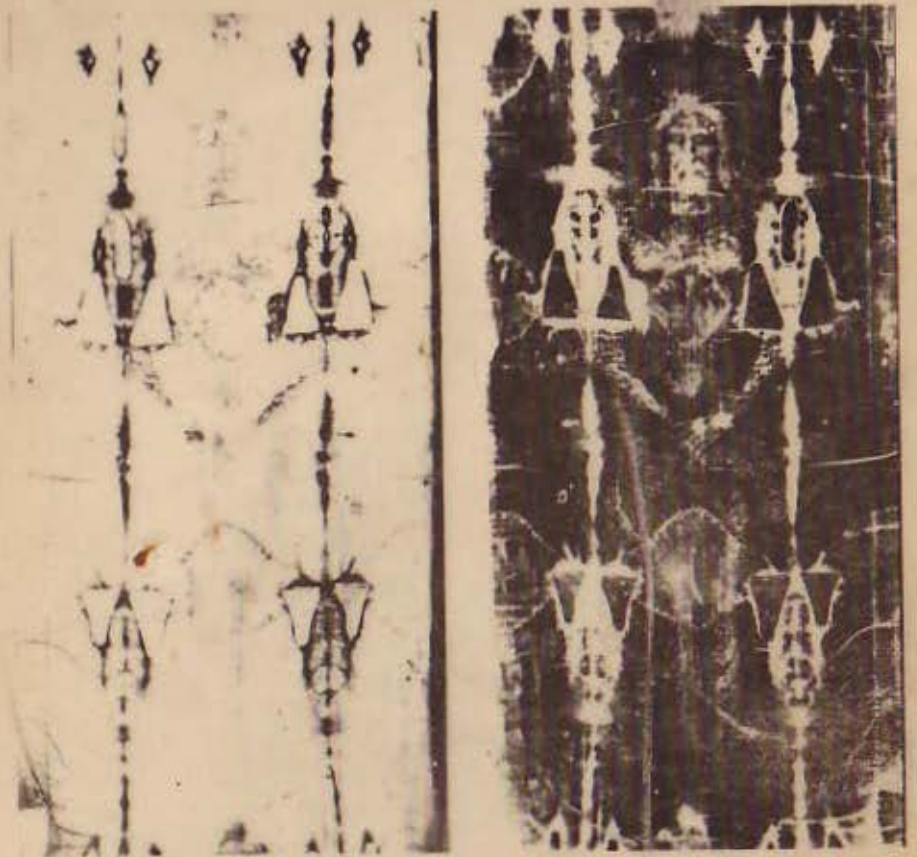


PROCEEDINGS  
OF THE



1977  
UNITED STATES CONFERENCE  
OF RESEARCH ON

**THE SHROUD OF TURIN**

March 23-24, 1977

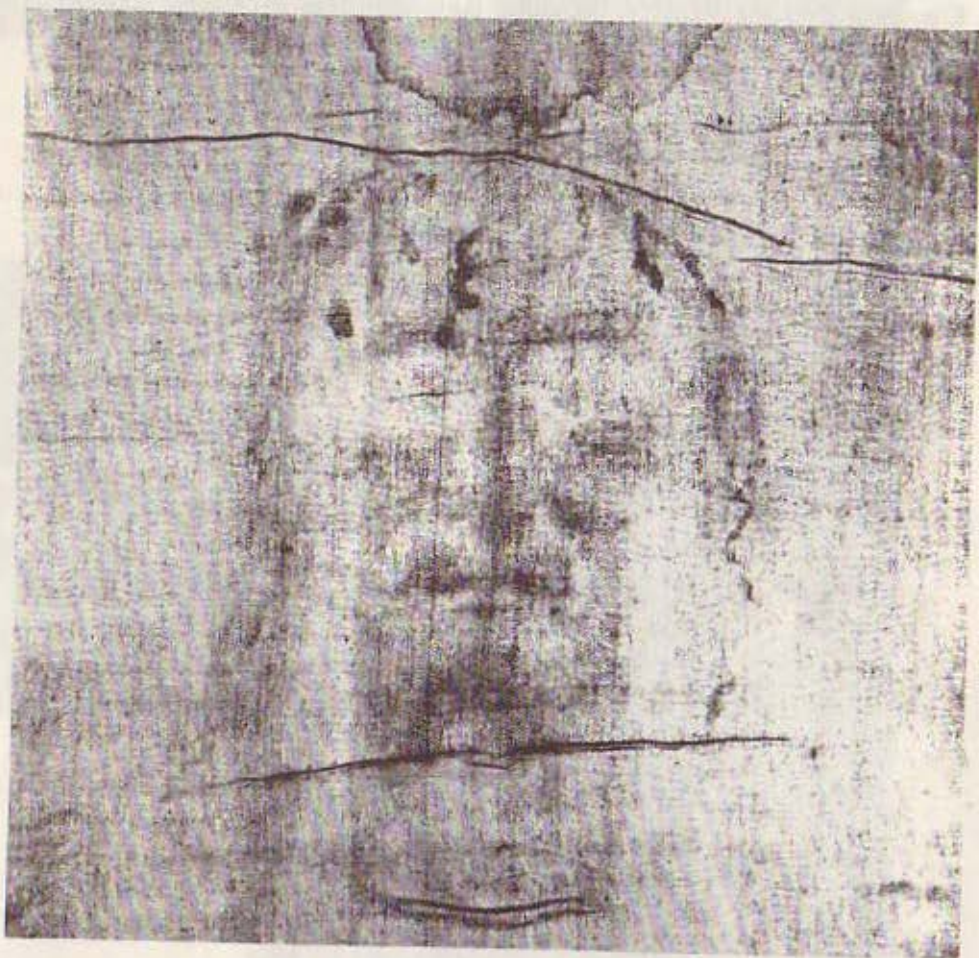
Albuquerque, New Mexico, USA



#### OFFICIAL CONFERENCE PHOTOGRAPH

Left to Right: Harry John, Msgr. Giulio Ricci, Dr. Mary Elizabeth Patrizi, Alan Mark (forehead only), Erica John, Charles Webb, Mary Gambescia, Roger Morris, Rev. Peter Rinaldi, Capt. Joseph Accetta, Elizabeth Watkins, Rt. Rev. Dr. John Robinson, Rev. H. David Sox, Bill Mottern, Thomas Humber, Patricia Lynn, Rev. Adam Otterbein, Donald Lynn, Dr. Robert Bucklin, Marge Jumper, Dr. Eric Jumper, Donald Devan, David Rolfe, Thomas Patterson, Cadet Thomas McCown, Christina Maria, Kay Jackson, Dr. John Jackson, Dr. Joseph Gambescia, Tom Dolle, Maria Gallagher, Dr. Donald Gallagher, Ian Wilson, Dr. Idella Gallagher

Not Shown: Maj. Rudolph Dichtl, Rev. Robert Dinegar, Rev. Francis Filas, Donald Janney, Dr. Walter McCrone, Dr. Ray Rogers



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Holy Shroud Guild  
294 East 150 Street  
Bronx, N.Y. 10451

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## ACKNOWLEDGEMENTS

If acknowledgements were made to everyone who influenced or added to these proceedings, they would almost equal the work. However try we must, and we hope and pray that no one will feel slighted.

First, we must thank God for the opportunity to study what may well prove to be Jesus' precious portrait — a portrait which clearly demonstrates His love for the world.

Second, we must thank all past pioneers of the Shroud, from the earliest — Vignon, Barbet, Delage — to those of the 1973 commission, on all of whose shoulders we stand. Moreover, in between stand a host of others who have been invaluable throughout the modern history of the Holy Shroud. These include but are in no way limited to: Fr. Adam Otterbein, president of the Holy Shroud Guild; Fr. Peter Rinaldi, author and vice-president of the Guild; King Umberto and the Turin authorities who graciously permitted the 1973 Commission Research.

Third, we must thank all who directly made these proceedings a reality. Among them are all the participants of the 1977 U.S. Conference of Research along with a host of technical experts who advised and helped us all. Certainly we must include all of our wives and secretaries for the thankless job of typing and retyping each manuscript. A special note of thanks to our typesetter, Cindy Johnson who along with Alonso Tirado of Alpha Printing worked overtime to help us meet tight deadlines. We owe a debt of gratitude to Drs. John P. Jackson and Eric J. Jumper for their outstanding efforts in organizing and directing both the Conference and the compilation of these proceedings. Most importantly we thank De Rance Inc. for making it all possible.

Finally, our thanks to all the authors included in this text, whose names follow and who may be reached through the Holy Shroud Guild.

Kenneth Stevenson (editor)

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The Shroud of Turin has been called the Fifth Gospel. It has also been denounced as a fraud. Fifth Gospel or fraud — the Shroud is certainly still a fascinating mystery in the twentieth century.

Prior to the twentieth century, historians attempted to trace the Shroud from Turin to Calvary, but the trail was lost in France during the fourteenth century. Although records were found in Constantinople which placed the Burial Cloth of Christ in that city during the twelfth century, although references were found in earlier documents, the broken links and gaps made a strong historical argument for authenticity impossible. However, new research during recent decades has filled in many of those gaps and has strengthened the historical argument.

Science became interested in the Shroud after the photograph of Secundo Pia revealed that the image on the cloth is actually a negative image. Paul Vignon, Yves de Lage, Pierre Barbet, and G. Judica-Cordiglia have been followed by other scientists and their conclusions have confirmed the scientific evidence in favor of authenticity. In 1969 the Shroud was examined by a Commission of Experts appointed by the Archbishop of Turin, Michael Cardinal Pellegrino. Further studies were made on the occasion of the television exposition of the Shroud in November 1973. The report of these studies was published in January 1976. (No official English translation has been published).

This report had been anxiously awaited by the Holy Shroud Guild in America. The Guild had been founded in 1951 for a two-fold purpose: a) to distribute accurate information in order to promote devotion to Christ crucified, and b) to encourage further scientific study of the Shroud. Although the Guild had contacted

both individual scientists and laboratories, no organized study of the Shroud was made in America. However, three years ago a young scientist, Dr. John P. Jackson, Ph.D., contacted the Guild and expressed his interest in the Shroud. Dr. Jackson's interest mushroomed. He was joined by Dr. Eric Jumper, Ph.D. After several preliminary meetings and voluminous correspondence, they organized several roundtable discussions of the Shroud by scientists in the Albuquerque area. I was delighted and tremendously encouraged by the interest and knowledge evidenced during those discussions. Hence, when Drs. Jackson and Jumper proposed that a United States Conference for Research on the Shroud of Turin be held in Albuquerque in March 1977, the Guild enthusiastically endorsed the proposal. The two young "space-age" scientists who had recently been appointed professors at the Air Force Academy in Colorado Springs, handled the organization down to the last detail. The response was most encouraging. Scholars and scientists came from many sections of the U.S., from England and from Italy.

The purpose of the Conference was to evaluate and discuss the Report of the studies made in 1969 and 1973, in order to make proposals to the authorities in Turin for further studies especially on the occasion of the 400th Anniversary of the arrival of the Shroud in Turin (1578). It was hoped that American "space-age" technology might be able to make a contribution to new Shroud studies.

The Holy Shroud Guild in America is happy to be able to make the Proceedings of the Conference available. I take this opportunity to express the gratitude of the Guild to all participants in the Conference for their time and unselfish sharing of their knowledge and expertise. I want to express a special word of gratitude to Dr. John P. Jackson and Dr. Eric Jumper for their organization of the Conference. Finally, a special debt of gratitude is owed to Kenneth E. Stevenson for his assistance in preparing the manuscripts for publication and to De Rance, Inc. for making possible the publication.

Adam J. Otterbein, C.S.S.R.  
President  
Holy Shroud Guild

New Smyrna Beach, Florida  
June 7, 1977

## AMERICAN CONFERENCE OF RESEARCH ON THE SHROUD OF TURIN

Adam J. Otterbein, C.S.S.R., President, Holy Shroud Guild  
Albuquerque, New Mexico, March 23-24, 1977

Welcome to the First American Conference of Research on the Shroud of Turin. It is a tremendous pleasure, I might say the realization of a lifetime dream to welcome to this conference the members of the Executive Council of the Holy Shroud Guild, Dr. John P. Jackson, Dr. Eric Jumper and their colleagues from the scientific community, the members of the De Rance Foundation, and finally our co-workers and scholars from London and Rome. May the Divine Assistance be with us during these days of serious study and deliberation.

### SHROUD OF TURIN

Most of you have received and read the preparatory material which was mailed by Drs. Jackson and Jumper. (Congratulations and sincere thanks to both of them.) Included in that material was a summary of an article on the Shroud from the New Catholic Encyclopedia. For the benefit of those who may not have received the literature allow me to answer briefly the question: What is the Shroud of Turin?

The Shroud of Turin is a large piece of linen cloth (14 feet 3 inches by 3 feet 7 inches) which is preserved today in a chapel attached to the cathedral in Turin, Italy. It is called the Shroud because tradition says that the Body of Christ was wrapped in this cloth at the time of His burial. It is called the Shroud of Turin because since 1578 the Shroud has been preserved in Turin.

Historians trace the cloth back to France where in 1389 it was the subject of a controversy between the Canons of the Cathedral at Lirey and the Bishop of Troyes. The Canons claimed that it was the Burial Cloth of Christ, while the Bishop said that the image on the

cloth was a painting. Historians never resolved the controversy and at the beginning of the twentieth century the opinion of the Bishop was still defended by such scholars as Ulysse Chevalier and Father Herbert Thurston, S.J.

However, in May 1898 an event occurred which should have caused these historians to pause and reconsider. From May 25th to June 2nd, 1898 the Shroud was displayed publicly in the Cathedral at Turin. Permission was sought to photograph the cloth for the first time, so that when the cloth was returned to its silver case above the altar where it would rest for another thirty-three years before seeing daylight again, it would be possible to have an actual photograph of the cloth and especially of the faint image on the cloth. When permission was granted, Secundo Pia was chosen to take the photograph. Pia had considerable experience in still photography (artistic objects, paintings, etc.) and so although he was impressed by the importance of the object to be photographed, he approached the subject in a rather routine manner. The resulting photograph was anything but routine. Pia could hardly believe his eyes. The image on the glass plate was not negative, but positive! He checked and rechecked his procedure and then reported to the authorities.

There could be no doubt about the positive character of the image on the glass plate from his camera but the camera always produced a negative image i.e. it reversed the highlights and shadows. Hence the only possible explanation for the positive image was that the image on the cloth — the image that Pia had photographed — was itself a negative image! But how could this be? Photography was less than a hundred years old. This cloth was certainly five hundred years. It existed long before anyone knew what a negative image was.

When Pia's discovery was reported in scientific journals, scientists became curious about the origin of this "negative" image which ante-dated photography by several hundred years. In Paris at the Sorbonne University under the direction of Dr. Paul Vignon a group of scientists studied the glass plates provided by Secunda Pia. The group included Rene Colson, tutor of Physics at the Ecole Polytechnique and Dr. Yves Delage, a member of the French Academy of Science and, incidentally, a professed agnostic. After an intensive investigation of eighteen months the scientists were convinced of the authenticity of the Shroud, and they believed that they had discovered a process by which the imprints could have been formed (Vignon's vaporograph theory). On April 12, 1902, Delage presented a report to the French Academy of Science. Delage rejected categorically the possibility that the image had been painted. All evidence indicated that the image was actually the imprint of a

human corpse. Accepting the Gospels as historical records, Delage the agnostic, went one step further and on purely scientific and circumstantial evidence accepted the identification of the Man of the Shroud as Christ of the Gospels.

I refer you to the Bibliography in Wuenschel's Self-Portrait of Christ (Holy Shroud Guild 1957) for the various studies that were published both before and after the Exposition of 1931. Perhaps one man should be singled out for his work during this period, not only because of his own personal studies but also as representative of attitude of medical men who have studied the Shroud during that period. I refer to Dr. Pierre Barbet, Surgeon General at St. Joseph's Hospital, Paris. ~

During the Exposition of May 1931 Giuseppe Enrie was commissioned to take a set of new Black and White Photographs. Due to advances in photography these photographs of Enrie are much superior to Pia's photograph and provided much more detail for study. New studies confirmed the previous studies and conclusions of Vignon and Delage.

The Exposition of 1931 and the Exposition of 1933 occasioned much research and some specialized studies e.g. Timossi's study of the weave of the cloth (1933).

