially constructed frame, in which the leaf was pressed against a plate of plane parallel glass by a pneumatic contrivance. Before the leaf was put in the frame it was softened in a damp atmosphere, after which all possible creases and superficial irregularities were smoothed out. As an objective we used either Zeiss Tessar 1 : 6.3, f = 60 cm., or Zeiss Apochromat-Tessar 1 : 10, f = 64 cm., both of which were fitted with Zeiss cuvettes made of plane glass.

As sources of light we used two quartz-mercury lamps with Jesionek tubes burning with about 150 volts in a horizontal position. They were inserted in light-tight boxes of zinc plate, provided with ventilation holes for the cooling of the lamps. These ventilation holes were so arranged that no appreciable amount of light could penetrate through them into the outer room. In the front wall of the lamp-house there could be inserted windows suitable to the different methods of photography used. The windows employed were 12″ × 15″ in size, and, since they had a frosted surface, could be regarded as secondary sources of light. The distance between the windows and the manuscript to be photographed was about 65 cm., and this was found to be sufficient to illuminate the leaf uniformly. The angle between the direction of the beam of light and the optical axis of the camera was kept just large enough to exclude the image of the lamp in the glass of the frame. Moreover, disturbing reflections were easily avoided by having the inside of the room in which the photography took place covered with a black, non-fluorescent paint.

As a background for the leaf white paper possessing a strong power of fluorescence was used. By this means the contour of the leaf and all possible holes in the parchment were reproduced directly on the plate in both the ultra-violet and fluorescence methods.

The photographs taken by these methods reproduced the exact size of the page; and since the position of the manuscript-holder was fixed, the position was determined once for all of each of the two lenses used. The insignificant difference between the sizes of the ultra-violet and the fluorescence photographs is due to the changing of the length of the camera which was made necessary by the use of different filters and by the imperfect corrections of the lenses for ultra-violet light.

For the development of the plates we have used, where nothing is said to the contrary, the following solution made up of equal parts of A and B.

A.	Hydroquinone	25 gr.
	Potassium meta-bisulphite	20 »
	Potassium bromide	12 »
	Water	1000 c.c.
B.	Potassium hydroxide	50 gr.
	Water	1000 c.c.

In the ultra-violet method an ordinary ground glass was used as a window, a wire gauze acting as a protection between the lamp and the glass.

Of the light reflected from the manuscript we only wished that of the wave-length 366 μμ to come into the camera. Thus there was placed in front of the objective a Wratten ultra-violet filter; a well-ground specimen three inches square was employed and this transmitted light of wave-lengths between 300—400 μμ. Furthermore, since during the photographing the light passed through several layers of ordinary glass—the lamp window, the sheet of glass in front of the manuscript and the objective—the shorter wave-lengths were absorbed, so that from the spectrum of the mercury lamp light chiefly of the wave-length 366 μμ was isolated.

We used as negative material Wellington »Ordinary» and Imperial »Process» plates. The aperture of the objective was adjusted to f : 12.5 during the photographing, and the time of exposure varied between five and twelve minutes. Since the flesh-side of the parchment is always faded more than the hair-side, the average time of exposure for the latter was somewhat longer than for the former.

In the fluorescence photography, moreover, modern ultra-violet glasses were used for the isolation of the wave-length 366 μμ — the suitability of these for the Codex Argenteus having been investigated earlier.[1] In this case we used glass with a stippolite face, supplied by Messrs. Chance Bros. and Co., Ltd., Birmingham. The size of the glasses was 12″× 15″, and they were introduced as windows into the lamp-houses. For the absorption of radiant heat there had to be inserted between the lamp and the glass one window composed of thin sheets of mica mounted on a wire gauze, and another of ordinary glass. In spite of the weakening of the illumination thus brought about, the time of exposure exceeded one hour only in exceptional cases. As a filter for absorbing the ultra-violet light reflected from the manuscript there was placed in front of the objective a 1 cm. cuvette, filled from a solution of the following composition:

Water	500 c.c.
Quinine sulphate	5 gr.
Sulphuric acid (about 4 × N)	5 c.c.
Hydrochloric acid (conc.) . . .	15 »

It has been the custom in fluorescence photography only to use objectives with large apertures. Because of this the above-mentioned Tessar 1 : 6.3 was procured and was used with full aperture for the greater part of the work. Later the better corrected Apochromat-Tessar was bought for other purposes. This was subsequently used for ultra-violet photography, and it was found that it was possible to make use of its properties also in fluorescence photography. The increase in the time of exposure necessitated by the smaller aperture was compensated by the advantage of being able to take the ultra-violet and the fluorescence photographs of the same page, one immediately after the other, without much change in the apparatus.

