FOLDMARKS AS A HISTORICAL RECORD OF THE TURIN SHROUD

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I. Introduction

For centuries the Shroud of Turin has attracted pilgrims who have come to see on its cloth surface the image of what appears to be a crucified man, believed by many to be that of Jesus. However, the Shroud has one serious shortcoming in any claim it might have to being the true burial shroud of Jesus; the first 1300 or so years of its supposed 2000 year history are uncertain. Thus, there is legitimate concern among scholars regarding the Shroud's authenticity because it is unclear how the burial cloth of Jesus could have passed nearly thirteen centuries without better historical documentation.

An interesting solution to this problem has been offered by Ian Wilson who hypothesized that the Shroud was the legendary Mandylion Cloth of Constantinople.[1] This cloth purportedly had an image of Jesus' face on it and was mounted in a frame. Wilson's proposed chronology of the Shroud/Mandylion begins with the assumption that the Shroud is the burial cloth of Jesus which was brought to Edessa, now the city of Urfa in Turkey, by a disciple of Jesus. In 944, the cloth was transferred to Constantinople. Wilson assumes that during approximately the first millennium of its history, the Shroud/ Mandylion was continuously folded into a frame (or frames) so that only the facial part of the image could be seen. Thus, he speculates, its identity as a burial cloth remained essentially hidden from history until someone, possibly around the XIth century, removed the cloth from its frame. In the following century, allusions to and reports of a burial Shroud in Constantinople bearing an image of Jesus began to appear in historical data. Robert de Clari, French crusader in Constantinople in 1203-1204, wrote that a burial shroud with a full-length image of Jesus was displayed there every Friday. This cloth disappeared in the XIIIth c., only to reappear in France about a hundred years later, having been, according to Wilson, secreted away in the intervening years by the Knights Templar.

Wilson claims that his theory is corroborated by a reference from the VIth c. suggesting that the Mandylion was "doubled in four" (i.e., folded in eights), an observation conceivably made by someone opening the hypothetical enveloping frame partway so as to observe the folding configuration of the Mandylion cloth but not the rest of the image.[1] Applied to the Shroud, folding in eights can position the facial image correctly for viewing in accord with some paintings from the Mandylion tradition.

It should be noted, however, that not all historians agree with Wilson's theory. Cameron,[2] for example, discounts Wilson's attempts to connect it with the existing Shroud of Turin. In addition, alternative historical scenarios have been proposed.[3] Other scholars, however, such as Bulst[4,5] and Green[6] do not discount the possible validity of the Shroud/Mandylion hypothesis; for it is conceivable that, while the Mandylion tradition may have some mythical elements associated with it, a genuine historical object (such as the Shroud) underlies its mythical structure.

What might settle or shed light on the issue are observations made directly from the Shroud which can substantiate or refute a testable consequence of Wilson's hypothesis. In particular, if the Shroud was once folded in eighths for a millennium, as Wilson hypothesizes, then deformations in the cloth at Mandylion foldmark locations would probably be unavoidable. If it could be shown that such foldmarks are likely to survive a second millennium until the present time, then Wilson's theory could be tested by searching for foldmarks consistent with a folding configuration in which the facial image alone would be on top and centered. This configuration would be both distinctive and restrictive since there are many other ways to fold the Shroud down to a smaller, more manageable size and do not allow the facial part of the Shroud image to be on top. Without this set of foldmarks on the Shroud, Wilson's theory would probably have to be discarded (unless it could be shown that such foldmarks would not be survivable); with them, Wilson's theory would be given substantial support.

II. Foldmark Generation and Survivability

To determine the feasibility of examining the Shroud for hypothetical Mandylion foldmarks, let us first consider the issues of foldmark generation and survivability. It is well known[7,8] that if a fiber, such as cellulose, is subjected to a tension force for a period of time, the fiber will elongate by a phenomenon known as "creep". If this tension load is sufficiently small and applied for a short enough time, the fiber will relax back to essentially its initial length. If, however, the load is applied for a sufficiently long time, the fiber will relax back to a significantly longer length than before the tension force was applied. The reason for this phenomenon is the direct consequence of cellulose, the fiber-forming substance of flax (of which the Shroud is made), consisting of long repetitive molecular chains held together by molecular side bonds. As the fiber chains are stressed, the chains are straightened and the side molecular bonds between the chains are deformed, broken, and restored into new configurations. Since this process takes place via laws of chemical kinetics, the fiber elongates over a period of time at a rate dependent upon temperature and moisture content (these factors tend to disrupt the restraining side bonds). When tension is removed from the fiber, the residual unbroken bonds pull the chains back towards their initial lengths rupturing some of the newly formed bonds. The final length of the chain depends upon how many and how stable are the newly formed bonds in relation to the residual, unbroken bonds. In general, this final length is longer than the initial one and permanent because a new molecular order has been created due to the long duration stressing of the fiber chains.

Consider now what happens when a cloth such as the Shroud is folded. The fold introduces stress in the fibers where the fold occurs. Fibers on the outside surface of the fold undergo tension, the ones on the inside undergo compression, and the slow process of fiber creep begins in these fibers. The longer the period of time the cloth is folded, the more permanent is the deformation of the fibers at the fold. Owing to differences in tension, there will be a differential elongation of fibers which will cause the cloth to buckle when it is laid flat, leaving a permanent crease pattern if the folding occurred over a sufficiently long period of time (seconds to months and even years depending on the folding radius of curvature, temperature, and moisture content).

Based on these considerations, it is reasonable to expect that fold-marks from a possible Mandylion phase of the Shroud's history should have been generated on the Shroud due to the millennium time period that, according to Wilson, the Shroud was folded in a frame. Because such foldmarks would represent irreversible deformation of fibers at the molecular level, they should persist indefinitely unless sufficient stress, moisture, or temperature are applied to remove them. For example, Mecklenburg[9,10] indicates that stress and moisture in excess of 85% relative humidity is sufficient to remove, overnight, an otherwise permanent foldmark deformation. In addition, since the creep process is temperature dependent,[7] stress and temperature (as in ironing) can remove foldmark structures as well. The reason why moisture has such an important effect on fiber deformations is that water molecules can successfully compete for attachment to the cellulose chain molecules at the expense of chain to chain restraining side bonds. It is as if the cellulose tries to go into aqueous solution but is unable to completely do so because of the inability of water to saturate crystalline regions of the fiber.[7]

The effects of moisture and temperature were demonstrated by the author using a linen cloth[11] which had apparently been folded continuously in a box for 55 years (as deduced from the presence of a 1929 copyright date printed on the cloth and the original price tag still attached to the top side of the folded linen). When unfolded, the innermost foldmarks had a sharp appearance as if produced by careful ironing while the outermost foldmarks had larger radii of curvature. The sharp foldmarks, although permanent deformations in the cloth, were readily removed by ironing (i.e., stress and temperature) with some moisture addition. They were also removed almost entirely by moisture (soaking) and slight smoothing. With just moisture and no attempt at smoothing, the foldmark remained but its sharpness was considerably reduced. Thus, moisture and stress, as well as temperature, are effective mechanisms for removing foldmarks and these factors must be considered in the issue of foldmark survivability.

Unfortunately, the environmental history of the Shroud and to some extent the physics are not known to the precision necessary to state whether conditions were ever reached that were capable of removing foldmarks. Generally, the Shroud appears to have been well cared for which argues in favor of foldmark survivability. However, in 1532 the Shroud was subjected to elevated temperatures and moisture sufficient to record their effects (as burnmarks and waterstains) on the cloth. It is therefore unclear if this event (or some other of which we may be ignorant) might have been sufficient to remove hypothetical Mandylion foldmark deformations.

However, it may not be necessary to know the precise environmental history of the Shroud in order to address the issue of foldmark survivability. An alternative approach would be to locate foldmarks which are demonstrably centuries old and ideally predate the 1532 fire/water event. As discussed below in Section III, it appears that such a foldmark might be present on the Shroud suggesting that (1) foldmark survivability over near-millennium time scales is probable and (2) the implied survivability suggests that Wilson's Shroud/Mandylion hypothesis can be tested by direct observation of the Shroud's crease structure.

III. Examination of Shroud for Possible Mandylion Foldmarks

A. Discussion

Let us now consider the problem of examining the Shroud for possible Mandylion foldmarks. The obvious and proper way to do this is directly on the Shroud. However, since this is not possible until the Shroud is again made available for scientific examination, we must instead rely on available photographic data from which a preliminary evaluation can be made. The available photographic imagery includes not only well-known standard photographs of the Shroud but also special photographs and radiographs, taken by the Shroud of Turin Research Project (STURP) in 1978, which are sensitive to certain fold-mark characteristics. Let us now examine this data for structures which might relate to hypothetical Mandylion foldlines. Figure 1 diagrams approximately where Mandylion foldmarks should be located on the Shroud according to Wilson's theory. These foldmark locations, indicated by arrows, are labeled consecutively from A to G. Figures 2 and 3 show respectively Miller's 1978 reflectance and raking light (grazing angle illumination) photographs of the Shroud, both to scale with Figure 1. Figure 4 shows Pia's 1898 Shroud photograph, also to the same scale. By comparing the photographs of Figures 2, 3,