Although many of the Popes were personally interested in the Shroud of Turin, the Church has never taken an "official" position with regard to its authenticity. Public statements by such men as Pope Pius XI, Pius XII, and Paul VI, who were knowledgeable and informed about the evidence certainly lend extrinsic weight in favor of authenticity. However, scholars are still free to dispute the matter, although those denying authenticity have been less numerous and less vocal in recent decades.

#### HOLY SHROUD GUILD

If you will bear with me while I reminisce for a few minutes, I will give you some background of events which led to the establishment of the Holy Shroud Guild in America. I shall also have an opportunity to introduce some of the personnel present here today.

In May 1931 when the Shroud was exhibited in Turin, Father William T. Barry, C.S.S.R. was a young priest at the Redemptorist Seminary at Esopus, New York. I am not sure whether at that time he had heard of the Shroud, but two years later when the Shroud was again exhibited, Father Barry was doing graduate work in Sacred Scripture in Rome and one of his classmates was a native of Turin. Father Barry not only learned about the Shroud but he agreed to

visit Turin before returning to the United States. He celebrated Mass in the Chapel of the Holy Shroud and was introduced to G. Enrie, who not only showed him the photographs of the Shroud, but actually gave him a set of 3 x 4 inch glass lantern slides.

Father Barry returned to Mount St. Alphonsus, Esopus, New York where his duties as a young professor of Sacred Scripture prevented him from pursuing his interest in the Shroud. However, when Father Edward Wuenschel, C.S.S.R. became interested later on after reading an article, "I Saw the Shroud" by Rev. Peter Rinaldi, S.D.B., Father Barry was able to give Father Wuenschel a complete set of Enrie's slides. Father Barry was a Charter member of the Guild. He is still Treasurer and Custodian of the Wuenschel Collection at Esopus. Regretfully poor health prevented him from attending this conference.

When the authorities in Turin were preparing for the Exposition of 1933 they looked about for an interpreter who could speak Italian, French and English. They chose a young Salesian seminarian who had been born in Turin, gone to America and studied at Fordham University in New York and then returned to enter the Salesian Seminary in Turin. His name was Peter Rinaldi. It was thus that Peter Rinaldi was given the opportunity to see the Shroud and meet the experts. After his ordination Father Rinaldi returned to America and in June 1934 published his article in Sign Magazine and thus provided the spark which ignited Father Wuenschel's interest in the Shroud. Father Rinaldi is not only a Charter member of the Guild but is Vice-President and a valuable liaison with Turin.

It was Father Rinaldi's article that introduced Father Wuenschel to the Shroud. He became a serious student of the Shroud. He was joined by Father Peter Weyland, S.V.D. who was studying sculpture in Philadelphia. It was his ambition to make an anatomically perfect corpus for a crucifix. After reading Msgr. Barnes' book, The Holy Shroud of Turin, he became an avid student of the Shroud. He devised a method of suspending himself from a cross by means of leather cuffs. He had a plaster cast made of his body as he hung on the cross and then studied the stress and strain on every muscle. Father Weyland and Father Wuenschel interested Msgr. Joseph Stedman of the Precious Blood Confraternity, Brooklyn, N.Y. in the Shroud and the three men spent many Sunday evenings discussing their research. Finally they collaborated to publish an edition of Chalice magazine on the Shroud. It had a very wide circulation and brought the story of the Shroud to millions.

Father Wuenschel corresponded with G. Enrie. He collaborated with Dr. Paul Vignon, the famous French authority, and in 1937

published an article in the Scientific American. He published many historical, theological, and biblical articles on the Shroud and lectured extensively during the 1940's.

The First Italian National Congress on the Shroud was held in 1939 but the Acts were destroyed during World War II. When a Second Congress was held in 1950, Father Wuenschel was one of the invited speakers.

Father Wuenschel introduced me to the Shroud while I was a seminarian in the late 1930's. I made photographic copies for him and became interested in the photographic aspect. After completing my graduate work for a doctorate in theology I was associated with Father Wuenschel on the faculty of Mount St. Alphonsus. We became close friends and I was introduced to all aspects of the Shroud. In 1950 Father Wuenschel was appointed Director of the Redemptorist Graduate School in Rome. He asked me to continue his work in America to make the Shroud known. A year later (1951) we established the Holy Shroud Guild with the approval of His Eminence Francis Cardinal Spellman and Very Reverend John Sephton, C.S.S.R. We published a pamphlet by Father Wuenschel and I began to lecture on the Shroud. In 1953 I was released to work full time as Director of the Guild. The purpose of the Guild was twofold: to spread accurate information about the Shroud, and secondly to contact scholars in various fields who could contribute to further study of the Shroud. I visited the New York City Crime Lab, the FBI Headquarters in Washington, the Eastman Kodak Company in Rochester, etc. Interest was keen and with each group I spent hours either in personal or roundtable discussions.

We organized the Executive Council of the Guild. It was composed of experts in various fields. Many of the original members are present here today: Father Francis L. Filas, S.J., Professor of Theology at Loyola University, Chicago. In 1951 he presented his first TV program on the Shroud. The response was so great that the program was carried by the network the following year and many succeeding years. The program has been telecast every year during the past 25 years and will be shown again this year.

Also present today is Dr. Anthony F. Sava who has written and lectured extensively on the medical aspects of the Shroud. I was privileged to be present at some post-mortems and experiments which Dr. Sava performed. His research took him to Paris to discuss with Dr. Pierre Barbet, the author of A Doctor at Calvary, the nail wound in the wrist and the blood and water from the wound in the side.

In Techny, Illinois, I witnessed some of Father Peter Weyland's

experiments in suspension on the cross. Unfortunately Father Weyland like Father Wuenschel has passed on to his reward, but we have with us today a doctor who also witnessed Father Weyland's experiments and monitored some of the medical aspects. He is another Charter member of the Guild, Dr. Robert Bucklin, M.D. whose interest in Pathology led him back to school to add to his doctorate in Medicine a doctorate in Law. Dr. Bucklin is now Assistant Medical Examiner of Los Angeles.

Monsignor Giulio Ricci is an Honorary Vice-President of the Guild, and Director of the Holy Shroud Center in Rome. I was introduced to Monsignor Ricci twenty five years ago by his writings and by letters. In recent years I have had the pleasure and benefit of discussions with him in New York, Rome, and in Turin in 1973 when we were present at the Exposition of the Shroud. In 1976 the Guild published his monumental work, LA SINDONE SANTA.

Dr. Joseph Gambescia, is Professor of Medicine at Hahnemann Medical College, and Chairman, Department of Medicine at St. Agnes Medical Center, Philadelphia, Pa. Dr. Gambescia's interest in the Shroud goes back many years. In 1967 he led the medical discussions at a Seminar conducted by the Guild at Manhattanville College, Purchase, N.Y.

Another member of the Executive Council, who was prevented by urgent business from joining us today is Father John V. McGuire, C.S.S.R. As a close personal friend he has been associated with the work of the Guild from the beginning. His special field is publications and his advice and assistance has been invaluable.

There have been others, but I cannot prolong the list. I beg their indulgence.

I stated that the purpose of the Guild is twofold: a) to spread accurate information and b) to contact scholars and experts. I have not had time to audit our records but I am certain that the Holy Shroud Guild Office (presently located at 254 East 150 Street, Bronx, N.Y. 10451) has distributed more than a million booklets, many thousands of books, several million pictures and photographs, and hundreds, yes, thousands of filmstrips. We have published and supplied information for many newspaper and magazine articles. We have presented TV programs in Philadelphia, Boston, and New York. We produced a 16 mm film which was shown to a certified audience of over a quarter of a million.

b) The second purpose is to contact scholars and experts who can aid and advise regarding future studies and research. During the past twenty five years I have contacted many experts, who manifested interest which wained rather quickly when I was forced to

reply to the inevitable question: "When can we see the Shroud?" OR, "When will they examine the cloth again?", by responding: "We do not know when the next Exposition will be held."

In 1973 Father Rinaldi and I went to Turin for a Press Conference. We hoped but had no assurance that we would see the Shroud. However, beyond all expectations, we were allowed to view the Shroud at close range on three separate occasions for a total of about six hours. We returned with renewed enthusiasm. It was about that time that Dr. John Jackson contacted the Guild. He brought a whole new approach to the study of the Shroud. Father Rinaldi and I were fascinated. Dr. Jackson met with us in Port Chester, N.Y. and illustrated the work that he and Dr. Eric Jumper were doing in Albuquerque. We arranged several other meetings, one of which was attended by Msgr. Ricci. Finally in February, 1976, I visited Albuquerque and Los Alamos, where we had a most interesting roundtable discussion. (I shall not attempt to introduce the scientific group. I leave that to Dr. Jackson.)

As a result of the discussions last year, and happily due to the insistence of Drs. Jackson and Jumper we were convinced that the work which had been done here may well be as significant as the first photograph of Secundo Pia. We were convinced that you have positive and constructive recommendations, which should be considered by the authorities in Turin prior to the next Examination. Moreover we feel justified in coming to you to seek your advice and recommendations, because we do not have to reply with a vague response: "We do not know when the next Examination will take place."

You have a copy of the Report of the examinations in 1969 and 1973. We welcome your comments and suggestions. New studies are in progress. 1978 will mark the 400th anniversary of the arrival of the Shroud in Turin and an International Congress is being planned. We hope that Dr. Jackson will be able to address the Congress. Hence we are not talking about a possible event in the nebulous future but of an International Congress in Turin in 1978.

I cannot begin to express my gratitude to each one of you for your interest, your time, and your generous cooperation. This is your conference. Do not hesitate to speak up. We came 2,000 miles — some of us 8,000 miles to listen. I hope that the sessions will be as interesting for you as they will be for us. Thank you.

## TURIN AND THE HOLY SHROUD

Rev. Peter M. Rinaldi, S.D.B.

It was but ten years ago that Monsignor Cottino, the delegate for Shroud's affairs of the Archbishop of Turin, wrote to me: "Stop being pushy. God's good time for the Holy Shroud has not yet come." Being in rather good terms with Monsignor, I replied to him: "You people in Turin expect the Lord to do everything. All you do is make things difficult for Him!"

We all know, of course that, for years, Turin was not just slow, but even reluctant to take action or even to speak on anything regarding the Shroud. For years, students of the Relic begged to be allowed to see and examine the Shroud. Practically all research work since the early thirties had been done solely on the official photographs made by Giuseppe Enrie. Reluctant the Turin authorities were even in the face of King Umberto's repeated assurance that he favored anything and everything that could advance the cause of the Shroud, provided the Church authorities took the initiative. We in the States were not the only ones who were "pushy" . . . I am convinced that Pope Paul had more than a small part in breaking down the resistance of the Turin authorities.

I have often been asked to explain Turin's puzzling position vis-a-vis their cherished and buried treasure. Actually we must not be too harsh. The Second World War and the disarray in the post-conciliar Church made for more grave and pressing preoccupations. But the fact is that the fires were kept burning. Two outstanding congresses were held at Turin's initiative in 1939 and in 1950. In Turin were and are most of the men and women who nurtured serious studies on the Relic. SINDON, the fine international magazine published at the Center, testifies to their earnestness, devotion and ability.

Let's be fair to Cardinal Pellegrino, too. In spite of his delaying

tactics and overcautiousness, he did finally open wide the gates of the Shroud's citadel, wider than any of his predecessors had ever done. Those of us who were in Turin on November 22, 1973, at his press conference and at the unexpected, almost incredible event that followed it, can vouch for that.

In retrospect, we may well regret that precious time was lost to the cause of the Shroud. Actually, we were not asking for the impossible. Was it asking too much to expect that something be done to advance the knowledge of the Shroud a little further than where Yves Delage, Paul Vignon or Pierre Barbet had left it? Was it asking too much to ask that present-day technical skill be applied to further the knowledge of an object that has gripped the imagination and stirred the hearts of millions of people? These were the questions we asked loud and clear.

Something began to stir in Turin in the summer of 1969. It was indeed the beginning of a new era for the great Relic. For the first time the barriers were lowered, and men of science were called together, constituted into a commission and officially detailed to examine the Shroud. Even if Turin botched this first positive step by limiting the work of the Commission and surrounding it with un-called for secrecy, it was a breakthrough of a sort.

A disappointing one, I regret to say. When in 1971, I asked King Umberto if he had seen the report of the Commission's finding, he replied: "What report? What findings? All they did was look at the Shroud." It was true. For three days in June, 1969, the members of the Commission gathered around the Shroud to examine its overall condition, to photograph it and to confer on ways in which it could be best preserved. Direct testing of the Relic was not to come until the end of 1973.

The rest is history. I was immensely pleased that the promoters of this Conference made the Commission's report available to all participants. Grateful we are, too, to our English friends for doing such an excellent job on the translation. Someone far more competent than I might want to comment on the Commission's Report. I do hope someone will. I am happy to inform you that an excellent Critique of the Report has just been published in Turin. It is a splendid little volume. It, too, should be translated and incorporated with the Commission's Report when and if the Report will be published in English. I should be glad to explore briefly with you the contents of this Critical Study, possibly tomorrow . . .

Kindly allow me one or two comments. Let us not minimize the work of the Commission. If nothing else, it proved that direct testing of the Relic, too long ignored, is, to a great extent, where the

IDEAL ATTITUDES CONCERNING RESEARCH  
ON THE SHROUD OF TURIN

Francis L. Filas, S.J.

future of much of the Shroud research lies. The findings of the Commission opened, too, new and unexpected doors to research, such as the amazing pollen discovery. Incidentally, new avenues is what we must explore. I do not wonder that we are genuinely excited at the totally new approach Dr. Jackson and his colleagues have brought to the study of the Shroud. We are, because we know that the Turin Cloth has only begun to yield some of its amazing secrets.

Secondly, I am convinced that, precisely because of the Commission's work, the 1978 Turin Congress will be blessed with a vigorous new thrust as it looks to the future. Its work will not be stymied (as it was in the two previous Congresses) by the fact that no direct access to the Cloth was possible and no direct testing permitted. We are now in a position to exploit fully the findings of the Commission and to ask for new and even more complex tests.

Some might say that we put too much faith in Science, as we stand amazed before the mystery of the Shroud. My friends, I am sure I will not surprise you if I tell you that I am happy to be one of many people (possibly including you) for whom the Turin Relic is no mystery at all. As I look at the Face of the Man on the Shroud, I need not be told that this is a face no artist could paint. To me it is a wonderfully familiar and beloved Face, overpowering, too, in the calm, serene majesty of death. I look at it, and say quite simply: "It Is The Lord!"

But there are many doubting Thomases in the world and in the Church, too. They are the ones who say: "Unless I see . . ." Why not let Science lead them to the Shroud, and, through the Shroud, to Him "Who loved us and sacrificed Himself for us?"

It is true to say, though, that in a way, the mystery of the Shroud, like the Mystery of Jesus Himself, will never be completely solved. Like the Man of Nazareth, the Man of the Shroud will continue to mystify our minds, trouble our hearts and challenge our faith. The words of Pope Paul come to mind at this point, the words he spoke to millions of people during the televised exposition of the Shroud over the Eurovision System. He said: "Whatever may be the historical and scientific judgment that learned scholars will express about this mysterious Relic, we cannot but wish that the viewers, looking beyond the exterior, mortal features of the Saviour's marvelous portrait, may be led to a clearer vision of His inmost and fascinating mystery."

At the outset, let me make it clear that this is a theoretical summary of attitudes which I personally consider ideally correct — or completely wrong — concerning inquiry on the Shroud of Turin. This is presented merely as a working outline. It is not, however, concocted from my own brain independently of outside experience. I think that I could offer names for every individual opinion presented here either for praise or for no-praise, but in the interest of charity, let us allow such names to remain suppressed.

My primary supposition is that the Shroud exists for the world, and therefore is the strictly private possession of no person and no group, no matter what the legal possession title might be. Legal possession should be exercised for the purpose of protecting the Shroud from destruction, harm, ridicule, and stupidity; not for any purpose of stifling research and publicity to help the world be aware of the evidence for the Shroud. Any aura of "secrecy" makes the Shroud a suspect subject for many.

