DISCUSSANT'S CONTRIBUTION

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Examination of the blood marks on the Shroud of Turin reveals that the fabric is a solemn portrait of human suffering. The following observations from the private exposition of the Shroud were made:

- The blood formed discrete globules.
- These globules adhere strongly to the flax fibers.
- They did not migrate with the water that contacted it in the fire of 1532.
- They were not soluble in organic compounds formed by the fire (formaldehyde, furfural, hydroxymethyl furfural, or acetic acid – all cellulose decomposition compounds known to form with thermal degradation).
- They appear to be viscous deposits.
- They penetrate to the back side.
- They are carmine red in color as due to:
  1. Glycosides from soapweed (saponaria, a cleaning agent) that can break down cell membranes (Raes theory), or
  2. Hemolysis from torture and trauma, known to break red blood corpuscles (Adler), or
  3. The formation of bacteria (biofilm) or mold of that color.

The blood marks on the Shroud are consistent with both the history of how the Jews buried their dead, and the biblical descriptions of the crucifixion.

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From Luke 23:44 there is an account of Jesus's death:

- Death was at 3 pm with burial shortly after.
- The Sabbath was imminent at 5 or 6 pm.
- According to the Mishnah, no part of the body may be moved on the Sabbath.
- Crucifixion was a dynamic, ongoing process of blood drippings or gushings.
- With death, blood would clot, exude serum, and dry up.
- Wrapping in a Shroud was not traditional for a Jewish funeral, but was acceptable for a traumatized body.
- Clots could transfer to the cloth if moisture were present from sweat or from washing from up to 1 ½ to 2 hours after death.

A particular concern of those who viewed the Shroud at this exposition was that the image of the Shroud on the linen was barely discernable. The visual perceptivity of the difference between image and off-image areas might be only 10 to 20%. However, the Enrie photographic negative (positive to the eye) can be more readily studied for it shows stronger contrast of the image. It is particularly interesting that the blood marks of the Shroud are positive in the negative image and negative in the positive image. The implication is that the image marks and the blood marks resulted from different formation mechanisms. A digital format of these areas could result in heightened clarity for greater enhancement and improvement by visual inspection.

When digital image analysis was applied to the photographic (positive) images of 1931 and 1978, clearer details were revealed. Digital details of the images were captured by a charged coupled device (CCD) camera that provided displays of pixels over a gray-scale range. Various filtering techniques were employed to "sharpen" or remove parts of the images in order to reveal discrete features. Investigators have worked with the 1931 and 1978 photographs as secondary sources to generate algorithms for enhancing and extracting specific information. Clearer images can now be archived and made available for further processing.

In the digital images of the photographs the textural quality of the Shroud fabric's twill weave is highly pronounced and can interfere with image resolution. In this textile, the twill line advances across the fabric; to the left and to the right in a point twill construction. The twill direction and its interaction with the S-direction by which the yarns were spun, provide a visual contrast because of the relationships of S:S×S, where "S" indicates that *the twill line moves to the left side of the point of the twill and "S×S" indicates that the yarns were spun in the clockwise direction*. This configuration contrasts with the advancement of the twill line after it *travels down the other side of the point of the twill*: Z: S×S. By these subtle interactions of yarn nesting and movement, a textural difference is produced on each side of the twill's point. The contribution that this textural effect makes to the perceived image can be subtracted from the digital image by applying a filtering technique. Alternatively, however, a conservator might prefer to filter out the image for closer inspection of the condition of the fabric.

We have seen the scholarly results of applying image analysis to the image of the Shroud.

We have suggested that the camera be brought on-site for a new session of image acquisitions taken directly from the Shroud, as a primary source. The CCD camera is more suitable than the 35-mm camera, used in the past to archive Shroud images, because of its photometric accuracy and geometric stability. The brightness response of the CCD camera is linear so that absolute intensities, especially at the low and high ends of the gray scale are easily determined. With a new image archive, Shroud researchers could have access to the same files, transmitted electronically in tagged-image-format (file. tif). Electronically transferred files would lead to greater and more efficient cooperative investigations to advance the science of Sindonology.

Most importantly, image analysis can be applied to document the relative rates of aging of the image and off-image areas. Because the extent of discoloration of these areas is different, each area can be represented graphically by a histo-

gram of pixel intensity over a gray-scale range. The discrete set of pixels on either side of the boundary between image and background can be resolved. Data extracted from these component histograms can be applied to algorithms. The algorithms can be used for quantitative measurement of rate and extent of degradation of these areas over time for as long as it is possible to resolve the boundary of image and background. A description of the use of image analysis for similar applications can be found in [1] and [2].

REFERENCES

[1] Cardamone, J.M. Damert, W.C., and Marmer, W.N. Image Analysis for Detecting Color defects in Dyed Wool Fabrics, in Proceedings of the 9th International Wool Textile Research Conference, Biella, Italy, Volume III, 161-173, 1996.

[2] Cardamone, J.M. and Marmer, W.N. Digital Image Analysis: Part I – Detection of Color Uniformity in Dyed Textiles. American Dyestuff Reporter 86 (7): 25-37, 1997.