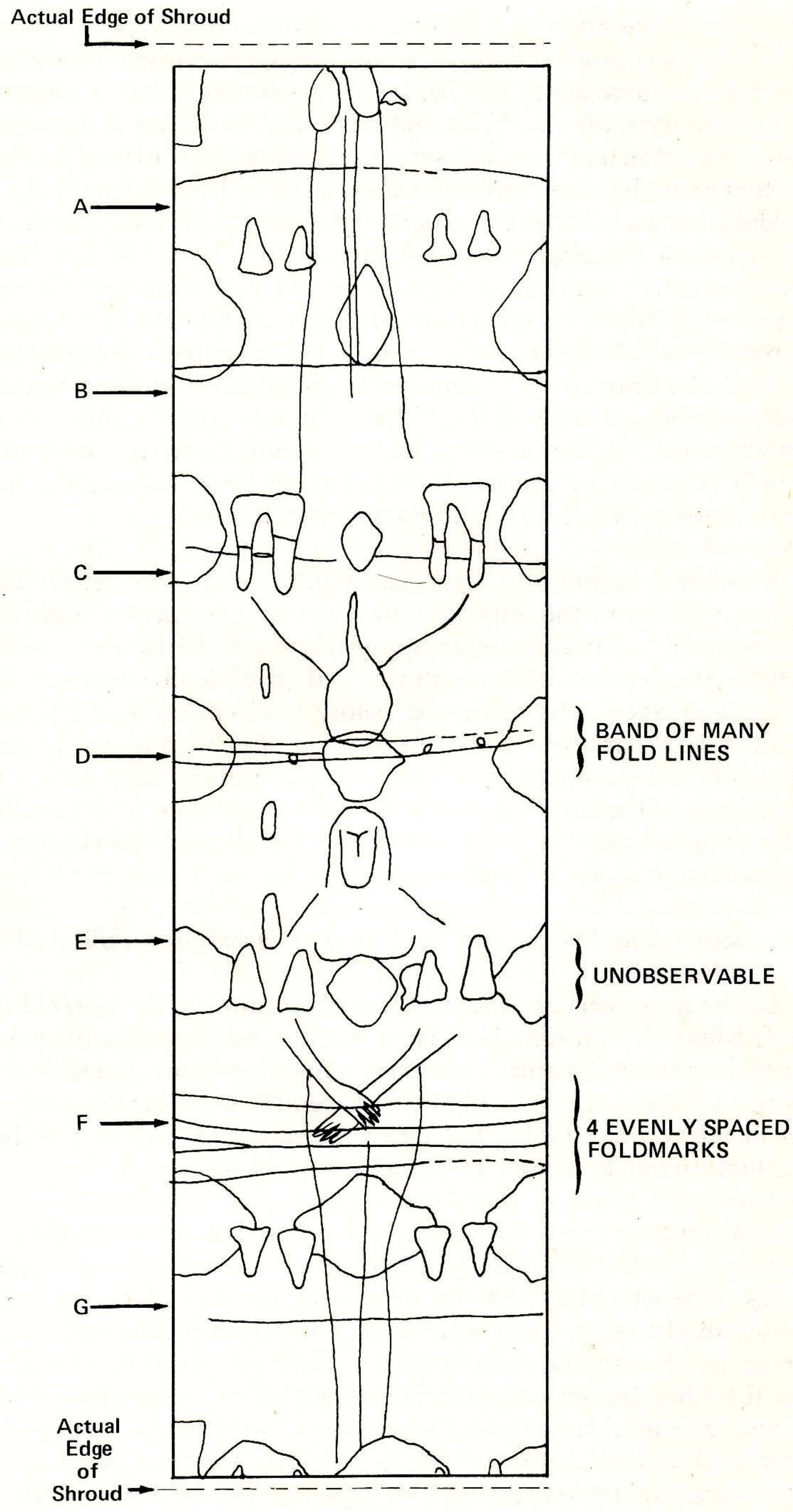


Fig. 1: Expected Mandylion foldmark locations (arrows) with corresponding foldmarks sketched from photographic data.

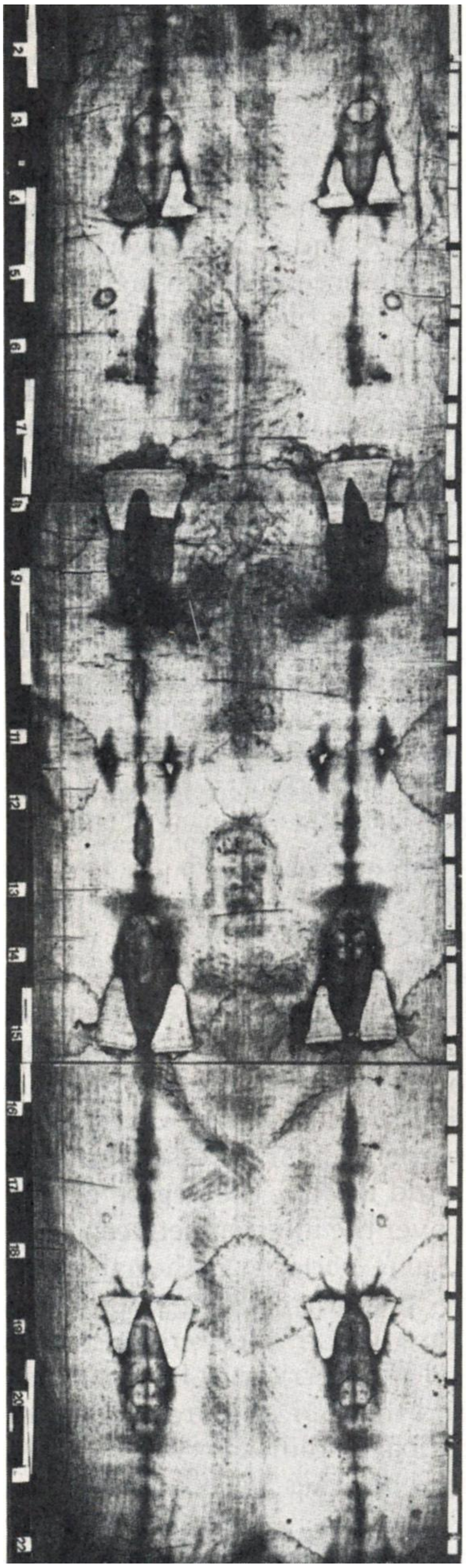
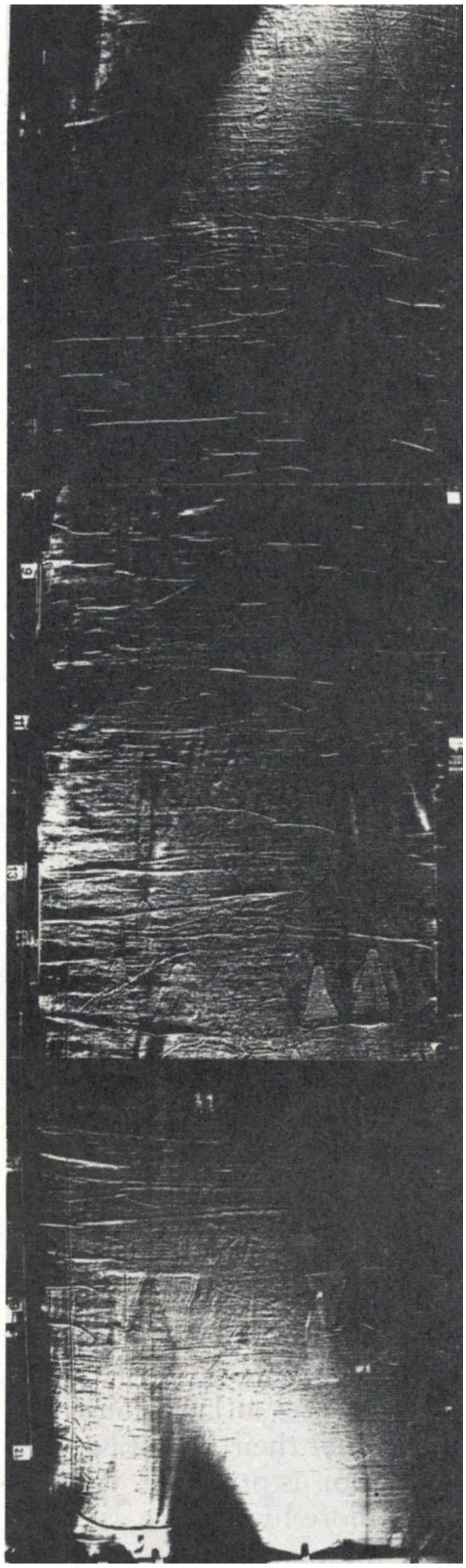



Fig. 2: (Left) Reflectance photograph of Shroud (Vern Miller, 1978).
Fig. 3: (Right) Impromptu raking light (grading angle illumination) photograph of Shroud (Vern Miller, 1978).

and 4 with the diagram of Figure 1, it appears as though foldmark-like deformations can be associated with most of the locations A-G (with some offset) and are sketched in Figure 1 for cross-reference. In particular, a continuous crease structure across the width of the Shroud at Location-C can be seen in Figures 2, 3, and 4. Probable foldmark structures at Locations-B, D, and F can be seen mainly in Figures 3 and 4, while tentative foldmarks at Locations-A and G and several more probable ones at Location-F seem to be present mainly in Figure 3. A recognizable foldmark at Location-E is not visible in any of the three figures. Figures 5, 6, and 7 show successive enlarged views of the corresponding reflectance and raking light imagery of Figures 2 and 3 with arrows indicating the proposed foldmark features (Note: Photographic reproduction has reduced the visibility of some features).

It is possible that in these identifications, a degree of subjectivity is involved especially since a multitude of other creasemarks are apparent over the entire surface of the Shroud in the raking light imagery of Figures 3, 5, 6 and 7. Some of the creasemarks may be due to the rolled configuration in which the Shroud is presently stored, as discussed below. Other creasemarks, however, might be due to asymmetric expansions or contractions of the border and patch fabrics to which the Shroud is affixed." And finally, still other creasemarks may be due to historical folding configurations. The problem is to discriminate which creases are historical foldlines and which are due to other causes. In general, such a discrimination should be possible by recognizing that foldlines, unlike randomly distributed creases due to rolling, stretching, shrinkage, etc., can be expected to occur at some periodic interval (i.e., halves, fourths, eighths, twelfths, etc.) parallel to the two axes of symmetry of the rectangular Shroud. In addition, foldmarks should propagate continuously across the entire width or length of the Shroud, possibly changing concavity (i.e., direction of fold inward or outward), at each perpendicular intersection with another foldline of the same pattern. And finally, the degree of concavity should be more or less constant over the interval between intersecting foldlines (if they exist) of the same pattern. Although direct examination of the Shroud is necessary to confirm all the preliminary identifications proposed herein, the crease-like structures referenced in Figure 1 appear to satisfy the above foldmark criteria. In particular, the structures at Locations-B, C, D, and the four at F are sufficiently visible that their identification as historical foldlines is considered by the author as probable, while the less visible ones at Locations-A and G are more hypothetical.