Another supposition is that one should avoid veering to extreme, cynical rationalism which would prevent an open mind to objective research; or in the other direction, one should avoid veering to emotional piosity, which would likewise prevent an open mind to the results of solid, objective research. As for the pious approach, if the individual man or woman postulates that some miraculous influence exists in the case of the Shroud, this automatically prevents all discussion and examination, on the basis that a miracle by definition is beyond human experience and beyond human probing. However, the assumption that highly providential conditions of time and temperature and humidity and historical preservation existed is not the same thing as shouting "miracle." Such an assumption of a providence in the order of nature does not hinder investigation from



the natural sciences in any way.

I suggest that all research proceed along the lines of the dilemma proposed long ago by some Shroud pioneer researcher; first, did the body of a human male make the marks on the cloth? Second, is that body the body of Jesus Christ? To my mind, research on the Shroud has been hampered by a fuzziness between these two distinctions. To assume or to deny that the Man of the Shroud IS Jesus Christ, as some have done, in order to hold this or that theory as to the interpretation of the gospels of Matthew, Mark, Luke, and John, is patently unscientific and illogical. This has happened only too often. The rule for the Shroud study must be the search for truth and truth alone; then let the chips fall where they may, even though the finding of new objective truth may uncover new problems and new questions. Is this not the rule in all areas of human knowledge, that the more we discover, the more we find we do not know?

At this point, all of us should recognize the demands of rigorous logic, noting that any theorizing we do should fit the rules of the discipline of minor logic, namely, it must explain everything that should be explained, with no biased emphasis on slurring over its possible contradiction of things that should be explained. Historically, Shroud researchers only too often exemplified this erroneous principle of selective explanation; my own opinion is that Vignon, Barbet, and Wuenschel were shining examples of the correct use of logic, when they had to come to the rescue of the Shroud because some other writer had claimed too much weight for his tentative or slight evidence.

Another point we should remember is the logic of distinguishing between internal or circumstantial evidence and external or human-testimonial evidence. Up to the time of Secondo Pia's primitive photograph, we must remember that the external negative testimony of history, so exploited by Ulysses Chevalier, held the field. Most of us have concentrated on the opposite type of internal or circumstantial evidence, which we should admit does have its limitations. Hence, any assistance we can get from positive external evidence of history is all the more to the good.

The demands of some researchers for full and uninhibited examination of the Shroud cloth represent to my mind a wild and utterly unwarranted outlook that forgets the need from protecting the cloth from unintentional no less than intentional harm. On the other hand, an attitude for excessive reverence which would prevent any responsible and detailed study seems equally reprehensible. In this connection, the religious affiliation — or non-affiliation — of the

researcher should have no bearing on the outcome of his or her studies, since the question of the origin of the Shroud is certainly not a part of official doctrine of the Roman Catholic Church or any other group, as far as I know. The history of repeated papal approvals should be properly interpreted as an approval for devotional reverence, not necessarily as the critical acceptance of historical authenticity borne out by scientific studies.

I conclude this very short summary with a tribute which I think is long overdue to the past pioneers who ought to be mentioned here for the selflessness of their work, the objectivity of their research, and the courage they manifested before the scathing scorn sometimes heaped on them by scholars differing with their opinions: I particularly single out Paul Vignon, Pierre Barbet, and Father Edward Wuenschel. Their attitudes should be the ideal for all of us, a tradition looking for the truth and the truth only, not sacrificing the Shroud to personal ambition for popularity, notoriety, money, or jealous self-aggrandizing control. We all know how much the Shroud has suffered in history from these curses: the thirst for money or power or notice. But we also know and can be encouraged by the example of living persons around us, whose ideals continue to protect the Shroud from abuse in one direction or the other. I borrow a comment in this connection, from the field of dignity in sex education, where I have had some experience in combatting the denial of values. A student once said, "Yeh, they told us all about sex, but they didn't tell us what to do with it." So, too, in the case of the Shroud: what good is all the research in the world, if we do not utilize it rightly, if "we don't know what to do with it." So noble a question as the identity and characteristics of the Man of the Shroud merits only equivalently dedicated and premium intellectual outlooks.

SOME ECUMENICAL CONSIDERATIONS CONCERNING  
THE TURIN RELIC

The Reverend H. David Sox

Ecumenical interest in the Turin Shroud has been almost non-existent until the past few months. Over the years there has been a handful of churchmen outside the Roman Catholic Church who have expressed more than just curious interest in the article. Understandably this is so, considering the Protestant\* feeling about relics and the post-Vatican II Council attitude toward such things.

Present day scattered interest by non-Roman Catholics has included Presbyterian Robert Wilcox's forthcoming Macmillan book, Shroud, and the vital and fascinating concern of Anglican bishop and theologian, John A. T. Robinson. Having this marvelously controversial Cambridge dean involved with a relic is incredible. (By his own admission — "What is the author of Honest to God up to, getting mixed up with a relic?") And he's not the only bishop from the Diocese of Southwark (South London) to be interested. The Bishop of Kingston, Hugh Montefiore, recently admitted a considerable fascination.

On September 16-17 at the Anglican Institute of Christian Studies in London, a symposium on the Shroud will be held which will involve not only Anglicans but also Orthodox and, of course, Roman Catholics. Members of other denominations will also be invited as well as people interested in the Shroud from a purely academic or scientific point of view. Presenting this type of event a few years ago would have been unthinkable.

It is slowly becoming apparent that a remarkable number of heretofore isolated non-Roman Catholic clergy and laity have a deep

\* The Eastern Orthodox attitude is an entirely different matter.

interest in the cloth.

Much of this is due, of course, to the incredible research on the Shroud occurring at the present. One of the chief difficulties for some in taking the article seriously has been that it is a relic and that word is loaded with ill feeling and repugnance.

Protestant reaction to relics has always been strong. The Anglican Thirty Nine Articles of Religion (very mild in comparison to some Reformation statements) said, "The Romish Doctrine concerning . . . Relics . . . is a fond thing, vainly invented and grounded upon no warranty of Scripture, but rather repugnant to the Word of God." "Vain inventions" — typically moderate Anglican language. To the Calvinists and Anabaptists, relics were inventions of the Devil. Not many Protestants go this far today. In fact no one takes much notice of them at all these days, since Roman Catholics themselves downplay their significance. It's almost like arguing about the use of Latin in church services.

Sir Steven Runciman, renowned Byzantine scholar, when writing about the Mandylion of Edessa said, "Christian relics have never received their due attention in history. Historians justly suspecting the authenticity of the more eminent of them, have tended to put them all to one side, forgetting that even a forgery can have its historical value."

Kenneth Clark in Civilisation echoed a similar note. "From our point of view nearly all the relics in the world depend on unhistorical assertions, and yet they, as much as any factor, led to that movement and diffusion of ideas from which Western civilisation derives part of its momentum." There is no doubt that the point of the medieval pilgrimage was to look at relics. This was not like modern tourists gazing at the "Pieta" or Leonardo's "Last Supper." Medieval pilgrims actually felt that in a very real sense they could participate in the reality of the mediator-saint before them.

Now it is impossible for us to enter the medieval mind on the subject of relics. The very word conjures up distasteful images — the Holy Blood of Bruges, the index finger of the Apostle Thomas at Rome or the incredible Holy Foreskin at the Collegiate Church of Calcata. We cannot understand what impact such articles as say the remains of St. Andrew at Vetralla had to the devout of the Middle Ages, the fifteenth century silver angel of this reliquary is carefully holding before him a firm link with Christ. St. Andrew brought his important brother, Peter, to the Lord and the faithful could share in the physical reality of this event and similarly through the accessible Andrew come to the Lord as well. For us, relics have no such meaning. We are repelled by them. They are part of the excess

baggage of Christian tradition easily discarded and forgotten.

When I was last in Rome, I went to the catacomb church of St. Calistos and was fascinated to see that their great horde of relics has been relegated to a museum setting. When I was there fifteen years before, I remember being subjected to a fifteen minute lecture given to the visitors by one of the church's monastic guides with endless detail as to the importance of each and every reliquary splendidly displayed before us. I am certain that this experience has been repeated ad infinitum all over the Roman Catholic world.

We find it difficult to understand relics, but any serious student of the Holy Shroud of Turin at one stage or another must come to terms with the fact that he is dealing with a relic . . . with remains as the word comes from the Latin "relinquere" meaning "to leave behind." And if that yellowish piece of linen indeed be Jesus' shroud — it is what he left behind for us.

Granted that the scientific nature of the Shroud studies raises it far above the countless assortment of dubious remains — to the point that most persons do not think of the cloth as a relic. However, those of us who in small or large ways write about or investigate the Shroud should never totally forget that to many persons in the Church the Shroud is a relic of Christ. This was brought home to me in a touching manner recently. King Umberto II, the exiled King of Italy and present day titled owner of the cloth, sent me a Christmas card which contained an old fashioned devotional tract dealing with his possession. It was a kind gesture but not the type of meditation rite to which I am accustomed and many of my Roman Catholic friends strongly dislike this form of piety today. But that gesture vividly reminded me that we have to be more aware of the feelings of others when we investigate this curious article. Those who visit Turin are made aware of this and future dealings with the Turin authorities must take this into consideration. We all want the scientific and historical truth regarding the Shroud but we have to realize what we may do to another's faith in the future. It is a responsibility we should think about and since I am an Anglican and not a Roman Catholic, I feel that perhaps I can say some of these things in this small paper without anyone feeling that I have a vested interest.

The Shroud has been a symbol of unity in the past when it was brought by the House of Savoy from Chambery to Turin; it united the people to a new capital. The Shroud may again become a symbol of unity now that interest and research into its complexities have united men from various religious and philosophical backgrounds. Who would have ever dreamed that in 1977 in the New Mexico town

of Albuquerque such an assortment of scientists, clergy, historians and writers would be brought together by a relic?

PASTORAL ASPECTS OF SCIENTIFIC RESEARCH  
ON THE SHROUD OF TURIN

The Reverend Dr. Robert H. Dinegar

I speak to this conference for a few minutes this morning on pastoral considerations which should accompany physical scientific research on the Holy Shroud of Turin. This subject may seem of secondary — perhaps no — importance to some here these 2 days. However, to those of us who are priests as well as physical scientists, this is a matter of utmost gravity. Here we have two intertwined responsibilities. One is to make unbiased observations and unprejudiced interpretations, and the other is to insure that the Faith of the Church is bolstered and propagated. In addition, those who have the care of souls must bend over backwards to be sure no scandal is caused through neglect to state exactly what data mean in terms understandable by everyone. We are not permitted the luxury of hiding behind the prideful claim that we know, and the uninitiated should, too. "Alice in Wonderland" language has no place in matters of the Faith.

Let us first consider how many look at the Shroud of Turin. I think 3 classes are evident. First, there are those who believe it to be the covering that wrapped the dead body of Jesus of Nazareth and consider the imprint to be a manifestation of the truth of the death/resurrection cycle of their Savior. I would even say these people feel the Shroud is a divine way of answering the "doubting Thomases" of all ages as surely as was our Lord's invitation to the Apostle to touch and believe. Second, there are those who are not sure but agree that "it just might be." They use it as a crutch to do away with infirmity of human nature that says, "Do not believe if the object/subject cannot be materialized in the here and now." We all need support like this, some more, others less. The faith of Abraham in the unseen is given to very few, no matter that those who do have it are greatly

blessed. The last group, of course, consists of those who claim the Shroud is basically a fraud. Probably most in this class would say it is a product of honest — but misguided — piety but not to be taken seriously by modern "scientific" man.

Let us now think about what kinds of interpretations could be put on physical scientific data obtained from an examination of the Shroud.

First, analysis may show that the material dates from the time and place of Jesus of Nazareth, perhaps even, that the image is of a male human being. At this the first group of believers will rejoice, their faith confirmed. The second class will be glad that they now have additional indications that previous teachings were correct. Both will also be pleased that a precious object has survived the ravages of time and persons. More importantly, these will see that a totally different portion of the Wisdom from on High substantiates that which they are asked to accept from the "unscientific" act of revelation! Instead of saying, "I believe because I believe," or "I believe because Father X says so," many can now emphasize, "I believe, and that which can't believe says so, too!" The effect of such data interpretation will even be of concern for the deniers — they must now reassess their stand. No longer can they claim all that's certain about the Shroud antedates valid, reliable methods of data collection and analysis. What a magnificent contribution to the strengthening of souls that act alone would be!

Let us suppose the data cannot be interpreted to show the *shroud* dates from the beginning of the Christian era with any degree of certainty. To those who really understand the process of drawing scientific conclusions, this will present no problem — they know an equivocal answer says nothing pro or contra. A great number of people do not understand this, however, and their backgrounds are usually such that they cannot be so convinced. In addition, it is one of the unfortunate fallouts of the nuclear age that most people think, "If science can't prove it, it isn't true!" You and I know this isn't so, but those we serve don't! This could: (1) weaken the faith of those who now believe; (2) cause possible crises in the Church's teaching magisterium among those who accept the Shroud on the conviction of others; and (3) erect almost insurmountable barriers that would exclude forever the doubters. Certainly no one involved in Shroud investigation wants any of these to happen. Perhaps this wouldn't occur — I hope not — but I think the warning should be stated.

The final possibility is that the data can only be interpreted to indicate the Shroud dates from an era so late in time that it cannot

be associated with the salvific act on Calvary. All the fears just mentioned for the doubtful case would be magnified. Many would feel betrayed by a host of incorrect, albeit well-meaning teachers. This feeling could extend even beyond the Shroud itself, to the very basis of "the faith once delivered to the Saints." Certainly no one would want this unfortunate ending to well-intentioned efforts.

Two final caveats should be raised:

(1) I see no way a one to one correspondence between the Shroud image and Jesus of Nazareth can be certified. This particular identification can come only through the eyes of faith, not from the witness of impartial data. It also matters not, I hasten to add, and there is absolutely no need to attempt this connection. But let this be stated before any investigation so that misinterpretation cannot possibly arise later.

(2) An explicit or implicit hope to associate the Shroud with any event except a burial is certainly also doomed to scientific failure. This must be clearly stated lest we risk a final verdict for many which is but a regeneration of the quip of the opening days of Vatican II — "We found the Body!"

Where does all this leave us? As scientists we have the duty to investigate and report; as Church members we have the duty to be sure no compromise of the Faith comes from our efforts. The path leading to both these ends is more deceptive than might first appear. Let each experiment be carefully weighed beforehand. Let each goal be clearly stated in advance. Let any data collected be interpreted through the eyes of the twin communities of science and the Church. We can be — we must be — found responsible to both.

## THE SHROUD OF TURIN AND THE GRAVE-CLOTHES OF THE GOSPELS

Rt. Rev. John A. T. Robinson

One of the things that shook my natural predisposition to scepticism about the Turin shroud was precisely that it could not at all easily be harmonized with the New Testament account of the grave-clothes. I am not saying that it is incompatible with them but simply that no forger starting, as he inevitably would, from the details of the Gospels, and especially that of the fourth, would have created the shroud we have. Yet if it is genuine it must make us look again at the Biblical evidence. The Gospel accounts are notoriously difficult to harmonize with themselves, let alone with what has been called this 'fifth gospel'. Nevertheless it may, I believe, help us to reconstruct the situation in a manner which I at any rate would never have arrived at unless I had been prepared to take account of this extra-canonical witness.<sup>1</sup>

Let us begin as we must with the burial of Jesus. This incidentally is one of the best attested of all historical facts about him. That Christ not only died and rose but was 'buried' is part of our earliest summary of the Christian faith in a letter (I Cor. 15:4) written within twenty-five years of the crucifixion, where Paul is appealing to tradition which he himself received from the Jerusalem church, probably within five years of it (cf. Gal. 1:18). The burial is

<sup>1</sup>I have deliberately not cluttered this paper with footnotes to authorities ancient and modern for the positions I have adopted. Suffice it to mention two masterly treatments which refer to a wealth of evidence:

Edward A. Wuenschel, 'The Shroud of Turin and the Burial of Christ', *Catholic Biblical Quarterly* 7 (1945), 405-437, and 8 (1946), 135-178.

