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Original article

Blood reinforced by pigments in the reddish stains of the Turin Shroud

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ABSTRACT

Samples from the Turin Shroud (TS) furnished by STERA Inc. have been analyzed and compared with both material coming from the TS and sticky tapes taken from a copy of the TS produced in 1656 and conserved at Palma di Montechiaro, Sicily, Italy. The attention has been focalized to the many reddish particles contained in these samples that appear to be of many types, shape and sizes. Some of them seem to correspond to the so called "sub-micron particles" recognized by W. McCrone in the form of red ochre (iron oxide) and vermillion (mercury sulfide); the others, as described by many researchers of the STuRP like A. Adler and J. Heller, seem typical of blood. After a detailed analysis of these particles by using various types of microscopes and by performing different spectral analyses like Raman and EDX, the results obtained are commented, reaching the conclusion that the analyzed reddish material, corresponding to some TS bloodstain area, contain human blood reinforced with pigments. It can therefore be supposed that the bloodstains, originally composed of blood, have been refreshed by some artist perhaps during the XVII century.

1. Introduction

The Turin Shroud (TS) [1–3] is a handmade 3–1 twill linen cloth, 4.4 m long and 1.1 m wide, on which the front and back images of a human body are permanently impressed. According to the Catholic Christian tradition, the TS is the burial cloth in which Jesus Christ was wrapped before being placed in a tomb in Palestine about 2000 years ago. The Catholic Christian Church does not impose any veneration of the TS, even if Science has not refuted what is reported by tradition.

There are some indications [4] that the TS was in Palestine in the first century A.D. and then taken to Edessa (current Sanliurfa in Turkey). The coincidence of the TS face with that of Christ on Byzantine coins starting from the VII century A.D. demonstrates that the TS was seen during the Byzantine empire [3,39]. The "Shroud of Christ" appeared in Europe in 1353 at Lirey in France [4] after the Sack of Constantinople in 1204 and a fire damaged it in 1532, at Chambéry in France.

In 1988 the TS was radiocarbon-dated to 1260–1390 A.D. [5], but the result is questionable [6,7]. As the process that formed the body image is still unknown, the dating method cannot be rigorously applied because the environment in which the object under analysis was conserved must be known from a contamination point of view. The imaging mechanism may in fact have varied the percentage of carbon isotopes of the TS, thus producing a non-negligible systematic effect. Moreover, the 1988 sample resulted not representative of the whole TS, because its chemical characteristics differ from the main part [8]. Many hypotheses have been formulated [9] to explain the double body image that up to now has been impossible to reproduce.

2. Research aim

Regarding the numerous red stains present on the TS, in 1969 Cardinal Pellegrino appointed a commission to investigate if these stains were of blood. In 1973, after the analysis of threads taken from the red stains, the discordant conclusion was: "The negative response of the investigation does not allow an absolute judgment of exclusion of blood nature of the material" [10].

This ambiguous answer pushed various researchers to better examine the TS reddish stains. In 1978, P.L. Baima Bollone [11,12] analyzed some TS threads while W. McCrone [13–19] and J. Heller and A. Adler [20–22] made their tests only using the reddish microscopic particles collected by means of sticky tapes put in contact with the TS during the campaign of the Shroud of Turin Research Project (STuRP) [23,24]. While independently J. Heller and A. Adler on one side and P.L. Baima Bollone on the other detected the

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presence of human blood on the TS (using different techniques), W. McCrone identified only red pigments like red ochre and vermillion on the same samples and named them "Sub-Micron Particles" (SMP) because they are very small in size. A dispute obviously arose among these researchers and unfortunately they died before a common conclusion was found. As a result, even today this misunderstanding continues especially among writers of opposite views [40]. Aim of the present paper is to clarify this dispute.

3. Materials and methods

Barrie Schwortz, on behalf of Shroud of Turin Education and Research Association, Inc. (STERA, Inc.), furnished to the authors 2 sticky tapes mounted on glasses that have been applied to and lifted from the surface of the Shroud in 1978 by R. Rogers of STuRP. They are labeled "1HB – Image Foot" and "3EF – Blood on Wrist" [25] (Fig. 1 – Supplementary Material [SM]). The authors took samples from these sticky tapes.

They have also compared the reddish particles there contained with others coming from the TS that were furnished by G. Riggi di Numana [26], again by R. Rogers (pieces of STuRP sticky tapes labeled "1EB – Image: Calf/Ankle" and "3AF – Image – Middle Finger") and with sticky tapes put in contact and lifted from the surface of a 1656 Copy of the TS, named CPM (Copy conserved at Palma di Montechiaro in Sicily, Italy) by the first author, see Fig. 2 – SM.