Of these possible foldmark structures, the most apparent and significant is the one occurring at Location-C which is visible in all three photographs of Figures 2, 3, 4, and 6 (A and B). This probable fold-mark extends across the entire width of the Shroud and is located approximately one-eighth of the way from the Shroud's central axis of symmetry, Location-D. The presence of a foldmark in this location is

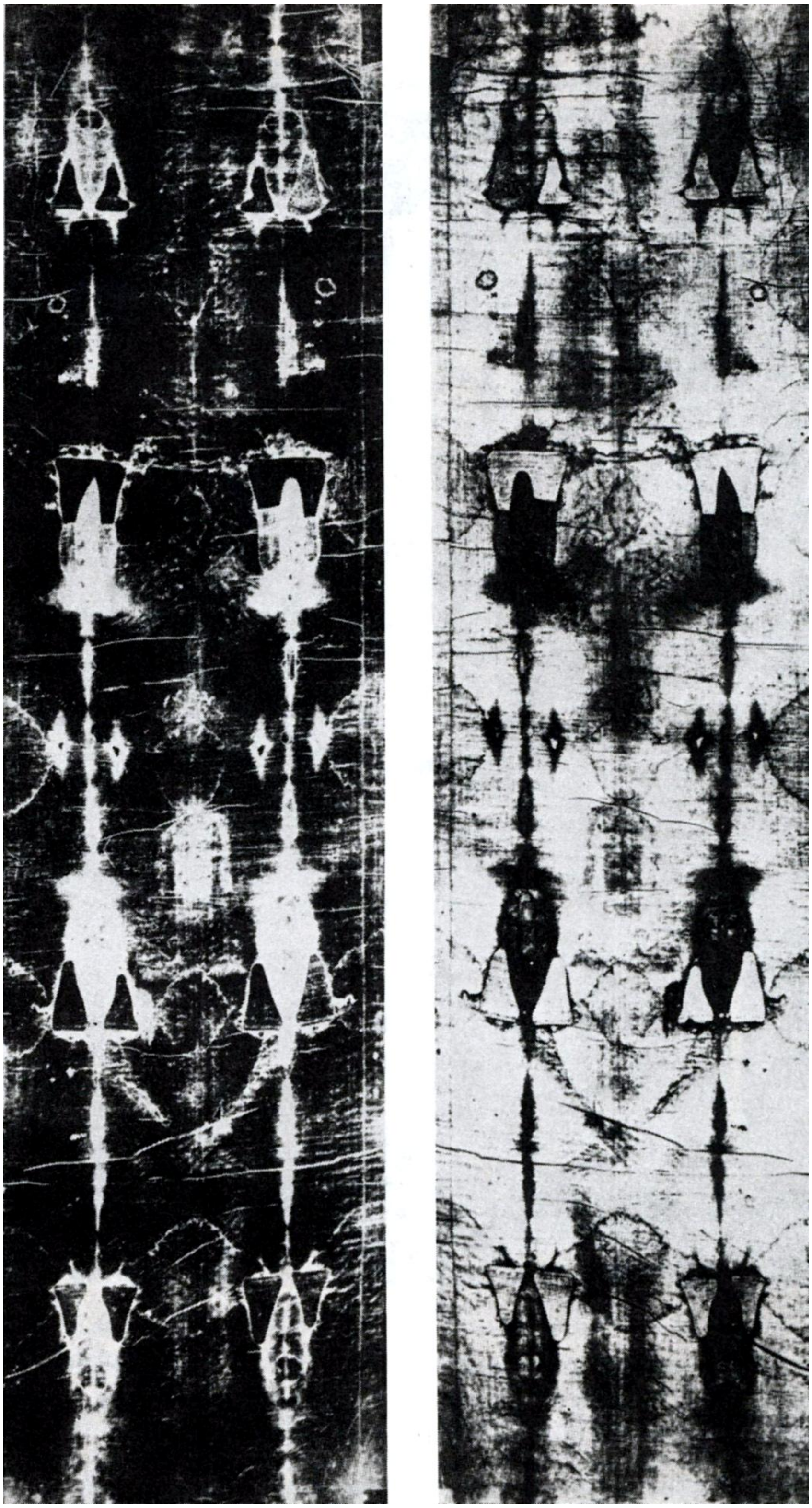


Fig. 4: Reflectance photograph of Shroud (Secondo Pia, 1898).

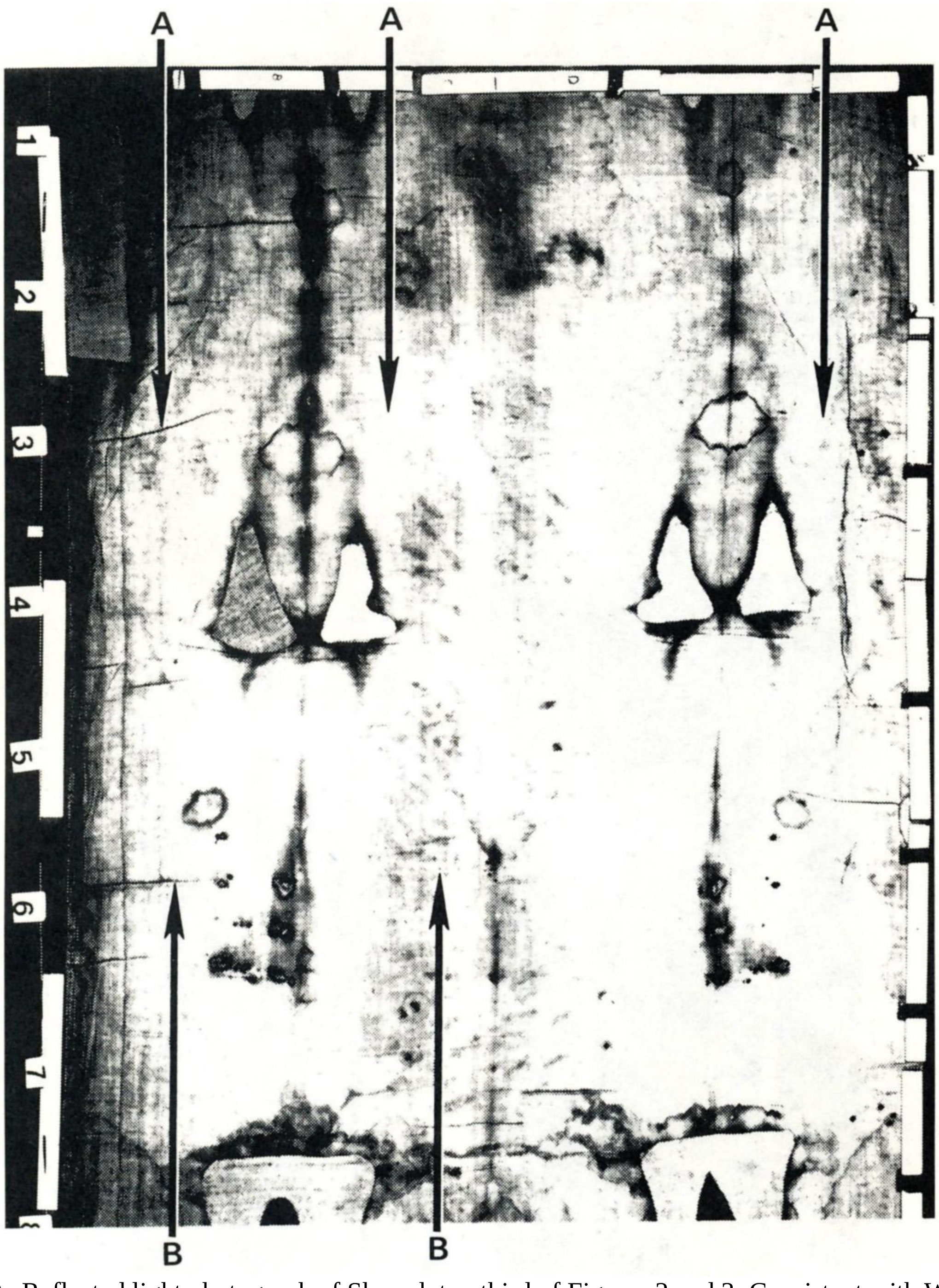


Fig. 5-A: Reflected light photograph of Shroud, top third of Figures 2 and 3. Consistent with Wilson's hypothesis that the Shroud was once folded in eighths at some time in its history as the Mandylion.

Under the assumption that the crease structures identified in Figure 1 are foldlines, let us now consider these structures in more detail—first from a historical and then from a physical point of view.

B. Historical Considerations

The Location-C foldmark appears to be a permanent deformation in the cloth because it is clearly visible in both the 1898 and 1978 photographs;