Ceslas Lavergne, O.P., 'La preuve de la résurrection de Jésus d'après Jean 20,7'; 'Le sudarium et la position des linges après la résurrection'; 'Le corps glorieux et la preuve que Jésus est ressuscité', *Sindon* 3 (1961), nos. 5 & 6.

also narrated in all four Gospels (Matt. 27:57-61; Mark 15:42-47; Luke 23:50-56; John 19:38-42), with John's account almost certainly independent of the others, and it is mentioned in a sermon summary in Acts, 'they took him down from the gibbet and laid him in a tomb' (13:29), which from the word xylon (wood or tree) may go back to pre-Lukan sources. The view that we can know nothing about the body of Jesus, because as the corpse of a condemned criminal it would have been thrown into a lime-pit, is sheer dogmatic scepticism, flying in the face of all the evidence that, contrary to what might have been expected, it met no such fate. In fact under Jewish law (cf. Deut. 21:23) it should have been buried before sundown in one of the two plots specifically reserved for criminals (The Mishnah Sahn. 6:5) and desire to remedy the concession of the pagan governor (especially unusual to a non-relative in the case of a man condemned for high treason) could have supplied a motive for fanatical Jews to raid the tomb and transfer the body.

Following therefore what evidence we have, which is factual and circumstantial and not obviously subject to doctrinal motivation or suspicious alignment, there is multiple testimony for the tradition that the body of Jesus, released by Pilate at the request of Joseph of Arimathea, was taken from the cross late on the Friday afternoon (Matt. 27:57; Mark 15:42) and laid in a rock tomb (Matt. 27:60; Mark 15:46; Luke 23:53) hitherto unused (Matt. 27:60; Luke 23:53; John 19:41). By then, despite the proximity of the grave (John 19:42), Luke tells us in an odd but graphic phrase (epephōsken; 23:54) it was already beginning to be what we should call 'lighting-up time' on the Sabbath, i.e., when the lamps were lit or, more probably, the first stars became visible. Clearly there was no time before further work became illegal and darkness set in for more than the most preliminary attention to the corpse. According to Mark (15:46) Joseph had already bought a linen cloth (sindon) and in this he wrapped (eneilēsen) or according to Matthew (27:59) and Luke (23:53) folded (enetylixen) the body of Jesus. According to John (20:39f) Joseph and Nicodemus 'bound' it (edēsan; though one uncial manuscript has 'wrapped', perhaps by assimilation to Mark) in othonia. This is a word of uncertain meaning but is probably best regarded as a generic plural for grave-clothes of unspecified material, though presumably linen. At any rate Luke, or his scribe, in 24:12 uses othonia to cover what he had previously (23:23) described as the sindon. John adds that a substantial mixture of myrrh and aloes, evidently in powdered or granule form like incense, was brought by Nicodemus and put 'with' the clothing, presumably to serve as a disinfectant to arrest the effects of putrefaction until further

attention could be given. One of the things specifically allowed by the Mishnah (Shab. 23:5) to be done for a corpse if need be on the Sabbath was to 'let it lie on sand that it may be the longer preserved'. The enormous quantity of material (100 lbs, though the Roman pound was only three-quarters of ours) could be an exaggerated figure to bring out the generosity of the gesture, like the stress in the earlier story of the anointing on the vastly expensive flask of oil the woman broke into (Matt. 26:6,9; Mark 14:3,5; John 12:3,5; cf. Luke 7:47). But there are parallels for such quantities, and if the mixture was packed under and around the sides of the body (perhaps thus explaining the flatness of the Shroud) a lot would have been needed. Finally, all the evangelists agree, a stone was 'rolled across' (Matt. 27:60; Mark 15:46; and by implication Luke 24:2 and John 20:1) the mouth of the tomb for protection until the women could return some thirty-six hours later at first light on Sunday. Meanwhile according to Mark (16:1) the women purchased aromatic oils after nightfall on the Sabbath, precisely as the Mishnah lays down (Shab. 23:4). (Luke 23:56) has them prepare spices and perfumes early on the Friday evening before resting on the Sabbath.) These were evidently in liquid form to 'anoint' the body of Jesus (Mark 16:1), just as before his death the woman had anointed it (Luke 7:38,46; John 12:3; cf. 11:2) by 'pouring' (Matt. 26:7; Mark 14:3) perfumed oil from her flask. The purpose of these unguents was quite different from that of the Johannine mixture. It was, after the obligatory washing of the corpse (cf. Acts 9:37), for which elementary act it is clear from the silence of all the witnesses there had been no time on the Friday, to clean it up and leave it in a decorous and fragrant condition. Normally of course this would have been done in preparation for burial (cf. Matt. 26:12; Mark 14:8; John 12:7) rather than after it.

So far there is no difficulty in correlating the Biblical evidence with that of the Shroud. Any presumption that the body was wrapped round in a winding sheet (contrast the swaddling cloths of Luke 2:7) or swathed in 'strips of linen' (John 19:40, NEB), rather like an Egyptian mummy, is read into the texts and has no support in Palestinian burial customs, which the fourth evangelist insists were followed (John 19:40). Later we read in Acts (5:6) that the body of Ananias was simply 'covered' (cf. Eccles, 38:16) and buried. That the corpse of Jesus was enfolded in a simple linen cloth passing lengthwise over the head and covering the whole body back and front is not, I submit, what any forger with medieval or modern presuppositions would have thought of; but it makes complete sense of the texts and comforts with the other ancient evidence.

It is when we come to the accounts of what was discovered on Easter morning that the problems begin. According to Luke 24:12, if it is part of the original text, as with a growing number of scholars I am now persuaded that it is (it is omitted by only one Greek manuscript), what Peter saw peering in was the othonia, which must, as I said, mean or at least include the sindon Luke has earlier mentioned. According to John (20:5-8) 'the other disciple' similarly 'peers in and sees the othonia lying', but then Peter, followed later by his companion, enters the tomb and we get a more detailed description. 'He sees the othonia lying and the napkin (sudarion) which had been over the head (epi tēs kephalēs) not lying with the othonia but folded or rolled (entetyligmenon; the same word used earlier by Matthew and Luke of the enshrouded body) in a place by itself (choris . . . eis hena topon)'. The Greek is in fact extraordinarily elusive, considering the significance that the evangelist evidently attached to the detail. His expressions are so loose that it could mean that the clothes were lying strewn about with the napkin that had been over the head rolled up or bundled into a heap by itself. This would be entirely compatible with Mary Magdalene's inference from the same evidence (20:11) that the grave had been tampered with: 'they have taken my Lord away, and I do not know where they have laid him' (20:13). So we should not expect the evidence of the eyes to be of unambiguous interpretation. It was only the faith of one man that put two and two together.

But what does the evangelist intend us to suppose that the disciples did see? This cannot be decided without taking into account his earlier description of the raising of Lazarus. His tomb was a cave with a stone placed against it (ep' auto; 11:38) and he 'came out' from it 'bound' (dedemenos) hand and foot with bands (keiriai) and his face bound round (periededeto) with a napkin (sudarion) (11:44). The New English Bible's translation 'his hands and feet swathed in linen bands' is again a paraphrase. There is nothing to say what the keiriai were made of — the only ancient evidence (the scholiast on Aristophanes' Birds, 816) tells us that a keiria was 'a kind of binder made of twisted rushes, somewhat like a thong, with which bedsteads were strung' (Wuenschel's translation). All we know is that they restricted, though evidently not totally, the movement of the man's hands and feet. On the assumption (too obvious to mention) that Lazarus had also been placed in a shroud, it would seem likely that the thongs had been tied loosely round the outside of it to hold it in place, functioning in this respect in lieu of a coffin. If so this is presumably what the women would have done to the body of Jesus after they had finished with it. The fact that they

had not finished with it would explain the absence of any mention of keiriai in his case, though they could be implied in John's phrase 'bound' it 'in' (not with) othonia (19:40).

But what of the sudarion which was 'round the face' of Lazarus and 'over the head' of Jesus? Sudarion is a loan word from the Latin and defines the object not by its material (though clearly it was cloth of some kind) but by its function, namely to wipe away sweat, rather like our handkerchief — and so it is used elsewhere in the New Testament (Luke 19:20; Acts 19:12). It seems in the highest degree improbable that it would be big enough to cover the length of a man twice. It is by John distinguished from the main body of the othonia, which Luke equates with the sindon. The only reason for supposing, as some have, that sudarion is itself the Shroud is that the latter clearly did go over the head and face, as well of course as over the whole body. Yet neither in the case of Lazarus nor in that of Jesus does it say that the sudarion covered the face. We are told that it was round the face of the former and over the head of the latter. The only position, I submit, which fits both these descriptions, assuming that they are referring to the same custom, is of something tied crossways over the head, round the face and under the chin. In other words it describes a jaw-band, which would have been required to keep the mouth shut and, together with the closing of the eyes (cf. Gen. 46:4), would have been functionally necessary before rigor mortis set in. Reference is specifically made to these customs again in the Mishnah (Shab. 23:5) and the chin could be bound on the Sabbath (though not the eyes closed), providing it was 'not in order to raise it but to prevent it sinking' (movement of any kind was 'work'). The jaw-band was evidently made by folding or rolling diagonally a large handkerchief or neck-cloth, rather like our triangular bandage. I had assumed that the only trace that the sudarion could possibly have left on the enveloping sindon was at the top of the head, where I took the whitish stripes in the negative photograph of the Turin shroud to be the space for it. But with the realization from the 3-D image produced by the computer that the white spots are the high spots, I can now see that this is more likely to be a ridge formed by the sudarion itself. Conversely the dark band immediately under the chin looks as if it is where the jaw-band has retracted a portion of the beard which would otherwise show up. The vertical dark strips on either side of the face between the cheeks and the locks, otherwise so odd, could similarly be caused by the band holding back the intervening hair. The band would then continue up in front of the ears and under the hair which grows from the front part of the head, thus forcing it into prominence. It would

then join over the crown of the head at the back, causing not only the white patch there but the 'pinched' effect by which the head narrows to a point at the top. If the shroud had simply gone straight over the head back and front one would surely have expected it to show a more or less continuous width of hair across the top. But if at this point the hair has been pressed in to follow the shape of the skull, this could explain the narrowing effect. So if I am right the presence of the jaw-band would be reflected on the Shroud, not only by where it directly touches it but still more by what it retracts and thus does not allow to show up.

That the sudarion was a jaw-band has been recognized by some commentators from the New Testament material alone (e.g. J. N. Sanders). It seems an altogether more likely interpretation of the Johannine evidence than that it refers to some purely hypothetical turban-like object collapsed in upon itself such as H. Latham presupposed in his famous chapter on the witness of the grave-clothes in The Risen Master. This in any case would be described as going 'round the head', which John does not say of Jesus, and could not possibly be said to go 'round the face', as he does say of Lazarus. But though the Turin shroud is not itself required to establish this point, it has certainly helped me to envisage more clearly what the function and position of the sudarion must have been. This again is not, I suggest, how any forger would have thought. He would have imagined it lying over the face, rather like the bogus St. Veronica's handkerchief, and incorporated its image on a separate piece of material.

But in what position are we to suppose that the sudarion was subsequently found? This depends on what picture the fourth evangelist is intending to present. That he means us to draw the conclusion that the grave had been rifled and the body removed from the clothes (as his expressions would allow) is clearly impossible: this first and most natural explanation is firmly corrected. Does he intend us to suppose that the grave-clothes had been left behind undisturbed in their original positions, the body having passed through and out of them, as Latham and many others argued? I had always assumed this was his intention but I am not so sure. He could of course have imagined the body passing through the clothes as later it did through locked doors (20:19,26), though why then was the stone moved away? Dematerialization is I suspect a modern way of envisaging the relationship between flesh and spirit, matter and energy, of being 'changed' or 'clothed upon' with a body of 'glory'. How a first-century Jew would naturally have envisaged resurrection (though this does not of course mean that this is how it actually

happened) would surely have been as a corpse waking up from sleep, like Tabitha in Acts (9:40), as indeed Jesus predicts of Lazarus (John 11:11), and then like Lazarus walking out of the tomb. The difference in the case of Jesus was that the grave-clothes did not need to be taken off him nor the stones removed: he did it himself. For, unlike Lazarus, he was not simply being restored to the weakness of a flesh-body. In the power of the Spirit he broke the bonds of death, because it was not possible for him to be held by it. Far from being viewed as helpless and naked, he would probably have been envisaged in robes of light like the angels at the tomb, as in the vision of the risen Christ in the Apocalypse (cf. especially Matt. 28:3 with Rev. 1:14). Something like this seems to have been imagined by the apocryphal Gospel according to the Hebrews where Jesus, having apparently divested himself, hands the sindon to the servant of the (high) priest. The same seems to be true of most exegetes until recent times (and even they are much divided). Thus Chrysostom makes the point that the arrangement of the grave-clothes argues not that they have not been moved but that it could not have been the work of robbers, who would either have taken them with the body or left them in disarray. Bengel, the great eighteenth-century commentator, says that it means that they were not 'thrown off in a disorderly or hasty manner: the angels doubtless ministered to the rising man, one of them composing the linen cloths, the other the napkin!'. Godet at the end of the nineteenth century says, 'The napkin especially, wrapped together and carefully put aside, attested not a precipitate removal, but a calm and holy awakening', and Westcott takes the same line. But one is bound to admit that the tidiness of the arrangement lies more in the eye of the beholder than in the Greek. Moreover, if the clothes had been left in position the sudarion would not have been separated from the rest in a place by itself, but been between the two layers of the sindon. To attempt with Père Lavergne, to make the Greek mean that it was not in a place apart but was 'on the contrary wrapped (in the shroud) in the same position as it had been' is I think a desperate expedient. If this is what the evangelist meant to say his language is not merely loose but positively misleading. I think indeed that he intends us to infer that while the othonia were lying flat the sudarion was still in its twisted oval shape (as it could have been however it was removed). But that the latter was inside the former is an impossible deduction.

Finally, what difference would the evidence of the Shroud, if genuine, make? It certainly supports the tradition of a tomb found empty and of grave-clothes separated from a body. For how else would this shroud, unlike others, not have disintegrated with the



body it wrapped? But I cannot see that it adds anything to the picture of how they became separated. It is obviously compatible with the apocryphal legend to which I have referred. Above all I do not think that it necessarily presupposes, let alone 'catches', some moment of dematerialization. The marks might conceivably have been left on the surface of the cloth by some kind of paranormal, though not necessarily miraculous, radiation from the body during the period when the two were in contact. Why they became separated, the Shroud, even if genuine, does not seem to me to indicate. I am not convinced that it rules out the removal of the body after it had left its record for the puzzled sleuths of this and every age. In fact it provides no knock-down proof of resurrection, and faith would surely not wish to have it so. What it has done, if genuine, is to take us into the tomb itself during those thirty-six hours. And this none of the canonical Gospels do. It is a unique story, complete with exclusive picture. But the picture is the latest and final testimony to the past. It is of the dead Jesus, however vivid and majestic, not of the living Christ. Yet if in the recognition of the face and the hands and the feet and all the other wounds, we, like those who knew him best, are led to say, 'It is the Lord!', then perhaps we may have to learn to count ourselves also among those who have 'seen and believed'. But that, as St. John makes clear, brings with it no special blessing (20:29) — rather special responsibility (17:18-21).

## THE SHROUD'S HISTORY BEFORE THE 14TH CENTURY

By Ian Wilson

A significant part of the mystery of the Shroud is the fact, that, like an iceberg, most of its history lies beneath the surface and unknown. Yet it is an unknown for which if there is a genuine scientific case for authenticity we have to try to explore.

Let me therefore recap on what lies above the surface. We know that the Shroud was brought in 1578 to Turin (figure 1) where it has been ever since, apart from the last war. We know that before then it was at Chambéry (figure 2) in the Sainte Chapelle. Here in 1532 it sustained the disfiguring burns during a chapel fire. Owned at this time by the Duke of Savoy we know that in 1453 they acquired the Shroud from the de Charny family, and we can trace it back for about one century more in the possession of this family, at Lirey, near Troyes in France (figure 3).