Encrusted linen fibers and free reddish crusts extracted from these samples, properly mounted on glasses or on aluminum stubs covered by a carbon-sticky-tape, have been studied, using the following instrumentation:

- Micro-Raman equipment of Labram using He-Ne laser, excitation wavelength of 785 nm, max power 20 mW, connected with a Olympus microscope BX-40, (of CIGS, Modena University); the probe spot size was of about 0.5 μm; spectra have been acquired in the range from 100 cm^{-1} to at least 1600 cm^{-1};
- ESEM (Environmental Scanning Electron Microscope) Fei-Quanta 200 (of CEASC, Padua University) equipped with BSE (Back-Scattered Electron) Detector integrated with
- EDX (Energy Dispersive X-ray Analysis) of EDAX, mod. Genesis (of CEASC, Padua University); the probe spot size is of 50 nm but the volume of X-rays production is 2–5 μm^3;
- optical stereomicroscope of Olympus equipped with transmitted light and epi-illumination;
- optical microscope equipped of both transmitted light, cross-polarization and epi-illumination having a variable inclination of the light beam;
- optical microscope of Officine Galileo equipped of both phase contrast and analysis in cross-polarization.

Besides the many fibers visually analyzed under optical microscopes, 32 samples consisting in colored linen fibers or single particles have been studied with ESEM-BSE and 14 samples have been analyzed with Raman instrumentation [37,38]. Table 1 reports the analysis made relative to single colored fibers coming from the TS, like that shown in Fig. 1 or relative to single particles dispersed in the sticky tapes.

4. Spectral analysis of reddish particles

In agreement with Heller and Adler [22], the SMP and the red crusts having sizes of the order of micrometers, recognized by them as blood, are not easy to study with traditional techniques even after decades later. McCrone [13–19] instead recognized the SMP as red ochre (iron oxide CAS RN 37338-85-5) and vermillion (cinnabar, i.e. mercury^{II} sulfide, CAS RN 1344-48-5). The present analysis, addressed to clarify this apparent disagreement, involves the following samples: reference samples, reddish particles from CPM, SMP of TS fibers, reddish TS crusts connected with fibers or dispersed in the sticky tapes.

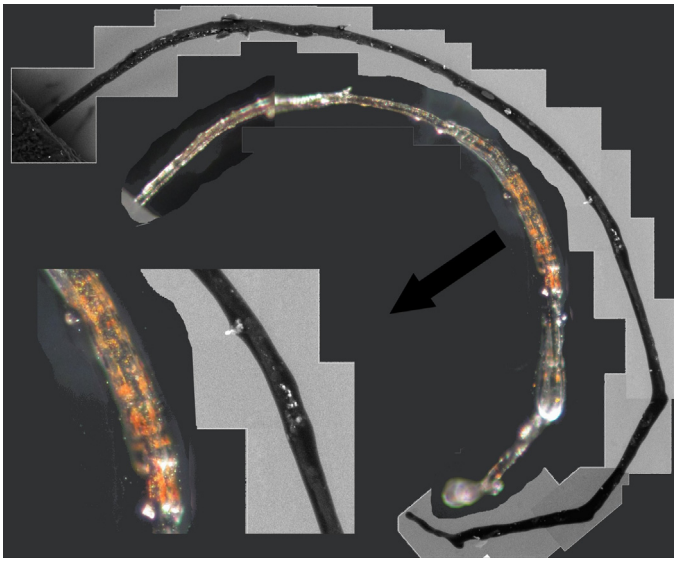

Fig. 1. Fiber 1 of 1HB sticky tape seen with its zoom on the bottom left, by means of both an optical microscope and an ESEM-BSE Detector. While both the blood particles and the inorganic SMP appear reddish in the optical microscope, the inorganic ones appear almost white in the photo obtained using an ESEM-BSE Detector and the blood particles appear dark grey, thus allowing to distinguish the organic from the inorganic particles.

4.1. Reference samples

Red ochre [27] is characterized by Raman bands at 225, 290, 402, 491 and 601 cm^{-1}, while cinnabar [28] is characterized by bands at 252, 285 and 342 cm^{-1}.

It is known that the TS was exposed to the Chambéry fire that probably exceeded 800 °C externally to the reliquary, while the inner TS linen, properly protected, was exposed to temperatures of the order of 200 °C [2]. In order to have samples of heated human blood, some drops have been soaked in a linen fabric. Small pieces of this fabric have been heated to about 200 °C and 800 °C for one minute after a week from the soaking, thus obtaining three reference samples of blood (one at ambience temperature, and two heated) to be compared with the supposed blood of the TS.

An EDX semi-quantitative analysis has been performed on the first sample of blood conserved at ambience temperature (Fig. 3 – SM) and put on a carbon conductive adhesive tape over an aluminum stub. The detected iron content of 0.25%, typical of the hemoglobin, is partially hidden by the background noise in the resulting spectrum (Fig. 4 – SM). Other elements typical of blood are evident like sodium, chlorine, potassium, calcium.

A Raman analysis (using an excitation wavelength of 785 nm) of the three reference samples of the linen fabric soaked with fresh blood and exposed to different temperatures has been performed (Fig. 5 – SM). The fluorescence level increases from 513 to 9760 (relative units) when heating the sample. Some peaks typical of blood are evident at ambience temperature and at 200 °C [29,30]: the bands at 754 cm^{-1} and at 1225 cm^{-1}, typical of blood result. Instead a band attributable to charcoal (at ~1346 cm^{-1} and at ~1594 cm^{-1}) appears in the sample heated at about 800 °C.

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