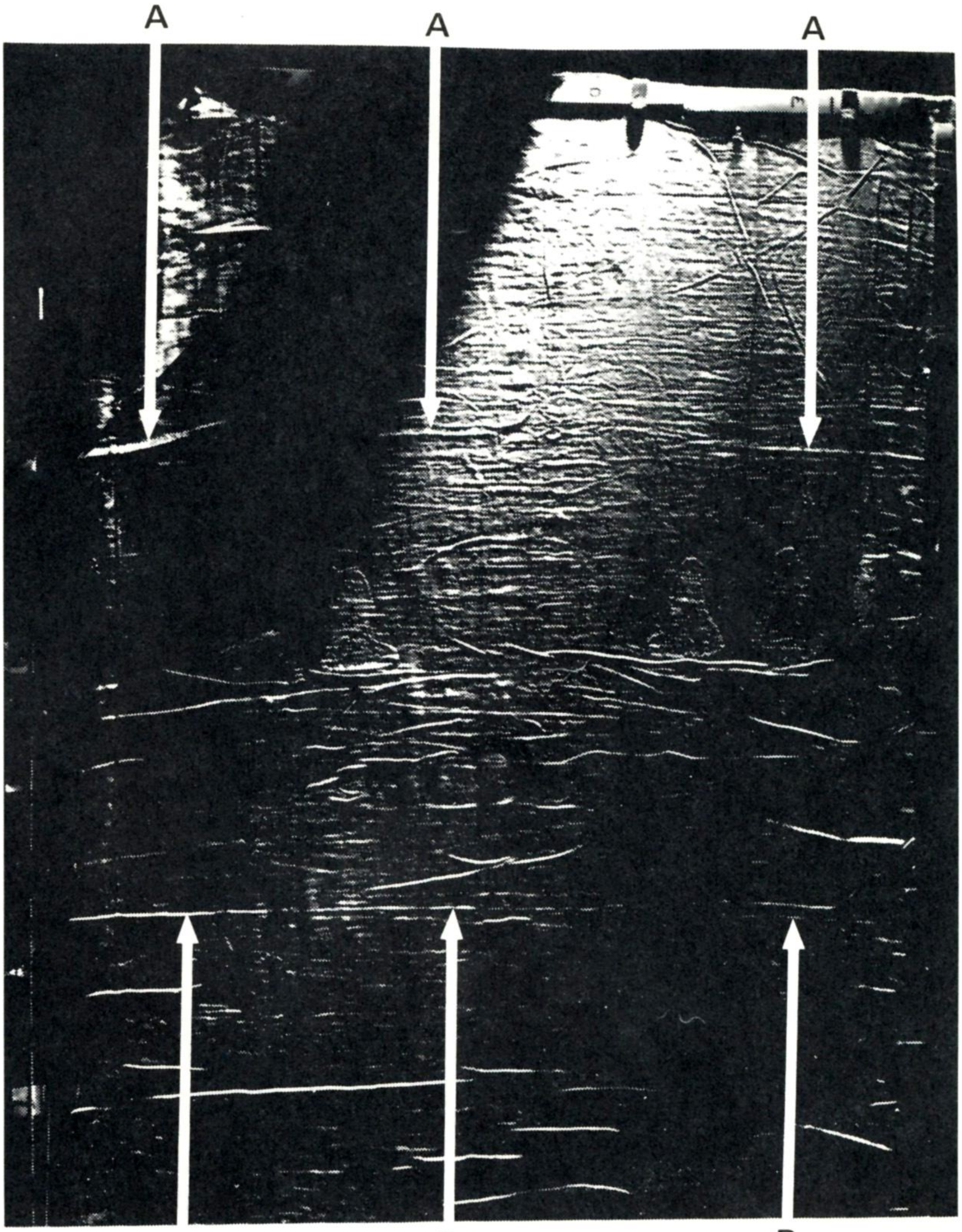


Fig. 5-B: Raking light photograph of Shroud, top third of Figures 2 and 3. (Vern Miller, 1978).

see Figures 2 and 4. It is unlikely that this foldmark represents a style of folding for storage during the past three centuries because the Shroud has been maintained in a rolled configuration since June, 1694 when the Royal Chapel was inaugurated and at least part of the time since 1534 after the fire.[12] It is, however, conceivable that this foldmark may be an accident of the rolling process; this possibility is considered below in Section III-C where it is noted that this foldmark has certain characteristics which appear to be inconsistent with the

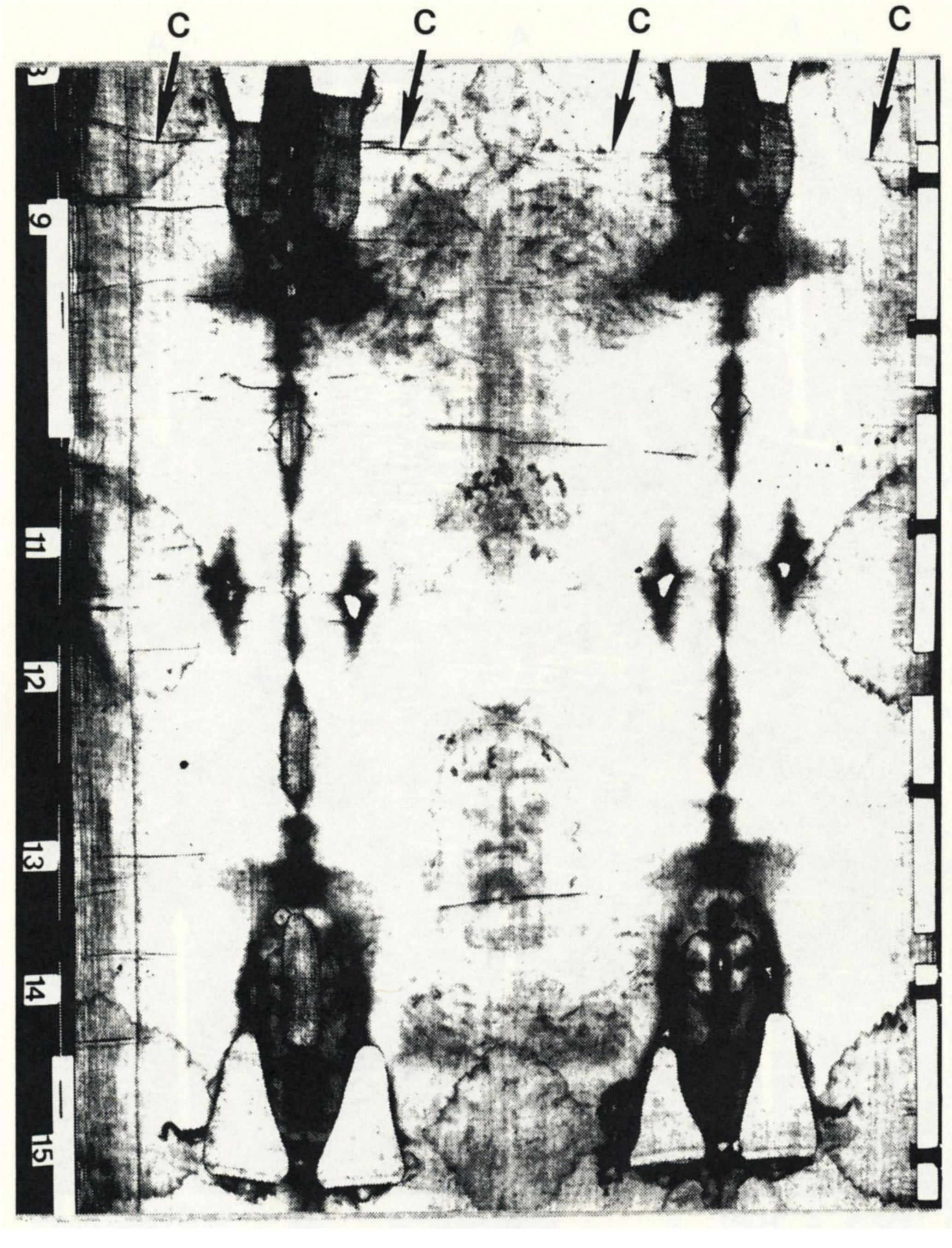


Fig. 6-A: Reflected light photograph of Shroud, middle third of Figures 2 and 3.

rolling process. Prior to 1532, the Shroud was not folded in eighths but in forty-eighths as deduced by the author's reconstructions based on the 1532 fire damage pattern (as seen in the 1978 transmission imagery which shows size of burn holes) and size of storage containers from that period.[13] Figure 8 shows where expected foldmarks would occur for the 1532 folding style with the numbers giving the location of layers of the folded stack in descending elevation beginning at number one (top) and ending at number forty-eight (bottom). It is noteworthy that the Location-C foldmark appears to be at a position inconsistent with the 1532 style of folding, which was probably used at

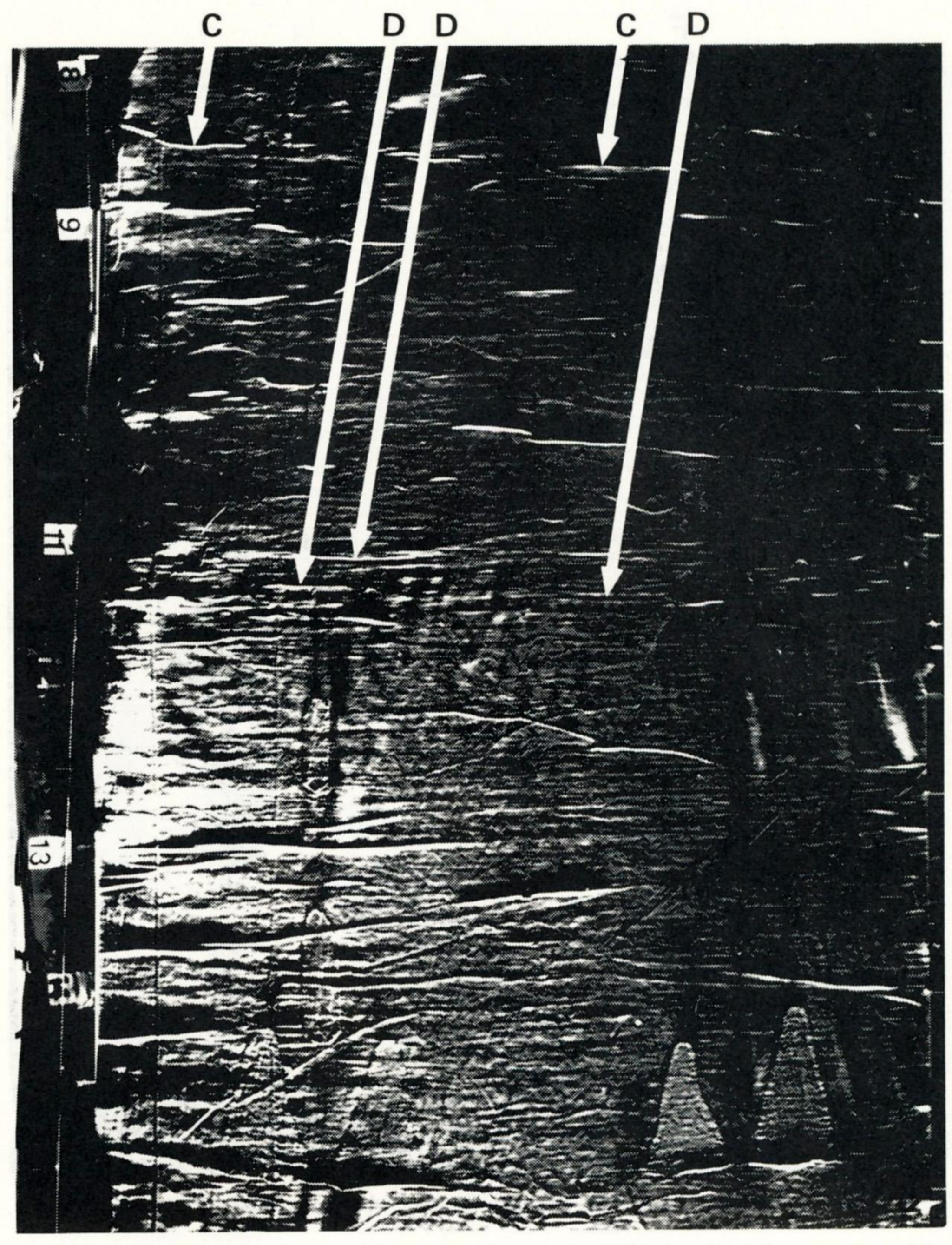


Fig. 6-B: Raking light photograph of Shroud, middle third of Figures 2 and 3. (Vern Miller, 1978).