Fig. 1. Turin, Italy



Fig. 2. Chambéry, France

At Lirey there seem to have been two significant expositions of the Shroud, one set about 1389 at the time of a man we may call for clarity Geoffrey II de Charny. In the earlier set of expositions, the cloth appears to have been directly claimed to be the Shroud, causing disbelief on the part of the local bishop, Henry of Poitiers. In the second set of expositions, Geoffrey II appears to have been more circumspect. He obtained Papal permission to call the cloth merely a "figure or representation" of the Shroud, in fact a somewhat farcical formula as he then went on to exhibit the cloth with all the pomp and ceremony as if it really was the true Shroud. This was not lost on the bishop of his time,

Pierre d'Arcis of Troyes, whom de Charny didn't consult about the matter. D'Arcis complained loudly to the Pope, whose response was to tell d'Arcis to be forever silent about the matter. But d'Arcis would not be silent. He sent a document (a very strong memo) that



Fig. 3. Lirey, France



Fig. 4. Photograph of the Shroud Face



Fig. 5. Faces of Christ in Art



Fig. 6. Painting by Jan van Eyck



Fig. 7. Byzantine Face of Christ



Fig. 8. 6th Century Byzantine Vase

has been the trump card of those who hold that the Shroud is a forgery — a Memorandum stating forcefully that back in his predecessor's time the Shroud had been virtually proven to be an adulteration, the de Charney's seeming to have offered no proper explanation for how they, a comparatively humble family, had acquired a relic that if genuine would be worth a prince's ransom, and had never been heard of before. Now unfortunately the circumstances of the earlier phase of expositions are obscure, as we know about them only from d'Arcis (writing about forty years later). Several authors have assumed that the Shroud came to light in 1353 because Geoffrey I de Charney founded a church for it in that year. (This was the church that the shroud was subsequently to be exhibited in). But the matter is not quite as straightforward as that. Although the documents of the church's foundation and subsequent consecration in 1356 have survived, they carry no mention of the Shroud, which normally they would be expected to do. Furthermore in May 1356 at the time of the consecration bishop Henry of Poitiers (the one who made all the complaints in the first place) is recorded both as present and liberally praising Geoffrey I for his work, strongly inferring that the expositions, and Henry's subsequent ire, had not yet occurred. Yet four months later Geoffrey I de Charney was dead, killed on the battlefield of Poitiers by the English, and it seems very unlikely that there had been time in the interim for the expositions, suggesting in turn that these may have taken place sometime after Geoffrey's death.

The trend of the evidence is that Geoffrey had been making preparations to hold expositions but never had the opportunity to do so in his lifetime. Nor, in the interim, did he publicly reveal that he had the Shroud. This suggests strongly a certain reticence, a guilty secret about the cloth — either that it really was a forgery, or that there was some murky matter associated with its past that could not be disclosed.

Now if from all the independent scientific evidence we believe the Shroud to be genuine, we are bound to back the "murky past" theory, and this is where the going gets very rough.

If we look before the 14th century for references to shrouds bearing an image, the 1300 years before the time of Geoffrey I de Charney are very, very silent. There is a shroud mentioned in Jerusalem in the 7th century, but from no point of view is it identifiable with the cloth we know in Turin. The only viable reference there is is one lone account of a French Crusader, Robert de Clari, in Constantinople in 1203 who said he saw there what he called a sydoine on which the figure of Christ could be seen. The

very isolation of this account has led historians to conclude that this Crusader must have been mistaken, and that the Shroud itself is, bluntly, a 14th century forgery.

This was the problem I began (to look at) ten years ago. The particular issue that intrigued me was the face on the Shroud and its reminiscence of two things:

1. The likeness of Christ in art which, displaying a strong resemblance to the Shroud, could be traced back long before the 14th century.
2. The tradition of Christ imprinting his face on cloth, as in stories such as that of Veronica's veil. (figure 4)

As there is no record in the gospels of Christ's earthly appearance, nor is there an unbroken artistic tradition from the 1st century A.D. of what Christ looked like, it seemed to me that if the Shroud was genuine it must somewhere, somehow have been an influence on both of these. A viable method of research seemed to be to try to trace back likeness and cloth traditions to see what they led to, whether there was some known common source that could be identified which might not at first sight appear to be the Shroud.

The first aspect I tackled was the Christ likeness in art (figure 5). On these examples of Medieval and Renaissance likenesses, note the compatibility with the face on the Shroud. The type of Christ portrait I was particularly interested in was this bearded, rigidly front face example (figure 6), and although Jan van Eyck painted this in the 15th century he is known to have derived the likeness not from the Shroud (at least directly), but from similar rigidly front facing examples in Byzantine art going back to the 11th century (figure 7), even as far back as the 6th century (figure 8), as in this Byzantine vase portrait from Syria. Compare the 6th century vase and the face on the Shroud and it looks very, very strongly as if whoever created this knew of the Shroud. Now an important discovery was that this type of likeness did not extend further back than the 6th century (figure 9). When one looked at earlier likenesses such as this 4th century example from a mosaic pavement in England, Christ was represented as Apollo-like and beardless, and yet we know it is Christ from the monogram. There were many similar examples of this type (figure 10) together with some vague bearded examples which had nothing of the definition of the 6th century and post-6th century likenesses. It all seemed as if no-one was sure what Jesus had looked like before the 6th century (except of course in the time of the apostles), and this is confirmed by a passage from St. Augustine in the 5th century who said quite bluntly "we know not his earthly appearance, nor that of his mother."



Fig. 9. 1st Century Apollo-like Christ Mosaic



Fig. 11. Roman Catacomb Christ and the Shroud Face



Fig. 10. 1st Century Beardless Christ

So it seemed that the likeness of Christ identifiable with the Shroud had emerged at one clearly determinable point in history, the 6th century. This was at least a background of fact on which to build.

One other aspect suggested that this method of research was along the right lines. Back in the Thirties, a Frenchman, Paul Vignon, had been struck by certain oddities in Byzantine Christ portraits of the front-facing type: intriguing markings to the face which he thought might be traceable to oddities on the Shroud (figure 11). A typical example was this Catacomb portrait from Rome, of the 8th century. Vignon noticed on this a curious topless square between the eyes, a most

odd feature for an otherwise competent artist to include. He looked at the Shroud, and found an identical marking in the same place, an as yet unidentifiable irregularity of the image.



Fig. 12. Shroud Face 10th Century St. Angelo

This was not an isolated instance. Other portraits such as this 11th century example (figure 13) from Daphni, near Athens, exhibited the same feature, generally in a more stylised form, but what made this line of thinking particularly significant was the discovery of some fifteen or so other features (figure 12) — a raised right eyebrow, a small triangle below the forehead, heavily accentuated eyes, an enlarged nostril, a hairless gap between lip and beard, exaggerated cheek markings, all of which seemed to occur with otherwise inexplicable repetitiveness in Byzantine portraits, and which seemed to be derived from the Shroud. (As in this 10th century, St. Angelo in Formos,

Italy). The point Vignon never managed satisfactorily to explain was how, if the Shroud had had this profound influence on art that his work seemed to indicate, it could have remained apparently so unknown in history.



Fig. 13. Face of Christ from Daphni near Athens, Greece



Fig. 14. Veronica's Veil being held by a pope

This is where I tried to push the argument further, and look in parallel at the tradition of Christ impressing his likeness on linen cloth, as on the Veronica (figure 14), seen here as the cloth relic looked in the 14th century, (being) held by a Pope. This so called Veronica cloth would seem to have been destroyed in 1527, there remaining in the original reliquary merely some form of cloth, but without an image. This was confirmed in 1907. We can trace the image-bearing cloth in Rome back to the 11th century but no further, and it would seem to have been merely a copy of an apparently similar looking cloth with a much longer history kept at that time in Constantinople. Here I am absolutely one with Dr. Robinson in dismissing the Veronica as in itself 'bogus.' Now, independently, the same applied to the tradition of Veronica. The concept of the



Fig. 15. Artist's rendition of the Mandylion



Fig. 17. Sepia monochrome of the Mandyllion

woman dashing forward on the Via Dolorosa is late, 13th or 14th century. It's earlier form is a tradition merely of a woman Veronica possessing some form of cloth portrait of Jesus, and this can only be traced back to the 6th century as merely a Roman version of an early Eastern tradition about the same cloth just referred to as having been in Constantinople.

Now it is this ancient cloth in Constantinople that is the whole focal-point of this study, because everything seems to lead back to it. Historians are agreed generally that it was the inspiration of the Veronica tradition and subsequent "relic." And Byzantine/Eastern Orthodox tradition identifies this cloth portrait (in Constantinople) as the source of inspiration also for the likeness of Christ that we have studied in art.

What then did it look like (figure 15)? Artists copies are varied, but their consistent feature is a front-facing face of Christ, depicted in a sepia monochrome, set curiously disembodied on a cloth. Descriptions of the composition of the image are quite riveting. I quote from a 10th century document, "... a moist secretion without coloring or artificial stain . . ." The name eventually given to the cloth was the Mandyllion, also known as the image "not made by hands" of Edessa.

It was an undoubted historical object for a certain clearly definable period commencing with the 6th century, precisely the period we have seen the identifiable portraits tracing back to. At this time it was discovered in a niche above a gate of the city of Edessa (figure 16), a rather obscure little town now called Urfa in eastern Turkey. It had clearly been put in the niche, in which it was found along with a lamp and a tile, at some earlier period.

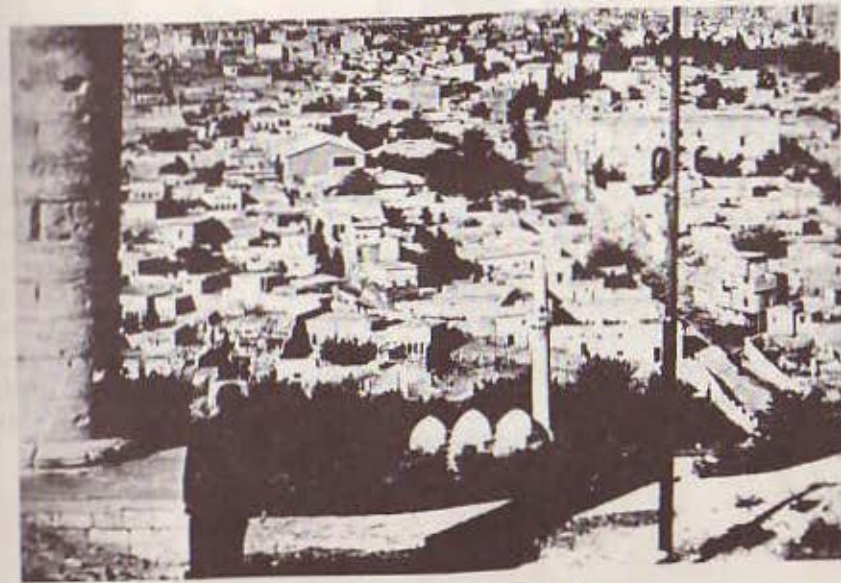


Fig. 16. Edessa, now Urfa, Turkey

In 944 it was transferred from Edessa to Constantinople from where, in 1204 it disappeared during the Crusader sack of the city. Subsequently one or two odd icons have been claimed to be the original Mandyllion but none have been conclusively identified as such.

Historically therefore, what is interesting is that the period of the known existence of the Mandyllion would fill in a very large gap in our knowledge of the history of the Shroud, if indeed this cloth was one and the same as the Shroud.

But was it the Shroud? There are large, apparent problems.

1. Artists copies and literary tradition alike suggest that there was no more than the face of Christ on the Mandyllion. (figure 17)
2. Artists copies show Jesus' eyes open and staring on the cloth, as if alive. This is corroborated by contemporary ideas of how the image had been formed — one version suggesting that Jesus had asked to wash himself and then imprinted his likeness on the linen towel, another that the image had been created at the time of the agony in the garden, when St. Luke described Jesus' face streaming with a blood-like sweat, Jesus again creating the imprint by wiping his face on a linen cloth.
3. There is not the slightest idea from the documents of the time that the Mandyllion cloth had been a burial wrapping.

These facts forced one into one direction of thinking only — that if the cloth described was indeed the Shroud, those of the time did not know or recognize it as such, something explicable only by some peculiar manner in which it may have been mounted already at the time of it's discovery.

Gradually a picture began to emerge. First, one 6th century account of the Mandyllion specifically described it as "doubled in four." I tried this on a photograph of the Shroud (figure 18). Doubled, then doubled again, the face on the Shroud emerged apparently disembodied, exactly as on the Mandyllion copies (figure 19). A scale model of the Shroud doubled in four shows the face disembodied. (You wouldn't have had the disfiguring markings from the 1532 fire). Next there was something significant about the early copies of the Mandyllion (figure 20) — those up to the time of it's disappearance. They showed the cloth apparently stretched flat and nailed by means of a fringe at each side. Literary accounts of the period confirmed this arrangement, specifically stating that the cloth was displayed stretched on a board. Access to the hidden folds might therefore have been impossible without dismantling.



Fig. 18. "Doubled in four" fold diagram



Fig. 19. Folded photograph of the Shroud

it might have been a depiction of the original cover or embellishment — and realized that if indeed there had been such a cover, with a folded cloth underneath, it would have effectively prevented anyone recognizing the Shroud as a shroud. There was one more feature to such an arrangement. Seen in isolation in this form the eyes on the Shroud, as visible on the cloth itself would appear open and staring,

And there was one further piece of information provided first by the literary accounts, and then by art. Tenth century documents described the image as having been embellished or covered with gold. At first I thought that artists' copies bore no visual clue to what the covering or embellishment might have been. Then recently one feature on the copies that had been troubling me suddenly made sense. — Most pre-1204 copies feature this trellis pattern. At first I thought it was a stylised way of representing the weave of the cloth, but it was too crude for this and too consistent from one copy to another. Then I began to consider whether





Fig. 20. Mandyllion with Gold trellis frame and fringe

as in life, a ready explanation for the early stories of how Christ had made the imprint. Note the Shroud positive how one might see the eyes as open (figure 18).

A clinching factor to the trellis-cover argument was the discovery in Parthian art of similar trellis-style embellishment used to adorn the costume of Parthian vassal kings. There is an excellent example of this on a Parthian statue of King Uthal of Hatra in Mosul Museum. For it was to precisely such a Parthian vassal-king of Edessa, Abgar V, a definite historical monarch that legend said the Mandyllion had been taken back in the 1st century A.D., there being extensive series of documents about a Christian mission to Edessa at this period. It was at this time that I believe the trellis cover was imposed, perhaps deliberately to disguise the somewhat unacceptable nature of the cloth as the wrapping of a dead body. Abgar would seem to have at least tolerated the Christians but one of his successors was less kindly disposed and began persecutions, which would have been about 57 A.D. It would have been in this episode that the Mandyllion/Shroud disappeared. The subsequent discovery in the 6th century of course meaning that those who discovered them would have no idea what had taken place beforehand.

There are many aspects which are quite impossible to deal with in the allotted time. Suffice it to say that late in the Mandyllion's stay in Constantinople someone appears to have undone the trellis cover and seen for the first time the full-length figure on the cloth. This is the implication from 12th century documents which suddenly actually describe a full-length figure on the Mandyllion, and from art



Fig. 21. Full length figure on an artist's copy of the cloth in Constantinople

of the time which suddenly begins to depict a figure of Christ (figure 21) with hands crossed over the loins in the characteristic (manner) of the Shroud. This would support the veracity of the French Crusader, Robert de Clari's description of the (figure-bearing) *sydoine* he saw in Constantinople in 1203. We have then the matter of the cloth's fate after 1204 when according to the Crusader, "neither Greek nor Frenchman knew what became of it."

This is the most mysterious period of all. But whoever came to possess it would seem to have possessed vast wealth, or otherwise they would have sold such a valuable relic; also they must have had some motive for keeping it secretly to themselves.

To me the prime suspects seem to have been the Order of Knights Templar, who had a great veneration for the Holy Sepulchre, and built for themselves vast fortresses so heavily guarded that they became the banks of Europe, and so mysterious that rumours began to circulate of secret Templar ceremonies at which some great relic was venerated, a relic which had the appearance of the face of an unidentified bearded man upon a panel.

In 1307 the rumours were all that were needed to give the King of France the excuse to lay his hands on Templar wealth by arresting every member of the Order, not without a struggle, a struggle in which the mysterious "idol" the Templars were accused of possessing certainly disappeared.

Just one clue survives to the appearance of the last Templar "idol," a clue found in the tiny village of Templecombe in England, once the home of a Templar preceptory. During the demolition of a cottage outhouse in the 1950's there came to light this oak panel painting (figure 22), undoubtedly Templar, answering exactly the documentary descriptions of the "idol" and with the uncanny appearance of being a copy of the face on the Shroud.



Fig. 22. Templar oak panel of the mysterious image



Fig. 23. Geoffrey De Charney at the stake

If the Shroud was indeed the idol possessed by the Templars, one further clue survives as to its fate. In 1314 two of the last Templar dignitaries were brought out to be burnt at the stake, proclaiming to the last their innocence (figure 23). One was the Order's Grand Master, Jacques de Molay, the other the Order's Master of Normandy, Geoffrey de Charny.