Numerous investigations with different kinds of plates resulted in the choice of Ilford Special Rapid (Extra Sensitive), Backed.

It has been remarked above that the penetration of the silver from the reverse side of the leaf often produced disturbances on the picture when the fluorescence method of photography was used. It appeared, though, that this was eliminated to a certain degree by increasing the time of exposure beyond that which was desirable from other points of view. The lines written in gold, paragraph signs and the decorative columns with their parallel figures were often exposed too much by this means, a disadvantage which was remedied in some degree by covering the text with one or more layers of transparent paper during the printing from the plates.

The times of exposure were much longer for the texts of the Gospels of St. Matthew and St. Luke than for St. John and St. Mark. If we reduce these times of exposure to a comparable base, f: 6.3, the average time for St. Matthew was 9 minutes, St. Luke 8 minutes, St. John 27 minutes and St. Mark 22 minutes. The appearance of the leaves of the Codex during

[1] The Svedberg and Hugo Andersson in The Photographic Journal, Vol. 63 (1923), p. 30.

fluorescence photography also suggests a difference in the writing of St. Matthew and St. Luke on the one hand and St. John and St. Mark on the other. The writing in the first two mentioned gospels stands out but feebly against the background, whereas in the other two the contrast is much greater, the text appearing almost coal-black. Since also the penetration of the writing was darker in St. John and St. Mark, it was necessary to increase the times of exposure for these gospels, and this accounts for the fact that the difference in type cannot be observed in the photographs. The decorative columns at the bottom of the pages, which during the fluorescence have roughly the same appearance in all the Gospels, consequently in the reproductions of St. Matthew and St. Luke generally stand out a little stronger than in the reproductions of St. John and St. Mark.

The negatives were printed on daylight paper and from these prints the phototypes were then prepared. For several reasons this proved more convenient than preparing the phototypes directly from the original negatives. First, this method enabled us to cover the plates suitably during the printing, and thus to reduce any unevenness in density on the plates and diminish the effect of the penetrated writing. Second, it permitted of an effective control over the work, since before sending the prints to be phototyped they could be carefully compared with the original manuscript and finally the prints, unchanged during the process, could be compared with the phototypes. Third, it enabled us to retain the undamaged original negatives for reference in the future.

The methods used in the photography for the supplementary collection have already been stated. The photography with a yellow filter was carried out with the same illumination as was used in the ultra-violet method, and as a filter the 1 cm. cuvette, filled with a 10 % ammonium bichromate solution, was employed.

The photography with secondary Röntgen-radiation was effected for the most part in the manner described by Svedberg and Nordlund. The leaf was pressed in a printing frame against a photographic plate, so that the script to be reproduced was in contact with the sensitive side of the plate. To exclude ordinary light black paper was inserted. On exposure the primary rays had to pass in order through the glass of the printing frame, the black paper and the plate, and then they struck the manuscript. The gold and silver characters then emitted powerful secondary rays which acted on the plate. This part of the work was done in the Röntgen-ray department of the University Hospital in Upsala, where the apparatus was very kindly placed at our disposal. Since it proved preferable to use very hard primary radiation, the stabilivolt apparatus of the hospital was used in conjunction with an A.E.G. tube for depth therapy (190 kilovolts, 6 milliamperes). The radiation was filtered through a double filter consisting of copper 1/2 mm. thick and aluminium 1 mm. thick. The distance between the anticathode and the photographic plate was in most cases 1 metre and in some cases 75 cms.