least from 1502 to 1532 while the Shroud was at Chambery,[1] and perhaps as early as 1483.[13] It is noteworthy that although other fold-marks at Locations-B, D, and F do occur at the widthwise foldline positions of 1532, they do not appear to manifest (as discussed in the above foldmark criteria) expected disruptions due to the three intersecting longitudinal foldmarks of the 1532 pattern. In addition, the four foldmarks at Location-F are unexplained by the 1532 folding configuration. We do not know the exact storage configurations of the Shroud from the 1532 fire until 1694, when the Shroud, rolled in its

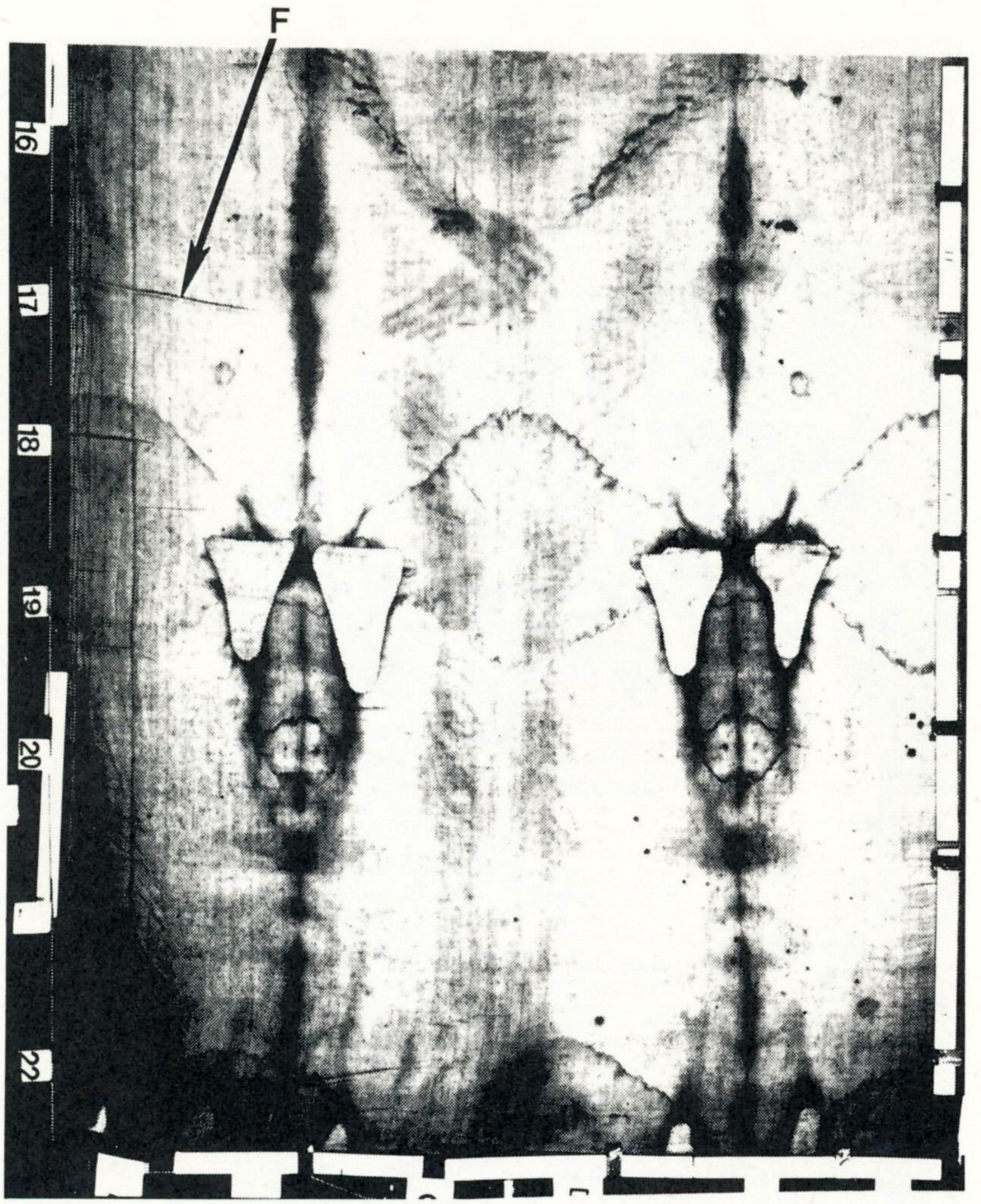


Fig. 7-A: Reflected light photograph of Shroud, bottom third of Figures 2 and 3.

present reliquary, was collocated in the altar of the Holy Shroud Chapel in Turin. However, if we assume that the Shroud was either rolled or folded in a chest similar to the one currently in the Museum of the Centro Internazionale (which implies a folding configuration similar to that of 1532), it would appear that these assumed storage configurations of the Shroud from 1502 (and possibly 1483) to the present are inconsistent with foldmarks at Locations B, C, D, and F.

C. Physical Considerations

The above discussion considers the foldmark at Location-C and others in the context of the Shroud's known history and argues in favor of these foldmarks having an age exceeding at least nearly one-

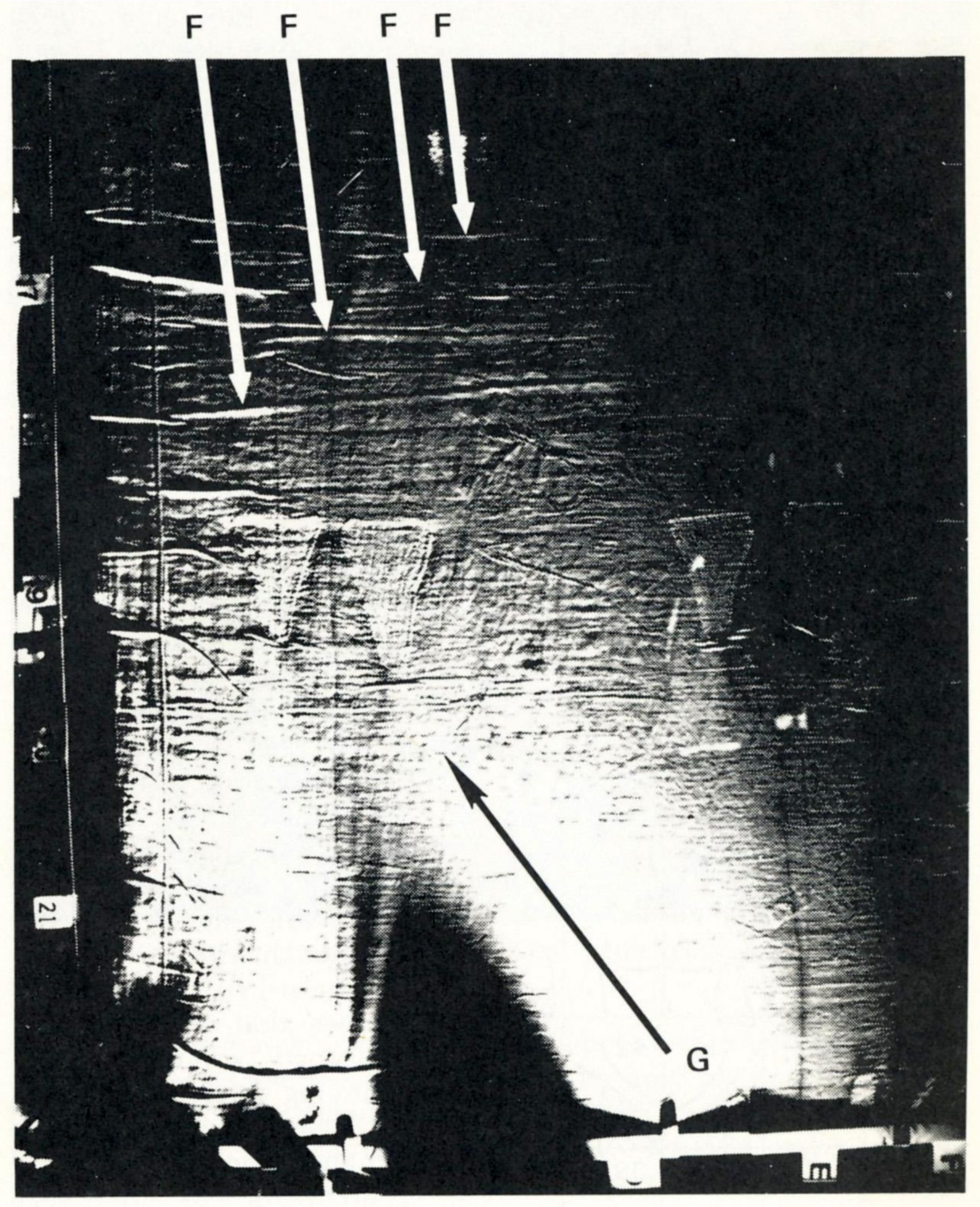
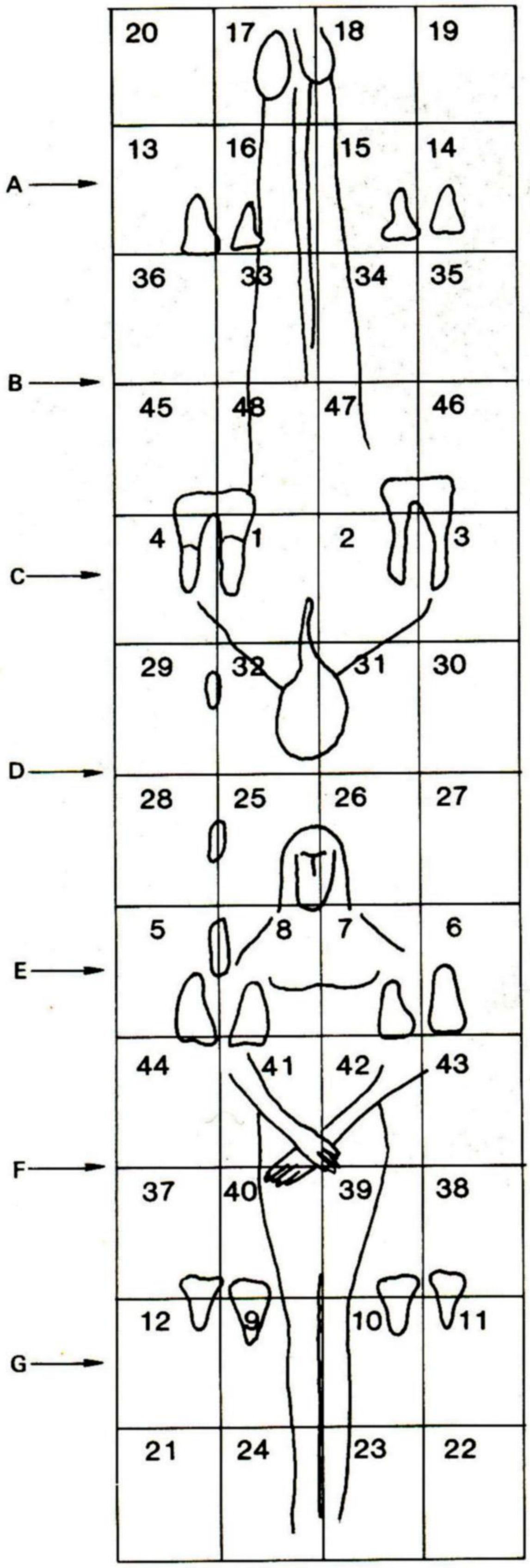