We do not know definitely if there was a family relationship between Geoffrey de Charny the Templar and Geoffrey I de Charny of Lirey, first known owner of the Shroud. But the likelihood is there. One may postulate the Shroud ripped or cut from its panel at the time of the Templar capture, stuffed under a jerkin, and spirited

away to safety with relatives of the Master of Normandy. The episode fits exactly the sort of murky past Geoffrey de Charny of Lirey would simply not have been able to reveal, particularly as a French King and Pope had been heavily implicated in the Templar demise.

Such is the bizarre chain of events that I believe constitutes the hitherto "lost" 1300 years of the Shroud's history.

## THE HOLY SHROUD ON TRIAL

By Dr. Anthony Sava, M.D.

For centuries the authenticity of the Holy Shroud has been on trial. Though long revered, every possible argument for and against authenticity was advanced, often exciting varying degrees of heat while at the same time failing to produce any lasting degree of light. Scholars of every discipline took sides but no verdict was ever reached that put the question to rest. With the advent of photography the tempo of what seems to us now to have been a smoldering debate took on a vigor heretofore unknown. The first photographs produced by Secondo Pia and the intensive studies by Delage and Vignon fired the interest of historians and scientists.

With his great prestige on the line, Professor Delage prefixed his assessment of the relic by stating that in spite of his being an agnostic, he was convinced that the image on the cloth could be none other than that of the historical Jesus.

It took very little time for eloquent and convinced scholars to bring the new knowledge to millions who had never heard of it. The nature of the image, the reputed antiquity of the burial cloth and the quite easily recognized details of the Passion from the scourging to the hasty burial, were so commanding that medical men lost no time and tried to analyze the image with faith in its authenticity which reflected their belief that the gospels were here detailed to a degree approaching scientific and legal certitude.

From the very beginning of this century, attempts to reproduce the photographic negative image were not very rewarding. Medical investigators, working with techniques and materials then known to them, wrote extensively but with limited objectivity. They seem to have become obsessed with images rather than any wish to formulate an explanation of the things they thought they saw. When they found themselves unable to relate the image to scientific truths

commonly accepted in their time, they resorted to near fantastic excursions which neither proved anything nor made the issues more clear.

Since 1898 the writings of Paul Vignon and Pierre Barbet have been rival companions to almost everyone interested in the subject. Of the two, the former adhered more faithfully to objective analysis while the personal piety and subjectivity of Barbet detracted materially from what he contributed. He took liberties which were far from being justified in order to make his position more acceptable. Nevertheless we cannot take issue with him because, in spite of his ardent desire to fathom the mysteries buried in the image of the Shroud, he was obliged to work within the limits of medical knowledge of his time and what handicapped him even more is the fact that by the time cadavers were available for his studies, the tissues already had lost the resiliency which is present only for a limited time after death.

Medical writings have not altogether cleared the air as far as satisfying the need for approaching some degree of agreement as to the appreciation of the Image on the Shroud and the factors which lie behind various patterns which make it, in terms of common medical experience.

It is the purpose of this discussion to avoid as much of the involved and intricate explanations so often found in the medical literature on the Shroud, mainly because it appears superfluous and confusing while too often not in keeping with anatomical and pathological conditions that most likely prevailed in the response of the body of the crucified to the torment imposed upon it.

There can be little doubt that the writings of Barbet brought the appreciation of the wounds of the Passion into nearer if not sharper focus. Readers become more knowledgeable as to the intense misery inflicted upon the crucified. However, the writer's personal piety clouded the boundary between subjectivity and scientific medical appraisal.

During the mid-nineteenth century, Stroud writing on the wounds of the Passion, stated that the heart of Jesus literally burst! It is inconceivable that in our day any medical writer would dare make such an assertion. It is commonly known that the human heart is not likely to rupture unless there has been severe structural damage of its wall from coronary artery occlusion or long standing syphilis. Others have been less reasonable than Stroud. One writer went so far as to state that Jesus was suffering from a mental derangement and also was a victim of tuberculosis. This so outraged Barbet, and well it should, that he refused to confer upon him the posthumous honor of being identified by name.

In 1930 Dr. E. Le Bec, a ten year senior to Barbet and associated with him at St. Joseph's Hospital, Paris, wrote a small work entitled "The Death on the Cross."<sup>1</sup> Le Bec's observations were poorly documented. His thesis often includes "must have been" and this in my opinion materially detracts from whatever a scientific thesis might claim. It was also far from being objective. Referring to the scourging, Le Bec wrote that the scourging "was one of the cruelest episodes of the passion," and "not infrequently prisoners died under the whip." It is strangely interesting that Le Bec explained that the water seen after the chest was pierced, was a "pleural exudate" . . . and "many people have thought that the lance entered the pericardium . . . we have no reason to suppose so."

He did not pursue this concept further; yet, he did indicate that "the presence of fluid, not related by him to the Crucifixion, would increase the suffering of the crucified, by impeding the action of the heart and making the respiration more difficult. In conclusion of this account, he states "It was thus, to nervous exhaustion that our Lord succumbed."

In our day, medical certification of death from "nervous exhaustion" is not acceptable.

F. La Cava<sup>2</sup> wrote in greater detail a medical thesis of the Crucifixion than did Le Bec. To him, crucifixion produced a state of distention of the thorax coupled with a marked retraction of the abdominal wall. This near fixation and immobilization of the chest and abdomen was seen as a major factor in producing respiratory distress which La Cava believed brought on the anoxemia and chemical disturbances associated with a derangement of the oxygen-carbon dioxide balance resulting in tetany. Allowing for some degree of tetany we must observe here that death is not a close follower of tetany seen in medical practice. Nevertheless, La Cava stresses the rapid onset of death in the case of Jesus. The same author then proceeds to point out that the "water could not have come from the pleural cavity but may well have originated in the pericardial sac which usually contains about 10 c.c." His difficulty is not apparently resolved for he concludes by saying that "therefore the theory that the blood and water came from the pericardial cavity is not scientifically maintained."

When La Cava tried to reproduce the blood and water sequence, the water issued first then the blood. As a result he felt obliged to report that too often the results of experiments are in reverse to what actually occurs in nature and that his results contradicted the gospel narrative! He went no further. Barbet and later Judica-Cordiglia took up the problem. Before detailing his own experi-

mental observations, Barbet stated: "It is possible, as Judica maintains that hydropericardium was the result of traumatic pericarditis caused by violent pain and anguish, but we cannot imagine that it precipitated the rapid death."

As to the "exact" cause of death, Barbet<sup>3</sup> was in total agreement with his former mentor at St. Joseph's Hospital. Le Bec had pointed out quite categorically that the death of Jesus was due to the general muscular tetany secondary to the position on the cross. Barbet considered this verdict to be "precise, exact and complete!" The fact that neither Barbet nor any of the medical writers on the subject placed much importance on the flagellation as being responsible for the early death of Jesus is most puzzling. What is even more bizarre is their failure to suspect that effusion into the pleural cavity may follow trauma to the chest wall.

The answers to my questionnaire sent to a number of outstanding thoracic surgeons leave no doubt that:

1. Repeated concussive blows on the chest wall may result in a bloody effusion within the chest without rib fracture or penetrating wound.
2. The bloody fluid collects between the outer surface of the lung and the inner lining of the chest wall.
3. The lung is compressed by the growing volume of fluid.
4. No clotting takes place so long as there is no access of air. This is true of blood collected in any closed cavity of the body.
5. The haemorrhagic fluid settles into two layers: the heavier (blood cells) below while the lighter collection remains above.
6. Pleural effusion caused by trauma to the chest wall is ten times more common than pericardial effusion.

This is not mere theory, but is instead the experience of specialists who see a large number of cases of chest violence in the course of routine practice. There seems now to be no difficulty in appreciating how the progressive increase of fluid will surely usher in death, by smothering or asphyxiation.

For many years I have been especially interested in the cause of death of Jesus, as expressed by medical authors. I have failed to find any so simple and so faithful to basic anatomical and physiological teaching of our day. My past utterances based on personal observations of chest wounds and experimentation with fresh cadavers were unheeded for a long time. However, in 1969, Dr. David Willis<sup>4</sup> wrote that my theory explaining the blood and water issue "best illustrates St. John's observation."<sup>5</sup>

My analysis of the long elusive manifestation is very simple to understand. In fact, I wonder how it escaped the past writers on the subject. It avoids the intricacies of hypothetical and complicated little understood changes in the bodies of persons who suffer violence. One might be justified to say that by its very simplicity, it deserves serious consideration.

Furthermore, it eliminated the need of a "tunnel" so necessary to support Barbet's contention that the wound through the lung made by the lance remained "gaping" and it was inevitable that "once the heart was pierced, blood coming from that organ had to make its way through the wound to the outside." This seems to me to be nothing more than superfluous propping, in order to justify Barbet's preconceived notion of what actually occurred.

Rather than ignore the claim of the French surgeon, I repeated his experiment on a fresh lung, less than twelve hours after death. To make certain that my knife passed through the lung and into the cavity of the heart, I removed enough of the front wall of the chest and exposed the lungs and the pericardial sac without disturbing the sac or the heart within it. Under direct vision I passed the long amputation knife through the chest wall, the right lung and into the heart. Nothing was seen coming from the heart chamber or the sac of the pericardium. Upon withdrawing the knife, it was not possible to locate on the surface of the lung any sign of the wound made by the knife only moments before. I saw no evidence of the "veritable" tunnel which seemed so important in the analysis proposed by Barbet. Several 35mm slides were made to record the findings which I trust will have sufficed to close the issue of the "gaping tunnel." The reason for my very contradictory findings as opposed to those of Barbet is that I had the great advantage of experimenting with bodies whose tissues had not lost their resiliency before the experiments were carried out.

In 1951 Doctor Barbet invited me for a discussion with him at his home in Paris. He was extremely charming and courteous but not more receptive to my conclusions than he had been toward those of Hynek. To my utter amazement he asked me not to publish any of my findings because "they were absolutely wrong. Besides, my findings were proven correct by the very wide acceptance by the experts!" He explained further that he had done his experimental work more than twenty years before and he was no longer young and therefore unable to become involved in any revival of controversy. In all kindness to Dr. Barbet, I confess that such an attitude is far from scientific. As I saw it then and still do, truth in such matters, is not determined by the degree of public approval nor by the longevity of a belief that unfortunately has a way of becoming enshrined, arbitrary and dogmatic.

Another area in which I found myself quite alone, but nevertheless very defensible, was in the analysis of the area of the wound of the nail in the wrist. The Shroud Image does not pinpoint the very spot through which the nail passed. The dark area may well have been somewhat differently spread before the body was taken down from the Cross. We do not exactly know in what manner the rigid, lifeless body of the crucified was carried from the cross. If those charged with the carrying of the body to the tomb were as reluctant to handle bloody, mutilated flesh as their people are reputed to have been, then we might allow that the need for secure grasp of the wrists might have required them to be wrapped by a turn or two of cloth as a bandage beneath the palm of the carrier hand. Close examination of the area on the large photographs of the Shroud reveals a clear area about as wide as the width of the palm of the hand. Any blood from the nail wound might certainly be taken up by the cloth which temporarily covered the wrist area during the carry.

The palm has long been discarded as the likely area for the nailing of the upper limb. Early in our century, the "Space of Destot" was chosen as the site for the transfixion. Barbet, his contemporaries and followers, claimed that such a site was ideal for the purpose. According to them, it was more secure by far than the traditional area of the palm. Barbet took great pains to detail his defense of this location and included in his published work, schematic and radiographic illustrations.<sup>6</sup> While these represented lateral and anteroposterior views of the area, they conceal, admittedly without intention, the very reason why I failed to agree with Barbet on the choice. An examination of an orthographic film of the wrist reveals that the so-called Space of Destot measures only 2 mm. in any direction. In order to pass a nail with a diameter above 2 mm., the space has to be widened to accept it. This can only take place at the expense of the very short ligaments which bind the carpal bones one to the other. The separation of bones and adjacent to the space is unfortunately not shown in Barbet's illustrations, but is hidden instead by the opacity of the nail. Once again I repeated the work of Barbet and avoided what I felt was an error on his part. I first secured an orthographic plate of the wrist. I then passed a heavy Kirschner wire through the space, using the fluoroscope to be certain that the wire avoided damage to any of the small bones in the area. With the Kirschner wire in situ, the heavy 9 mm. nail was passed from the palmar to the dorsal surface of the area. The effect of this as seen on the X-ray was more surprising than I had expected. Following the removal of the nail, the radiograph revealed a valley-like separation that had been produced by the nail. What was even

more astounding was the fact that the long axis of the valley separation was in the very direction of the pull of traction through the forearms while the body hung on the cross. One could not overlook the fact that a nail introduced in the area heretofore defended by writers could offer no greater security against tearing away than the transfixion through the middle of the palm.

Had the nail been passed through the space between the lower ends of the radius and the ulna, there could be no risk of separation from the cross. The reason for this lies in the fact that the lower ends of two bones are virtually fused as they contact each other at that point, thus forming a bony bridge quite capable of supporting far more than the weight of a hanging body. This would place my site selected at a very short distance above the line of the wrist joint. Any anxiety concerning a conflict between this and prophecy will promptly disappear when we realize that the Aramaic word "yad" is translated as *Manus, et carpus et brachium anteriore*.<sup>7</sup> The appearance of the dark transfer terminating at a little distance below the lower end of the interosseous space is not sufficient to disqualify that space for reasons given.

As one who has happily devoted many years to the study of the Shroud, I am thrilled to learn of the participation of more and more highly competent men from various scientific disciplines. Research and study never were nor can ever be a private domain and the findings arrived at need to be pooled, in order that the accumulated knowledge of the Shroud and its message for all men and for all time may enrich the lives of the "harvesters and the sharers" that we are.

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# HISTORICAL, MEDICAL AND PHYSICAL STUDY OF THE HOLY SHROUD

By Monsignor Giulio Ricci

## Introduction

Ladies and Gentlemen, Members of the Organizing Board, Dear Colleagues of the Holy Shroud Guild, I am happy to bring to you the greetings of the Roman Center of Sindonology as the Roman Delegation of the International Center of Sindonology of Turin and their Representative at this Congress. The Executive Secretary of the Roman Center of Sindonology, Maria Elisabetta Patrizi, will present in English my report. This report is the summary of 27 years of attentive reading of the Holy Shroud. I present myself, therefore, as a Reader, in the classical, traditional sense, reader of a document that must be minutely examined and analyzed as a necessary preliminary before we set out to plan future research. This, to my mind, is essential if we want our findings to be really correspondent to the document itself.

Before proceeding with the aesthetic analysis of a message transmitted by a paleographic document, it is indispensable to proceed with the reconstruction of the text, carrying out a grammatical and logical analysis, in order to obtain the message itself beyond any shadow of doubt. In the same way, it seems to me, it will be necessary to proceed with the examination of this strange paleography, written perhaps in letters of blood for the purpose of deciphering its marvellous contents: it might be the good news of the Son of God, who became incarnate, died and rose again for the redemption of the world.

I am limiting my study to this "elementary grammar" as a condition to proceed with the logical connection of the facts in order to limit them to the time and place to which we can attribute them.

A curious premise, which, however, is not just a curiosity, concerns the excessive length of the Turin Shroud. At present, it is 4.36 meters by 1.12 meters. Until 1247, it was roughly about 5 meters; in that year, in fact, the emperor Baldwin II sent from Constantinople "partem Sydonis" to his cousin Louis IX of France. The relic was placed in the "Sainte Chapelle" in Paris. Speaking of this relic, Bergier says it was "un grand lambeau de linceul" (a large piece of shroud — about 14 inches.)

We find a confirmation in the measurement of the Shroud made by Arculf in Jerusalem, in 670, when the linteum maius bearing the figure of the Lord, was found to be eight feet long (but of the Normandy foot which is about 29.4 cm. long), equal to 2.50 meters. This measurement suggests a length of 188 inches (but we have to add the piece cut off in 1247) since the Shroud, as seen later in Constantinople was obviously presented to the veneration of the faithful folded in two, in view of its exceptional length. In other words, our measurement corresponds to the Shroud of Turin plus the piece that was cut off.