As negative material for this kind of photography emulsions of the »Process» type were most suitable. In the beginning we used plates (Wellington »Ordinary» and Imperial »Process») but these were later on given up in favour of films (Agfa Phototechnischer Film A). One of the advantages in using films was that less risk of damaging the manuscript was incurred when it was pressed in the printing frame. Bad contact between the manuscript and the sensitive layers obviously gave a certain slight blurring on the photograph; this defect was especially noticeable when we used plates in taking the photographs.

The times of exposure varied between two and six minutes. The following developing solution proved to be suitable for this photography:

Water	1000 c.c.
Glycin	16 gr.
Sodium sulphite (anhydrous)	20 »
Potassium carbonate	80 »

The radiation, negative material and developer were so chosen as to reduce the fogging of the negative caused by the primary radiation. We were generally successful in this, and the negatives obtained showed so strong a contrast between the script and its background that they could be printed directly on hard gas-light paper. These prints were then reduced to half size, so that they could be fitted into the supplementary collection.

In certain cases, however, the contrasts on the original negative were too weak to give clear photographs by direct printing with gas-light paper. When this occurred a diapositive was made by printing the original negative on a phototechnical film, and making a duplicate negative from the diapositive by a similar method of printing. This negative then showed distinctly deeper contrasts than the original. One drawback to this method was that the fog on the original negative appeared on different parts of the photograph with varying density. The attempts to overcome this difficulty were not always successful, and in some cases even acted to the detriment of the more minute details.

In the photography with oblique illumination only one source of light was used, and this was so placed that the light struck the paper at an angle of 45°. The camera was also placed obliquely so as to receive the light reflected directly from the manuscript. In this way the indentions left in the parchment by the writing which has fallen off are revealed quite distinctly against the smooth, reflective surface of the parchment. By choosing a suitable kind of illumination it was possible to accentuate even more this contrast on the negative. It was found suitable to use the same source of light as in the ultra-violet method, a quinine sulphate filter in front of the objective and ordinary (not orthochromatic) plates.

With this method it was not possible to press out the leaf against a plate of glass, for the reflections from the glass were then too disturbing; instead the leaf had to be fixed between a sheet of cardboard and a frame. The creases and other irregularities of the surface of the parchment presented difficulties which were found insuperable. The perspective distortion caused by the oblique position of the camera was remedied in the ordinary way during the printing from the negative.

The photographs in the supplementary collection have been cut to a rectangular form. When taking the photographs numbered $^{F}41$ and $^{R}42$ some of the creases of the highly injured parchment were, by an oversight, not pressed out. These photographs were not intended to give any further information on the condition of the parchment, so we have not thought it necessary to correct the existing discrepancies between $^{F}41$ and $^{R}42$ and the corresponding photographs in the main part of the book.

We contemplate giving a fuller account of our investigations and results in the scientific journals.

In reading the photographs the following should be borne in mind:

1. In the main collection a fluorescence photograph is always on the left-hand page and an ultra-violet photograph on the right-hand page. Corresponding photographs have the same number but the ultra-violet photograph is indicated by an asterisk.

2. In the ultra-violet photographs the present form, size and appearance of the leaf are faithfully reproduced, and the silver text even with some improvement.

3. In many cases when the contrast in colour between the writing and the background is unsuitable for the ultra-violet method, the fluorescence photograph acts as a complement by giving a more legible text. In certain cases, too, a legible text is obtained although the script has fallen off from the parchment. The notes in ordinary ink and the parallel numbers show up clearly. On the other hand, the phototypes from the fluorescence method do not

reveal distinctly the contour of the leaves and the holes in the parchment, but this was not considered necessary.

4. In the supplementary section each page of the manuscript reproduced has the same number as in the main section of the work but with the following prefixes, indicating the photographic method used:

F = yellow filter
O = oblique illumination
R = secondary Röntgen-radiation.

5. The purpose of the photographs in the supplementary section is simply to clarify the more indistinct parts in the main section, particularly parts of the gold text. Where destroyed letters in the manuscript have at some time been restored with ordinary ink, the Röntgen-photographs can often verify the original text.