Fig. 7-B: Raking light photograph of Shroud, bottom third of Figures 2 and 3. (Vern Miller, 1978).

half of a millennium (i.e. pre-1532). It also appears possible to arrive at a similar conclusion (and hence demonstrate foldmark survivability) from detailed observations on the Shroud itself. Figures 2, 3, 4 and 6 (A and B) show that the Location-C foldmark intersects the patchwork (i.e., patches and backing cloth) sewn onto the Shroud as a reinforcement to the 1532 fire damage. The light colored patches and backing cloth attached to the Shroud are known to date from 1534 while the darker cloth patches, which the Location-C foldmark intersects, are thought to date from later periods.[14] Figure 9 shows the intersection with the dark patchwork in more detail and it is noteworthy that in this photograph the patches do not appear to contain the foldmark. On



other photographs, however, some degree of patch deformation is visible but this appears to be more of a buckling effect at the edges of some patches, probably due to the flexible patches being firmly attached at a location where the Shroud is creased. Although this observation needs to be confirmed directly from the Shroud, the absence of a clear, continuous foldmark across all four dark patches in available imagery suggests that the Location-C foldmark predates the repair patch (probably several centuries old) through which it propagates.

Another, probably better, indication of the age of the Location-C foldmark can be seen in Figure 10 which shows an x-ray of the foldmark intersection with the patchwork as taken by Mottern in 1978. Figure 10 shows that the foldmark, sketched in the accompanying reference diagram of Figure 11, propagates up to and underneath the dark patchwork to the very edges of the, burned Shroud fabric on both sides of the hole. Figure 12 shows a photographically brightened view in which the weave structure of the patchwork within the burned hole in the Shroud is visible. It is significant that there does not appear to be any obvious disruption of the nearly rectangular, Cartesian weave

Fig. 8: Approximate foldmark locations for 1532 folding configuration. Numbers give folding order from top (#1) to bottom (#48).

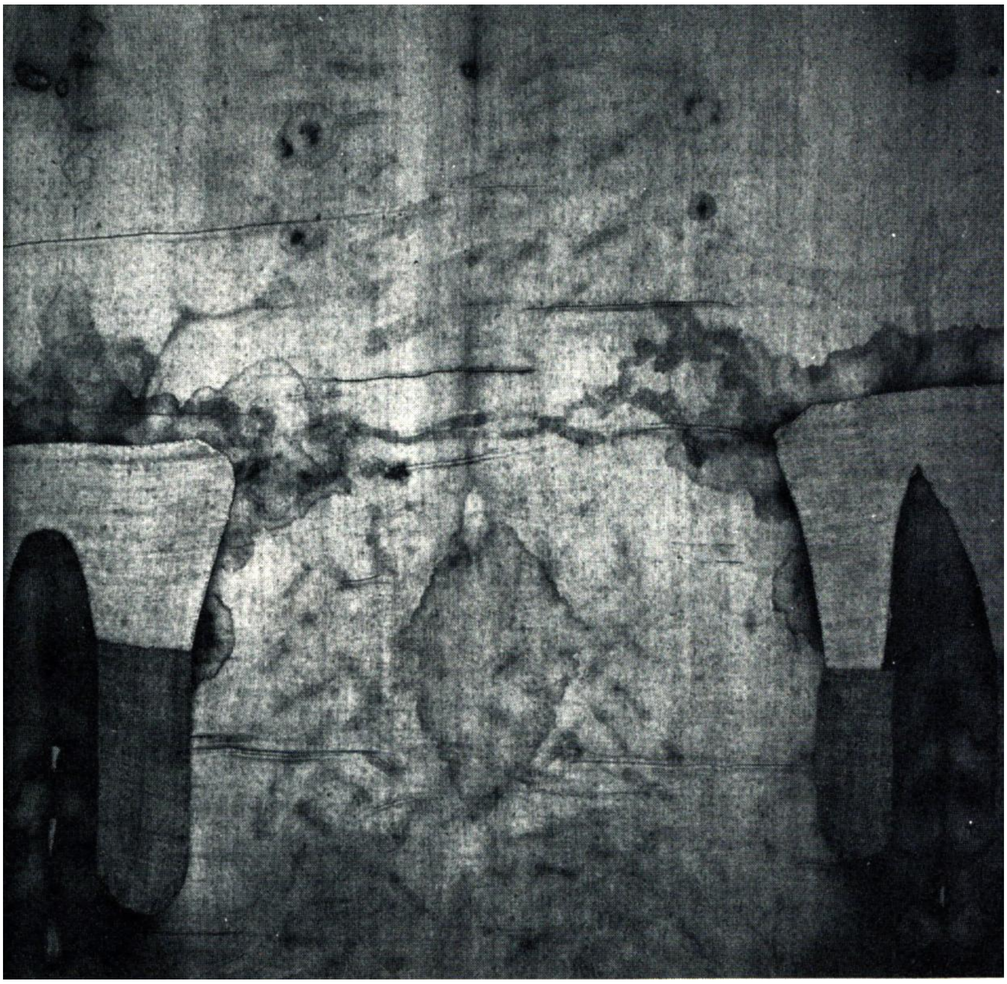


Fig. 9: Intersection of Location-C foldmark with patchwork (Vern Miller, 1978).

structure of the patch material. It should be noted, however, that it is unclear whether the weave pattern in the hole region of the x-ray image is due to the backing cloth sewn on the Shroud in 1534, or the dark cloth patch which presumably postdates the 1534 repair, or both; the Shroud is sandwiched between these two cloths and the x-rays necessarily passed through both patching materials when the exposures were made. However, in the three small holes to the right of the large patch only the backing cloth is present. Since this cloth does not appear radiographically in the small holes, it is likely that the weave structure in the large hole region is primarily due to the dark patch. In any case, the absence of an obvious geometric perturbation of the patch cloth weave structure appears to be a further indication that the Location-C foldmark predates at least the youngest patch material and therefore must probably be at least several centuries old.

The radiograph of Figure 10 also shows that the Location-C fold-mark extends unperturbed to the very edge of the burned-away Shroud on both sides of the hole; see also the diagram of Figure 11. It is probable that the Shroud material is charred in this region which