Further confirmation can be obtained if we add the information given by Isidorus about the "Crux mensuralis" of Justinian (527-565), a cross of gilt silver, made "ad formam corporis Christi" according to measurements taken by persons he had sent to Jerusalem, to obtain from them the stature of Jesus. In fact, only from the figure imprinted on the Holy Shroud, measured on the front and back parts (dividing by two and subtracting the 25.4 cm. of the sole of the foot) could they have obtained that height of 180 cm. for the "Crux mensuralis," which was venerated in Constantinople and of which we have the measurement to scale, made by a pilgrim before its disappearance from the treasury of St. Sophia.

The same result is obtained today if we measure the two imprints by the formula  $((204+208)/2)-25=181$  cm. of the Turin Shroud.

These two arguments, stemming from an elementary internal examination, border on the curious but they link together fourteen centuries on the much discussed problem of the transmission of the document in question.

The first objection that comes to mind is the fact that the person who bought this Shroud was well aware that it would be used to wrap a corpse whose clothes had been divided among the soldiers; a corpse, therefore, that was completely naked, for a hurried burial rite, in view of the imminence of the Sabbath: it was to be used as a temporary covering. For a normal burial on the other hand, a shroud of just over 3 meters was sufficient to wrap round the body (already

washed 7 times, beard and hair completely shaven, sprinkled with spices and dressed in its clothes), leaving the face bare; the latter would be suitably covered at the last moment with a napkin costing a shekel.

That the Holy Shroud was used for this type of temporary burial while waiting for the second definitive phase, as permitted by law for persons who died on Friday, is shown, not only by the morphology of the whole imprint, which reveals a body that had not been washed, but also by the fact that the Man of the Shroud has a beard and a fine head of hair, which someone had lovingly combed at the end of that first Good Friday. (Figure 2:1, 2, 3, 4, 5, 6).

### Hermeneutics of the Writing in Blood: the Scourging

But the internal examination of the relic becomes very important when compared with the Gospel account of the Passion.

The exceptional elements are constituted by those very facts that are considered normal in the Gospel story, but which, from the archeological or exegetical standpoint, are real exceptions either because of the fact itself or because of the way it was carried out.

The scourging: The scourging in itself, is clear from the Gospel narrative was supposed to be a punishment in itself, before release; however, the way in which it was carried out, in this case, interests us closely.

According to the Gospel, the scourging was to be exemplary. A "lesson," the Greek text says, but it was not to result in death: this was the precise will of the judge, who wished to set the prisoner free, having found him innocent.

This exemplarity and this will to set free are precisely and unexpectedly confirmed by the internal examination of the Shroud. As regards the former, we can appeal to the very large number of wounds, inflicted systematically on nearly every part of the body. There are over two hundred and twenty of them. This scourging, therefore, was carried out according to canons of a procedure not limited by number, therefore in the Roman way. Whereas the Jewish procedure would not have permitted more than forty lashes "lest your brother be degraded in your sight" (Deut. 25,3; 2 Cor. 11,24).

"Horrible scourge": But, as it seems, the Romans must have been far less pitiful and more expert than the Jews if they were able to leave the victim alive in spite of the large number of lashes. In fact, the only part untouched is the part in front of the pericardium; the skill of the scourgers enabled them to direct their blows where they wanted, while their experience prompted them not to hit in

that area, the most delicate one, to avoid death which, in the judgment of doctors, would have occurred from traumatic serous pericarditis. In this case the scourgers themselves would have had to answer personally to the judge.

But other interesting particulars emerge from examination of the Shroud. The type of scourge is the "flagrum taxillatum," the "horrible scourge" (Horace), which excludes the possibility that the Man of the Shroud was a Roman citizen, in which case rods had to be used.

The blunt parts, consisting of pointed little metal spheres or animal bones, placed two by two along the line of the three strips of leather or cord, have marked two precise semicircles of blows, converging at two focal points, which while they reveal the number of the scourgers, show that this type of scourging, with its geometric precision, was quite different from the one normally inflicted on those condemned to die on the cross. In the latter case, in fact, the scourging took place while the victims were on their way to the place of execution, naked, with their arms bound to the cross on their back: and therefore without any geometric order (see figure 1).

But the language of the Shroud becomes even more precise when it shows us, in the left scapular area and above the right one, which were in contact with the heavy cross, two large contusions, with the marks of the flagrum clearly visible: it is clear that they had been inflicted before the cross was attached to the back. This before and after is a nicety in full agreement with Pilate's subsequent capitulation before the crowd, when fear of being involved politically with an alleged "king of the Jews" (Rome did not pardon such weaknesses!) induced him to make a second pronouncement: "ibis ad crucem!" (see figure 2).

Thus the Shroud, too, offers documentation that the promised release was not granted to that scourged man. At this point research adds to its wealth new and revealing elements: blood trickles that are very evident in the scourged areas were less subjected to absorption by a robe put on him after the flogging — for instance the legs.

The device of observing the photographs in transparency, illuminated from behind, makes the phenomenon more evident. The documentation consists of a few marks which clearly appear to be a double flow of blood gushing from the same source, the components of which vary: 100°; 90°; 30° (see figure 2).

If we want to trace the origin of this fact we must come to the conclusion that the phenomenon is due to the position of the victim's body during and after flagellation. The side flocked with



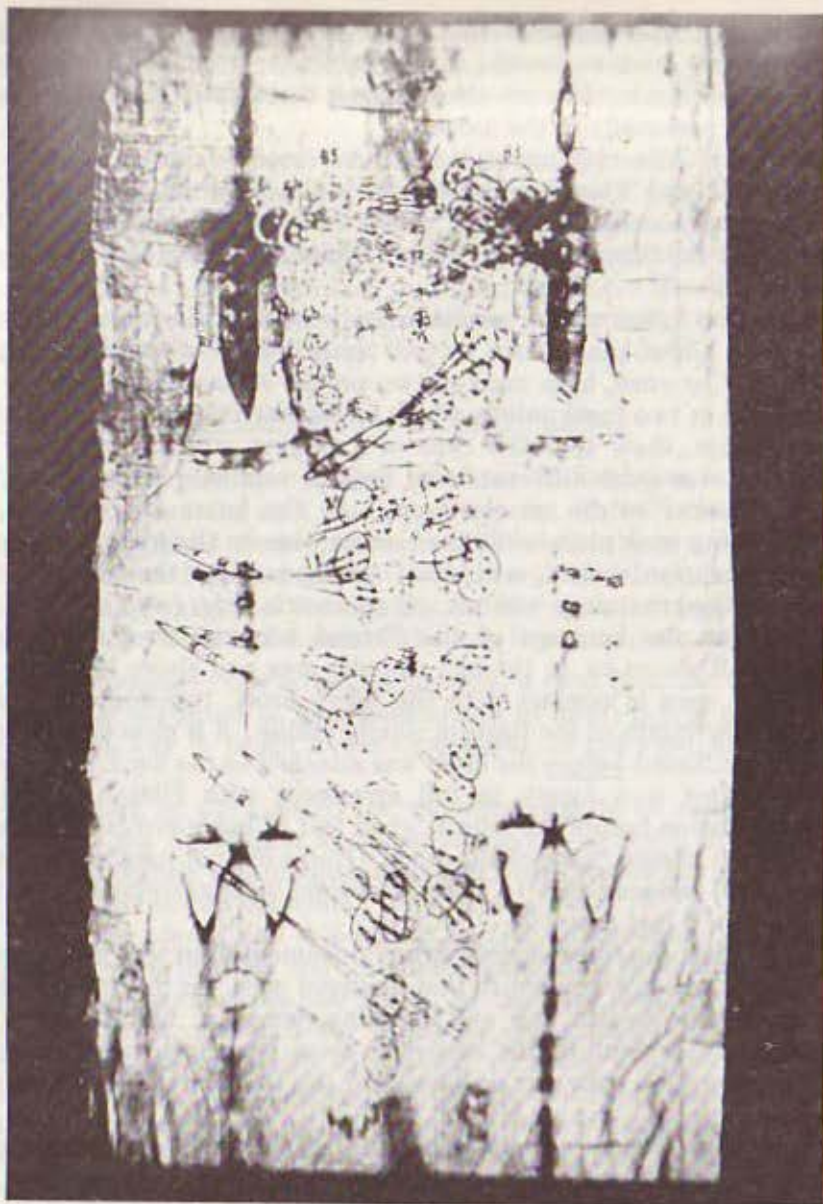


Figure 1. Scourge Markings



Figure 2. Blood Goniometry

blood seems to indicate that the victim's back was exposed to the flagellators almost bent at a right angle, and that when, instead, the body resumed its normal upright position, the blood from the same wounds, produced by the "flagrum," flowed out in an opposite direction, that is to say vertically.

\* Even a different goniometry has a logical explanation that might interest those who would like to reconstruct the victim's exact position during and after flagellation. In fact, in the drooping parts or the thorax, at the level of the scapular triangles, we observe a few of these trickles, goniometrically calculated around 90 to 80 degrees, an angle which, as the phenomenon repeats itself, gradually descends to 45 degrees in the gluteal areas.

It is therefore easy to opt for a right angle position of the thorax related to the inferior limbs during flagellation, which alone justifies the evidence of blood, that according to normal physical laws, flowed out sideways from the wounds of a drooping thorax, after flagellation, when the thorax was restored to an upright position, the blood of the same with still wide open wounds took the correspondent vertical position.

### The Tiny "Blood Roses"

Let us transfer our attention to the central part of the thorax's dorsal impression and we will find that the blood trickles strangely confirm this interpretation of the body being bent over during flagellation. The photographs taken with ultraviolet rays prove it. If we circumscribe the small zones which came into direct contact with the "flagrum," we immediately observe the morphologic difference between these, which appear to be endowed with a small halo of ematic substance, and the side ones, examined above. The flagrum's strokes of the latter, in fact, do not show these tiny "roses of blood" but just blood trails that are more filliform. In my opinion, the explanation consists in the fact that the blood from the wounds in the drooping part of the thorax hit by the "flagrum taxillatum" flowed out immediately, according to physical laws, while it stagnated in the spine area and only later when the victim was detached from the column and assumed the upright position, did it flow vertically, leaving the mark of those "small roses of blood" and quantitatively more plentiful trickles.

### Survey of the Top Part of the Shoulders

A further confirmation as regarding the body's curved position during flagellation can be found when examining the ramified marks on the dorsal impression of the top part of the shoulders, which also appear to have blood residues — and their typical carmine-mallow colouring would prove it — that converge into one point and which would seem to fit in perfectly with the hypothesis of the two positions described above.

It is obvious, in fact, that in the above area, which corresponds to the top part of the shoulders, when the body was bent over, blood would flow out of the wounds toward the front part of the thorax, while when the body stood upright, the blood from the same wounds would flow out vertically towards the dorsal area. This is what may be proved in various points where the convergence, as well as the direction of the flows, seem to confirm the exactitude of the interpretation with a further nuance which could reveal a few movements connected with the violence of the pain. Also, let us examine carefully points 1, 2 and 3 of my figure;\* the convergence of the blood trickles implies a common origin, but also reveals a different lateral curvature of the shoulders, due to their alternate lowering. I don't think, in fact, I would be far from truth in attributing this to an instinctive, very human, movement of self defense, withering under the blows of the terrible scourge. It is good to remember that the bent down position of the head, documented by the Holy Shroud, and

\* figure 32, page 59, La Sindone Santa, Edition, Centro Romano di Sindonologia, 1977.

and maintained also in the sepulchre, facilitated the wrapping of the sheet on that part of the body and therefore, with the contact, also the possibility of documenting the top part of the shoulders.

### The Gluteal Region

Let us now concentrate our attention on the central area of the back imprint before examining the lower limbs. In addition to the numerous marks left by the scourge, our attention is attracted by those four or five characteristic marks with the shape of small, more or less accentuated, trickles, located immediately above the left gluteus and in the superior and central part of the large right gluteus. Superimposing the skeleton of a man of the same height as the Man of the Shroud, we may observe that n. 1 corresponds to the space immediately above the hipbone (see my figure\*). Let us return to our hypothesis of the bent over position of the scourged man; having already ascertained from its coloring that if it is true blood it would flow along the light groove above the hipbone, starting from the lacerated point in the skin and terminating in a fold of the skin that would naturally have formed between the left side hip and rib cage, while he was bent over. The shape of this imprint would seem to confirm this course: (1) mark left by the scourge above the hip bone; (2) direction of blood flow along the iliac fossa; (3) course of the blood flow in the fold of the skin. On the large right gluteus, the marks show a characteristic, oblique, direction to the right in perfect harmony with the inclination of the surface at that point, and in conformity with the hypothesis of a bent over position of the body. The angle of the three blood trickles, related to the axis of the body can be calculated, and is of 30; 35 and 40 degrees (see figure 3).

### Lower Limbs

Let us now examine the lower limbs that seem to present an even more persuasive documentation of the blood trickles which flowed from the numerous wounds. The morphology of numbers 1, 2, 3, 4, 5, seems to present minor difficulties of interpretation of these marks (that must not be confused with those of the wool, that in some case, accompanies this phenomenon disturbing it.) The contact with the robe, that in other parts of the body has been considerable (first with the purple cloak, put on him immediately after the scourging, then with his own robes after his death sentence), even modifying the morphology of the blood flows in the particular parts we are examining, was evidently less, allowing the blood to transfer onto the Shroud in a more considerable way. When in a second movement they removed the purple cloak, and he put on his own garments again, the phenomenon of coagulation was perhaps not yet

\* figure 35, page 61, La Sindone Santa, Edition, Centro Romano di Sindonologia, 1977.



Figure 3. Skeletal Overprint

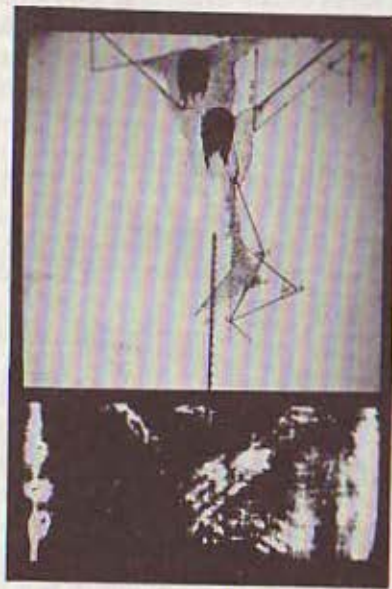


Figure 6. Body Shift Diagram

terminated. Worthy of note is the ruthless obstination revealed by the blows of the scourge on the calves, where the attention of the scourgers must have concentrated repeatedly and mercilessly, and where the phenomenon of the blood trickles is extremely evident (see figure 4).



Figure 4. Calf Blood Stains

### The Crowning with Thorns

The fact of the crowning with thorns and the way in which it was done are expressed concisely but precisely by the Gospel of John: "And the soldiers plaited a crown of thorns, and put it on his head" (Jn. 19,2).

Students of law may be surprised by this punishment, which was not contemplated by the penal procedure of Rome. No other crucified man in history, in fact, is known to have been crowned with thorns!

The way in which it was done, on the hand, implicates the artists, who have universally represented a type of crowning borrowed from the customs of Orientals, who crowned their kings with precious mitres placed on their heads. It is easy to clear Pilate from responsibility in this matter. Presumably he met the prisoner after the scourging had taken place without suspecting the mock

crowning, improvised by the soldiers as a result of the declaration of kingship made during the trial, to which Pilate responded with that sardonic smile that we glimpse behind the Gospel text: "So you are a king?" (Jn. 18,37).

In any case this departure from procedure would not have displeased the emperor Tiberius . . . if some malicious tongues should have reported it . . .

But the way in which it was carried out is unexpectedly documented by the marks on the Shroud: the whole top of the skull, in fact, from the occiput to the bregma, is covered with trickles of blood, while the dark colour of all the same area makes one think of sweat mixed with blood, in which the mass of the hair was steeped, creating the conditions for the resulting imprint. (see figure 5).