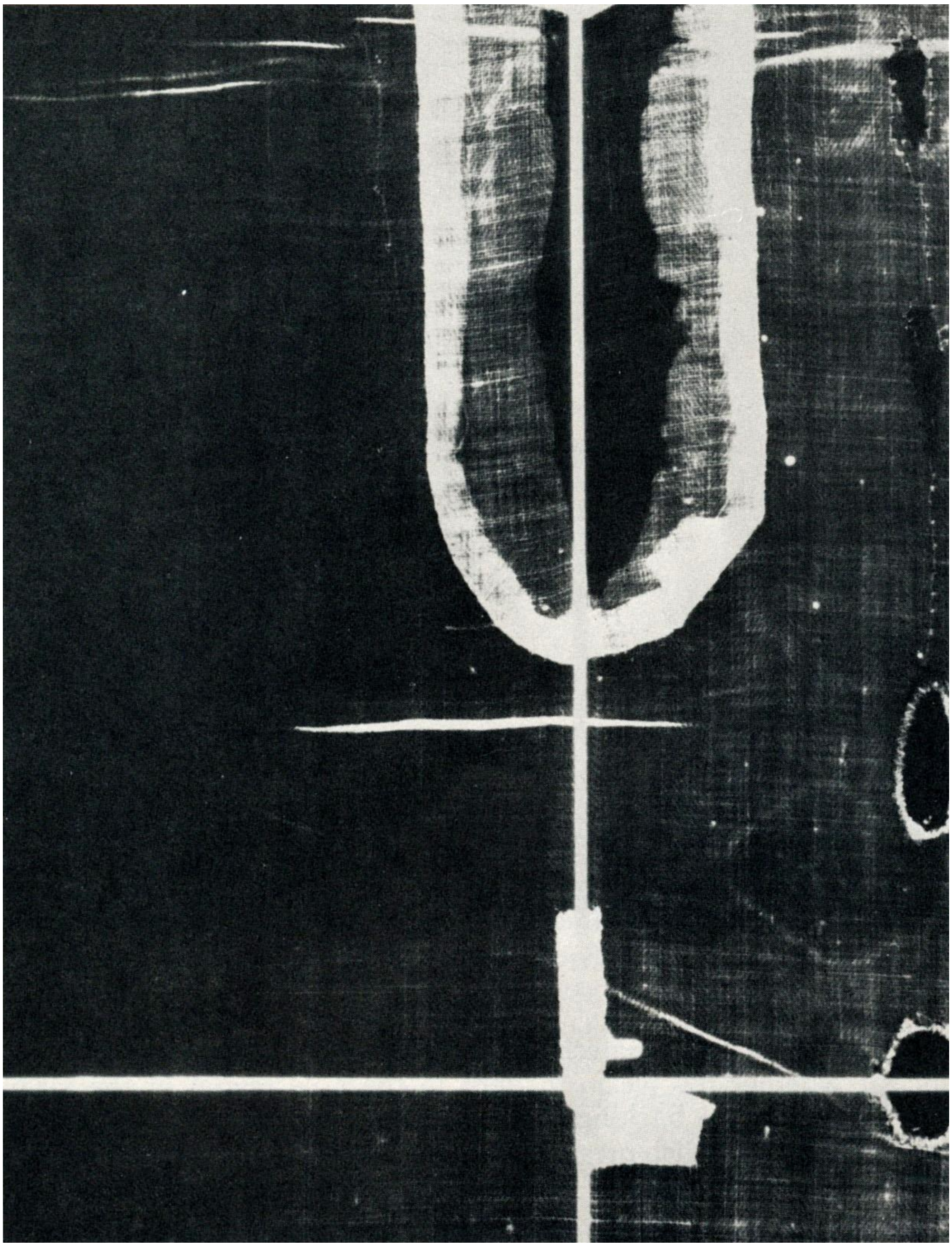


Fig. 10: X-Radiograph of Location-C foldmark intersection with patchwork (Bill Mottern, 1978).

implies a significantly reduced capability to produce foldmark deformation via fiber creep without fiber fracture (i.e., charred cloth is brittle). In experiments performed by the author with linen scorched dark brown to black, the linen was observed to rupture and separate under a normal folding stress owing to its significant degradation. Thus, assuming that the Shroud cloth in the vicinity of the large hole is deeply charred (note the discoloration of the cloth just outside the patch), it seems difficult to account for an intact foldmark in the

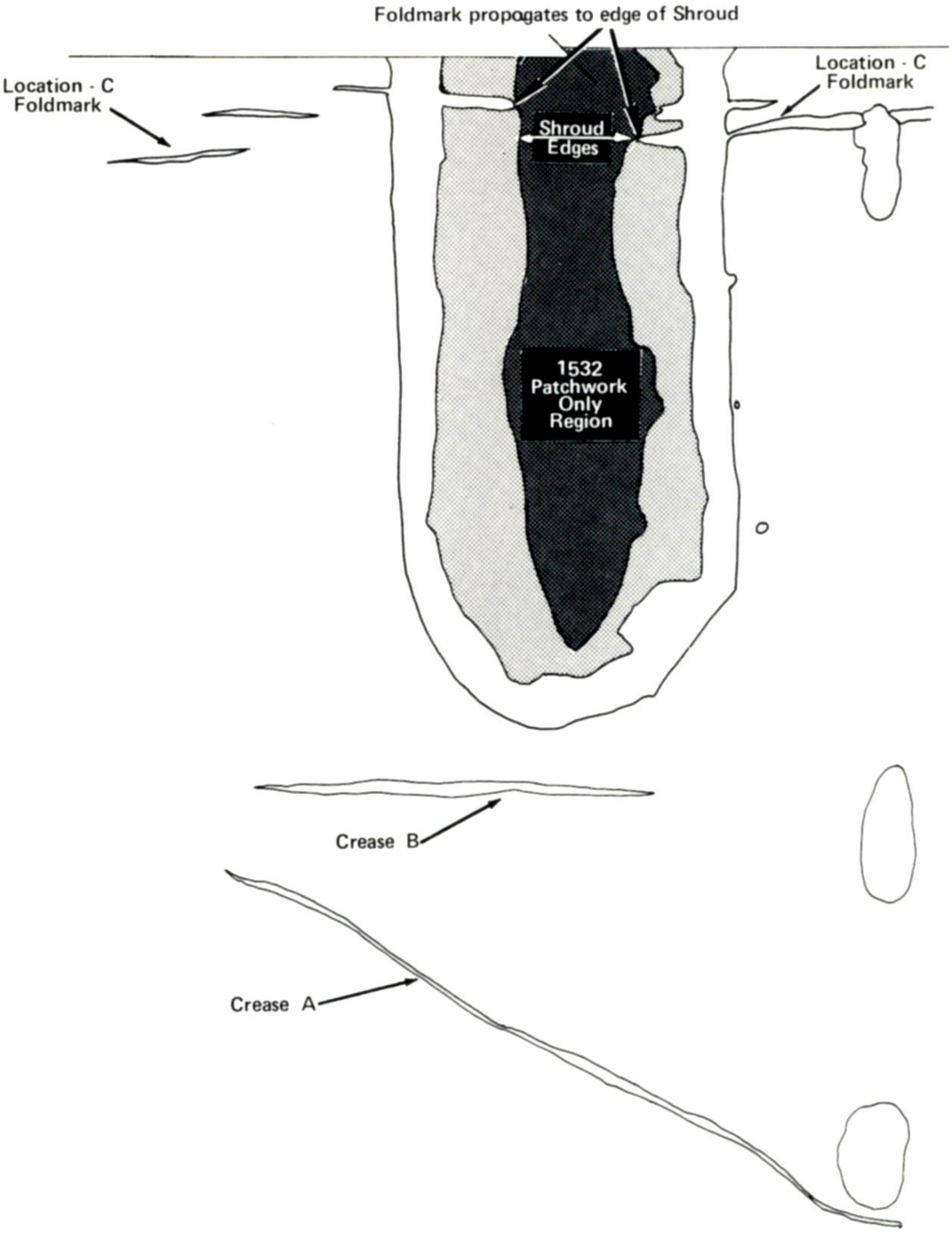


Fig. 11: Diagram illustrating details of Location-C foldmark intersection with patchwork as observed in X-radiograph.

burned region under the patch by positing that it was deformed into the degraded cloth after the fire. Further, in the reflected imagery of Figures 2 and 9, the Location-C foldmark can be seen propagating through browned cloth regions. It is questionable if the cloth in this region has enough integrity to sustain a subsequent folding stress with the relatively sharp curvatures as seen. In fact, the foldmark propagates just above and intersects one small hole; see Figure 10. In this region the cloth is probably weak as evidenced by the presence of the burned hole and the apparent requirement for someone to have

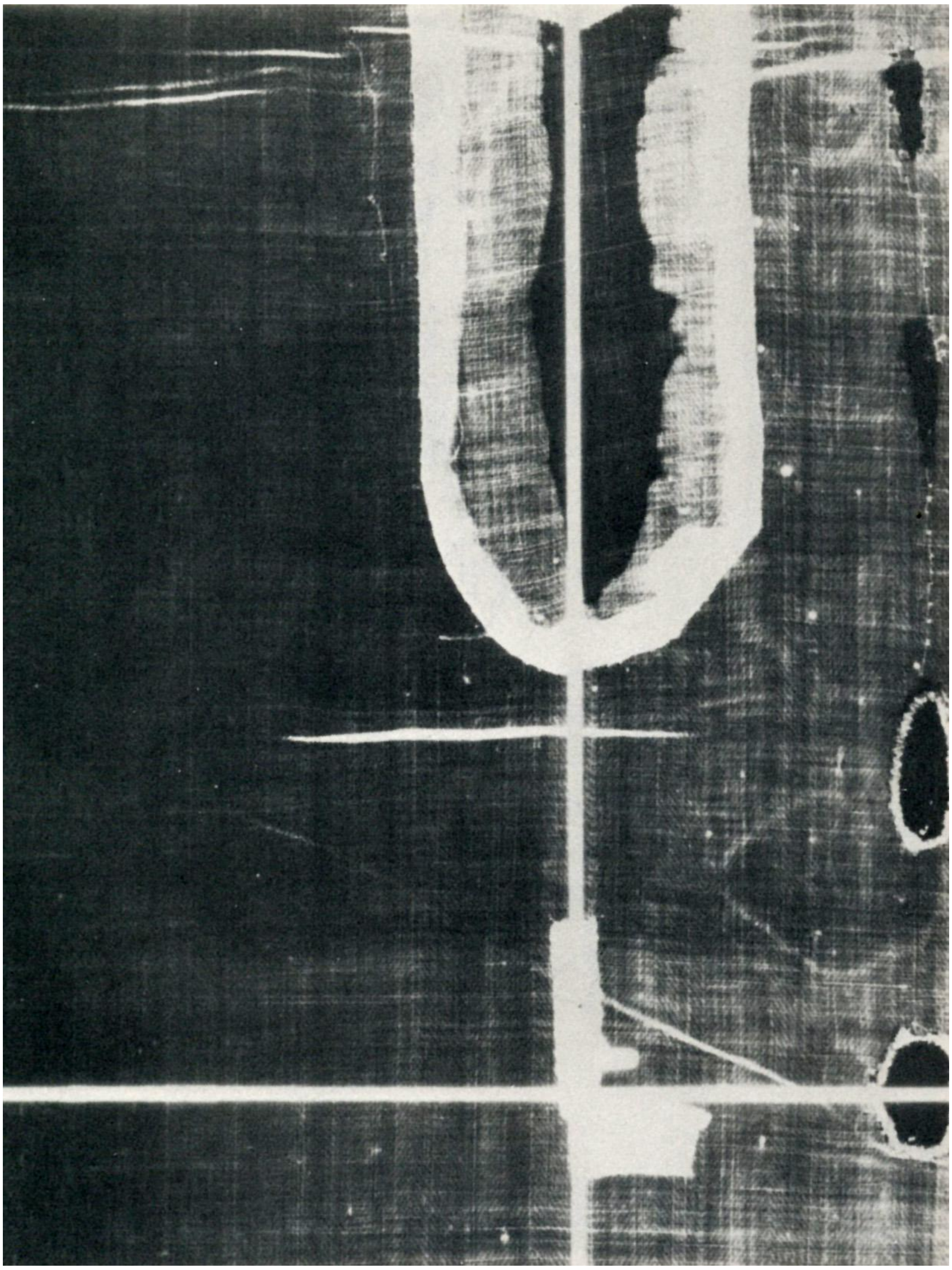


Fig. 12: Enhanced view of X-radiograph showing intersection of Location-C foldmark with patchwork (Bill Mottern, 1978).

stitched around the hole for reasons of added strength (see Figure 10); thus, the presence of a foldmark in this region might be further evidence that the Location-C foldmark predates the 1532 fire.

In addition to the presence of the Location-C foldmark in a charred region of the Shroud, it is noteworthy how the foldmark seems to propagate unhesitatingly up to both edges of the large and small holes visible in the radiograph. If the foldmark was produced after the 1532 fire, it would seem reasonable to expect that the presence of the hole boundary should have exerted some mechanical influence on the fold-mark structure (as it was being formed) near the edge; however, no obvious perturbation is seen. A simple explanation is that the fold-mark was set in place before the fire, and the fire burned away part of the cloth containing the foldmark.

The appearance of the Location-C foldmark beneath the patch also argues against the foldmark being generated by the rolling process used for storage. Since the large hole is completely surrounded by stitching which attaches the patch to the backing cloth through the Shroud (see Figure 10), it is likely that the stitchings and patchwork would bear and transfer the stress to other exterior regions of the cloth, thereby protecting the Shroud sandwiched within the interior regions of the patch from being creased by rolling. This was demonstrated by an experiment involving the rolling of two Shroud-size linen cloths together. One cloth served as the backing cloth and the other the Shroud. The patches were simulated by pins holding the two cloths together. As the cloths were rolled, the inner one unavoidably bulged upward and often had to be hand-tucked into the coiled cloths as they were rolled, forming a significant crease deformation. However, when a patch was encountered, the bulge was forcibly and automatically pushed into the oncoming roll. This did two things; first it created a sharp crease at the base of the patch, as when the bulge was hand tucked or naturally swallowed by the rolling action. Second, with the bulge and associated stresses temporarily relieved, there did not seem to be any tendency for a crease to be formed over the patch; the pins appeared to take up the stress and protect the interior regions of the patch from creasing. It then took some rolling distance to reform the bulge, but only after the patch had been rolled into the cloth. This simple experiment seemed to explain some of the crease structures visible on the Shroud, like the one at the bottom of the chin, and how patch regions tend to reject stress associated with rolling. For example, a careful examination of the Shroud shows the presence of sharp creases at the bases or tips of most patches, always widthwise (i.e., perpendicular to the traditional rolling direction) and never lengthwise; see Figures 2, 5-A, 6-A, and 7-A or any good reflectance photograph of the Shroud. In particular, two notable examples can be seen in the radiograph of Figure 10, labeled A and B. These and other similar ones are probably due to rolling with the Shroud on the inside (it has also been rolled on the outside) and the bulge being forced into the roll by the patchwork as discussed above. This effect is especially apparent on crease A which appears to be "hung up", as it were, on the edge of the reinforced small hole. Thus, it is unlikely that the Location-C foldmark, which is protected by a patched region (as evidenced by the existence of Crease B), was formed by the rolling process and must therefore predate the period when that technique was used (i.e., 1534 to present).

One further aspect of the Location-C foldmark should be pointed out. Not only does this foldmark traverse fire damage regions, but it also intersects a waterstain region, also dating to the 1532 fire. In Figure 9, the foldmark can be seen to smooth out in this region. It is possible that this might be due to other causes, but, as discussed in Section II, water with only modest stress is quite effective in removing permanent crease structures. If this is what has happened, then it would again follow that the Location-C foldmark predates the 1532 fire/water event. However, it should be noted that the Location-C foldmark appears to persist at the edge regions of the Shroud where it also intersects waterstains; see Figure 1. It is unclear if the foldmark suffered any significant degradation there; hence direct examination of the Shroud is needed to determine, if possible, waterstain/foldmark ordering.

Let us now consider other foldmark deformations visible in the photographic imagery. The foldmarks at Location-F as shown in Figures 3, 4, and 7-B propagate continuously across the width of the Shroud and, like the foldmark at Location-C, appear to be permanent deformations in the cloth since at least one of them appears in the 1898 photograph of Figure 4. However, their appearance as four equally spaced foldmarks is unexpected and needs explanation. In the context of the Mandylion/Shroud theory, they could represent a method for supporting the cloth in a frame; however, without additional data, in particular the concavity structure of various foldmarks in terms of radius of curvature and folding direction (inward or outward), attempts to reconstruct the folding pattern are at this time impossible and conjectural. It is noteworthy that no disruption of the Location-F foldmarks is apparent at the mid-point which should be expected if the Shroud had been first folded lengthwise (such a folding configuration would be inconsistent with the Mandylion/Shroud hypothesis which requires the face image to be visible and centered). Unfortunately, except for one corner (see Figure 1), none of these foldmarks intersect the relatively intense waterstain regions which lie directly below and so evaluating the effects of the 1532 waterstains on these foldmarks is not possible.

At Location-B, a continuous and recognizable foldmark across the entire width of the Shroud is visible in Figures 3, 4, and 5-B. However, like all possible Mandylion-like foldmarks indicated in Figure 1 (except the one at Location-C), it does not intersect the 1532 fire patchwork and so an age determination does not appear possible except by association with the Location-C foldmark owing to similarity of structure and suggested folding periodicity. As noted above, there appear to be structures in Figure 3, 5-B and 7-B, at Locations A and G which might represent foldmarks; however their presence, while suggested, is not well-founded in the available imagery and accordingly more definitive conclusions for or against their proposed existence must await direct examination of the Shroud. Finally, the absence of an obvious foldmark at Location-E should be noted. This may represent a potential problem for the Mandylion/Shroud hypothesis or may simply not be visible in available photographs; hence a foldmark in this location needs to be checked directly on the Shroud. However, the absence of such a foldmark may not necessarily be contrary to the Mandylion/Shroud hypothesis if, when the concavity structure of other foldmarks can be determined, a folding configuration is implied for which the radius of curvature at Location-E is sufficiently large that a significant deformation is unlikely to have been formed.

IV. Conclusions and Recommendations

The above discussion indicates that on the Shroud are foldmark deformations which, in a preliminary sense, occur at locations roughly consistent with Wilson's Mandylion/Shroud hypothesis. Especially noteworthy is the foldmark that occurs at Location-C. This foldmark by itself suggests that the Shroud was once folded at least in eighths since it is located one-eighth of the Shroud's fourteen foot length from the center axis of symmetry, at Location-D. In addition, this foldmark intersects the patchwork and waterstain regions of the 1532 fire in such a way that it appears to predate the patchwork and probably the fire. As such, this structure appears to be a genuine centuries-old fold-mark and therefore a plausible candidate for a Mandylion foldline. Other foldmarks occurring at expected Mandylion locations are probably associated with the Location-C foldmark owing to (1) their similar continuous appearance across the entire width of the Shroud and (2) their roughly eightfold periodic symmetry; but since the concavity structure of the foldmarks cannot be discerned from available photographs, it is not currently possible without additional data to determine the folding configuration implied by the foldmark pattern and hence test the Mandylion/Shroud hypothesis. If the concavity structure were known for all foldmarks, it is probable that an unambiguous folding configuration could be determined.

Based on these considerations, I think that the foldmark observations discussed herein indicate that the Mandylion/Shroud hypothesis merits serious consideration and that a test of this hypothesis, appears feasible. In general, the conclusions reached in this paper based on photographic data should be considered preliminary until such time as direct, physical inspection of the Shroud can be performed. No claim is made of having demonstrated Mandylion foldlines on the Shroud, only that certain features exist on the Shroud which, within the limited data available, seem consistent and perhaps suggestive of such an identification. The purpose of this paper is to introduce the foldmark problem so that a proper examination might be performed in the future.

My recommendations for further study are as follows. New raking light photographs should be taken to extend the imagery represented in Figures 3, 5-B, 6-B, and 7-B which were taken as a hurried, impromptu addition to the 1978 testing protocol. It is possible that a direct study would allow other artifacts such as stitchings or shading anomalies (like perhaps the horizontal band intersecting the dorsal head) associated with the implied folding configuration to be recognized (such stitchings, if they exist, and the patchwork which the Location-C foldmark intersects could be radiocarbon dated giving data relevant to the age of the foldmark pattern). I would further recommend direct inspection (with microscopy) of the Location-C foldmark under the dark patch and to see if corresponding foldmarks exist in the backing cloth sewn onto the Shroud in 1534. Mechanical studies should be performed in the charred region of the Location-C foldmark to see how susceptible the cloth is to foldmark deformation by fiber creep, thereby determining if indeed the foldmark predates the 1532 fire as suggested in this paper. Inspection of the Location-C foldmark with the 1532 waterstain region should also be made to see if the foldmark reduction is directly correlated with this area. It should also be possible to obtain evidence as to whether or not the Shroud image predates the foldmark pattern as required by Wilson's hypothesis. In Figure 9, the Location-C foldmark can be seen to intersect several blood images which, if examined, might indicate the relative sequence of the blood/foldmark appearance on the Shroud. Another recommendation is to examine how various creases and wrinkles are influenced by the body-only image. For example, if the body-only image were composed of some hypothetical paint medium, such as a gelatine base proposed by McCrone,[15] or if the body image is a cellulose degradation[16,17], then it would seem that a dried coloring medium or degraded cloth might mechanically influence the Shroud in such a way that a rough outline of the body image would be visible in the subtle, omnipresent wrinkle structure over the Shroud surface. If detectable, the character of the wrinkle structure variation should allow independent physical testing of the pigment versus cloth degradation hypotheses because one (paint) tends to stiffen while the other (cellulose degradation) tends to weaken the cloth structure. Further, if the Shroud image was produced by a thermal mechanism from a body shape or bas-relief, deformations in the cloth structure might be visible since elevated temperatures have a strong effect on fiber creep as discussed above. Inspection of Figures 3, 5-B, 6-B, and 7-B, however, does not readily reveal such effects; but these might be discernible with better raking light imagery. Finally, foldmarks from other folding patterns (such as 1532) might be detected in a serious foldmark examination, thereby providing further information concerning the history of the Shroud.

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