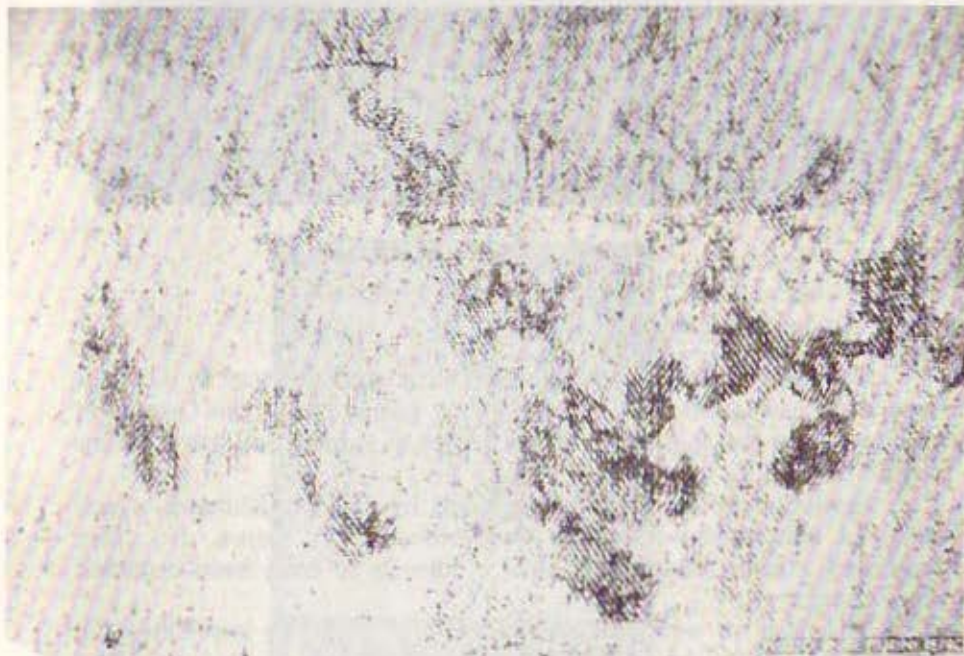


Figure 5. Hair Blood Stains

Noteworthy, too, is the exceptional morphological documentation of the blood which is seen to have flowed while the victim was living, with the characteristics of coagulated blood, formed as a result of the well-known physiological process, and not subject to falsification by the brush.

The evangelist notes further that after the scourging and the crowning with thorns, Jesus put on his clothes again. This is an important fact, because it constituted an exception to the rule, since those about to be crucified were scourged naked on the way. It was the Roman custom: this is the reason for the clothes.

The Shroud reveals a morphological detail in the imprints of the shoulders already wounded by the scourges. If the cross had been in direct contact with the lacerated shoulders, the laceration would have widened — forming wide sores — but, on the contrary, they have kept their shape. This would not have happened without the presence of a robe protecting the shoulders already wounded by the scourges.

That the arms of the Man of the Shroud were in a state of adduction, because they were tightly bound to the cross, is shown by the anatomical localization of the left scapular triangle, the contusion of which reveals a rotation from the natural position (Prof. N. Miani).

#### The Help of Simon of Cyrene

Another exception to the rule is the intervention of the Cyrenean. It might be taken as an act of compassion on the part of the soldiers or persons accompanying the sad procession. Far from it — it was a question of false pity to make it possible to continue to Calvary, now near at hand — nothing more!

The bruises on the face of the Man of the Shroud are directly involved. His hands being bound to the bar of the cross, they were caused by the inevitable impacts with the ground, in falling, and there was the danger of concussion. This would have prevented the spectacle of the "King of the Jews" on the cross! In common cases, if the death of the person about to undergo crucifixion took place incidentally, the matter was considered ended and it was only at the request of relatives that the corpse was handed over to them; otherwise stray dogs, vultures and crows completed the execution or, anyway, the common pit.

#### The writing of the charge

"And over his head they put the charge against him" (Mt. 27, 37).

Why is this further particular given? Because usually a tablet

with the name of the condemned man was nailed together with his feet. This is confirmed by the archeological discovery recently made in Jerusalem: the heels of John ed Ezechia — this was the name of the crucified man found by Prof. Nicu Haas — placed side by side, were found still joined by a long nail which, in the external space between the head of the nail and the right heel, still held firm the remains of a tablet made of acacia; the name of the condemned man was written on the latter. The imprint of the feet of the Man of the Shroud reveals that they were, on the contrary, on top of each other, the left over the right. In particular it would have been difficult to nail the charge for which he had been condemned to death over the crossed feet, since it was a charge of unusual proportions, written in three languages, Hebrew, Greek and Latin — a charge that was not limited to the name, but also to the cause of death: “the king of the Jews”; the letters on the title, which “many of the Jews read” (Jn. 19, 20), call for a tablet at least 60 by 20 cm. long.

### The Crucifixion

The Gospel description is more sparing of information about the technique of the crucifixion. For this reason the study of the Shroud is of even greater value, since it provides unexpected technical data.

From a careful examination of the Shroud the question may rise whether the material executors of the sentence made any special choices in the technique of the execution. Certainly they did not opt for a method that would reduce the pain or prolong the throes of death, in view of the imminence of the sabbath. In fact nails — Tertullian’s “atrociosa crucis” — were chosen instead of ropes, and furthermore they were placed in the carpi, instead of the distal area, as in the case of John of Ezechia; the thumb in opposition in the metacarpal area, revealed by the Shroud, is an evident indication of a lesion of the median nerve. The axonometry of the movements revealed by the goniometric examination of the trickles of blood from the forearms, describes to us an initial state of prostration, bound to lead to sudden death from asphyxia or orthostatic collapse, unless the physical condition for a shifting of the body upwards (raising) were created immediately. This would enable the crucified man to breathe, speak and prolong the death agony for some time. There remained only to nail the body with the knees very bent, as is made evident by the 35 degree angle of the trickles of blood from the left carpus and by the corresponding shift of the body to the right, which is revealed by the direction of the blood that has flowed as far as the elbow on the right forearm (see figure 6).

The extent of these movements and the different direction of the blood on the forearms exclude any support at the perineum, which, if it might have prolonged the death throes, would have, in this case, prevented or at least reduced the excruciating pain in the median nerve, in continual, forced attrition with the nails . . .

I do not know whether to set in this dynamic reconstruction of this crucified man the attitude of the Pharisees under the cross who sneered: “Teipsum salvum facere non potes! (Mt. 27, 42), that is, “whatever efforts you make, you won’t manage to save yourself!” This refinement, nails and bent knees, in any case, would have ended the life of any man on the cross in a few hours. For this reason we will not be surprised by Pilate’s surprise, when he heard the news of the death from Joseph of Arimathaea at sunset. His experience in the matter was based on cases in which the common systems of crucifixion had been used. Evidently, in this case, the executioners had opted in favour of hastier methods . . .

### Death and the Piercing of his Side

. . . and bowing his head he gave up his spirit” (Jn. 19, 30).

This particular of the bowed head can clearly be shown for the Man of the Shroud. It is proved by the linear distance from the sterno-clavicular articulation to the rima oris, which is the typical distance in the case of a man with his head considerably bent. It is said precisely of Jesus in the Gospel that “bowing his head he gave up his spirit.” Rigor mortis set in, fixing that position, now revealed by the shroud which was in contact with the body when the head was still bowed on his breast.

“ . . . one of the soldiers pierced his side with a lance; and immediately there came out blood and water” (Jn. 19, 34).

That this, too, is an exceptional procedure is shown by the fact the thieves’ legs were broken (crucifragium), according to custom, as the Gospel narrates, and the recent archeological discovery in Jerusalem: in fact, the tibias of John of Ezechia are broken.

Also the detail of the piercing of the side, of which there is no other example in the history of crucifixions in Jerusalem, is clearly documented on the Shroud imprint: in the right hemithorax, 13 cm. from the sternum, a wound from an edged weapon can be seen, 4 cm. wide (in recent excavations in Jerusalem many Roman lances of the period have been found with a maximum width of 4 cm.); the flow of blood and water is transferred onto the Shroud with the characteristic of clots of blood, subsequent to death, surrounded by a circle of serum, as the different coloring shows . . .

These are some of the most significant exceptions revealed by the internal study of the Holy Shroud, in full harmony with the Gospel account of the Passion of Christ.

## The Burial

We must not forget that the Holy Shroud is the direct proof of an incomplete hurried and provisional burial (he was not washed; hair and beard were not shaved; he was left completely naked because his garments had been taken by the soldiers). The fact that it was a hurried burial is an indirect proof of the death of the Man of the Shroud on a Friday and of the fact he must have been buried at a time in which it was not possible to complete the burial (as would have been possible had he died in the morning or early afternoon), nearly at sunset of Friday when, because of the oncoming Sabbath, the law permitted the ritual to be terminated after the Sabbath rest . . . In proof of this we have it in the attitude of the pious women who bought the annointments and prepared them on Saturday night, then set out for the sepulchre at sunrise of Sunday morning. On Friday they had just wrapped him partially in the Shroud unwashed, therefore all covered with blood clots. The intentional wrapping and tucking in of the Shroud permitted the necessary conditions for the fusion of an imprint that is impressive but has some serious anatomical anomalies (the imprint of course!) due to such tucking and wrapping of the sheet with the intention of bringing it into contact with the major wounds. Some experimental data obtained from the direct handling of bodies gave as not anatomically possible the following linear distances of the imprint — (I quote just two major facts) — from the lips to the wound of the left carpus 68 cm. (due to the tucking of the sheet around the hands that were one over the other with the thumb bent inside the palm, and due to the tucking of the sheet between the right arm and the right side. This can be proved by the presence of the imprint of blood on the right ribcage and the interruption of flow of the blood trickles (on the right arm) that from the right wrist moves down to the elbow. The excessive length of the imprint is about 20 cm.

The other not anatomically possible measurement is in the front part of the legs, that in their lower portion is excessive, reaching 51 cm. in the front imprint that is 14 cm. (5.6 inches) longer than the 14.5 inches back imprint that is not interrupted. The U.V. photos with Wood's filter, show some side pleats where organic substances (like aloes and myrrh) deposited at the beginning of the phenomenon. It would be interesting in a future chemical (quantitative and qualitative) experimentation to try to detect what substances are present in that area of the Shroud. There are possibly, I believe, residues of aloes and myrrh that collected within those folds in the first Good Friday of history.

## Conclusion

Have we got definitive proof of the authenticity of the Shroud? We have certainly reached the point of absolutely excluding the work of a painter forger or a plagiarist of experiments, since it is a question of a real scourging, a real crowning with thorns, a real thrust of a lance in the side of a corpse. Even the burial is seen to be mysteriously interrupted: the perfect transfer of the blood onto the material which happens "when the fibrin is half dissolved, neither before, nor after," would seem to prove that the phenomenon of fibrinolysis, the rate of which varies with time, was suspended after some hours of contact.

In addition to what has been set forth above, if biochemical tests of the imprint should show that it is real blood that has kept its typical faded carmine-mallow coloration owing to the presence of aloes and myrrh in a shroud subjected to intense heat (experiments of Vignon and others) — if the process of fibrinolysis makes it possible to explain the perfect transfer of the coagulated or coagulated blood in the precise limits of time of the temporary burial — then the convergence of the findings, some of which cannot be repeated by the paint-brush, such as that of the photographic negative and the phenomenon of coagulation with real blood, transferred to the material, will cause us to conclude that the Man of the Shroud is that Jesus of whom the Gospels speak, excluding any other crucified person in history. In the present state of research, there are so few probabilities in favor of the latter hypothesis that it verges upon the ridiculous merely to put it forward.

## THE THREE DIMENSIONAL IMAGE ON JESUS' BURIAL CLOTH

By John P. Jackson, Eric J. Jumper  
Bill Mottern, Kenneth E. Stevenson (ed.)

The image on the purported burial cloth of Jesus of Nazareth, called today the Shroud of Turin, possesses two notable characteristics. First, the image on the Shroud has the properties of a photographic negative in which shades of light and dark, rights and lefts are interchanged from the way in which objects are conventionally seen. This property of the Shroud was discovered by Secondo Pia who, in photographing the Shroud for the first time in 1898, noticed that his negative plate contained a positive image of the man of the Shroud (taken in this paper to be Jesus) with the normal properties of a photograph. Second, our computer research has shown that the Shroud image is additionally three dimensional in that information defining the spatial contours of Jesus' body are encoded in the varying intensity levels of the image.

Our purpose here is to present our research into the three dimensionality of the Shroud image. This three dimensionality was first alluded to by Vignon when he noted that the intensity of the image seemed to vary inversely with cloth-body distance.<sup>1</sup> In Vignon's day there was no way to quantitatively demonstrate this relationship. Today however, we have highly sensitive image recording equipment which allows us to test this hypothesis. Using one such device, we tested Vignon's hypothesis by finding how image intensity on the Shroud varied with cloth-body distance. Our approach consisted of three parts: (1) measurement of cloth-body distance, (2) measurement of image intensity, and (3) comparison of cloth-body distance with image intensity at various locations on the Shroud.

To measure cloth-body distance,  $d$ , we reconstructed Jesus' burial configuration as suggested by the Shroud. We accomplished this by covering a volunteer subject of proper height and proportions with a full-scale model of the Shroud on which we had traced all

image features from a photographic projection of the Shroud.<sup>2</sup> Correct draping of the cloth was the most important aspect of this stage since we had to ensure that all image features were positioned over the corresponding body part. Because of this correct positioning, we believe our method of burial reconfiguring must have been reasonably accurate. Two photographs, shown in Figure 1, were taken, one with the cloth in place and one with it removed. Then a drawing similar to the reclining body shown in Figure 2 was prepared from these photographs. Using this drawing, it was a simple procedure to measure cloth-body distance from the ridge line of the cloth model.

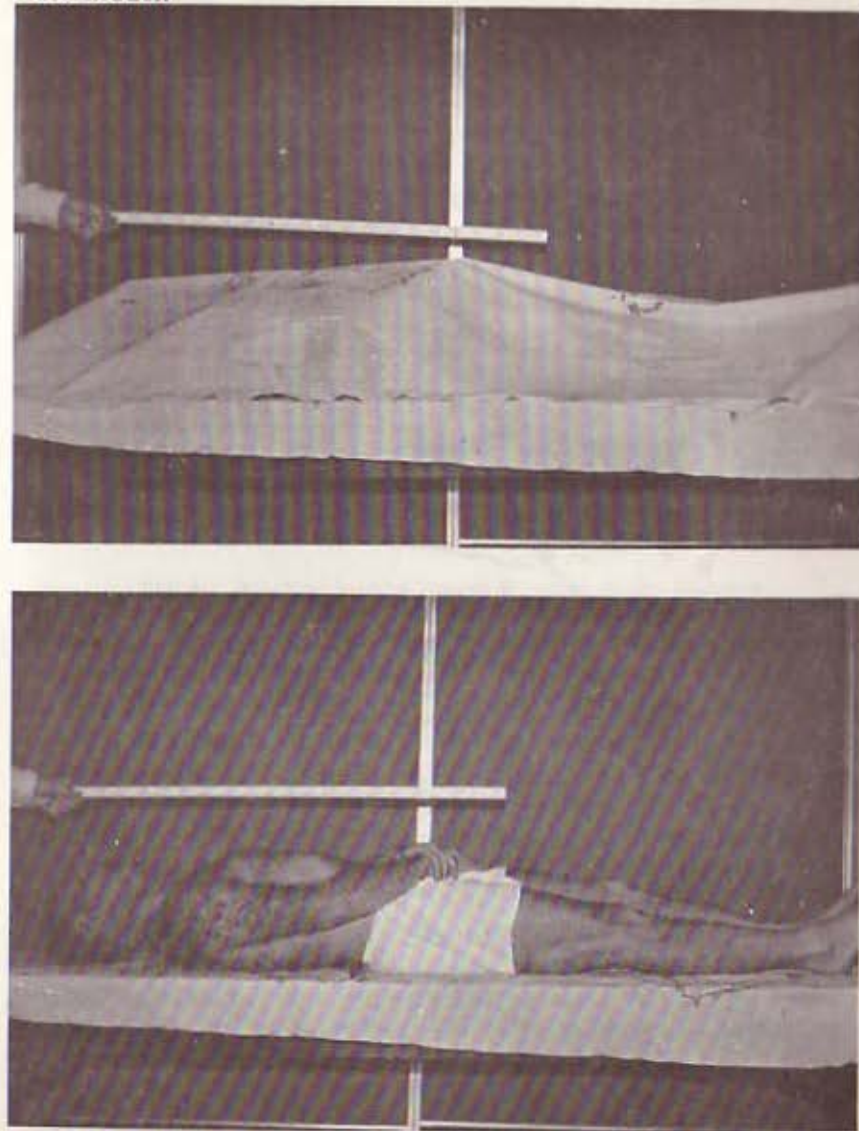
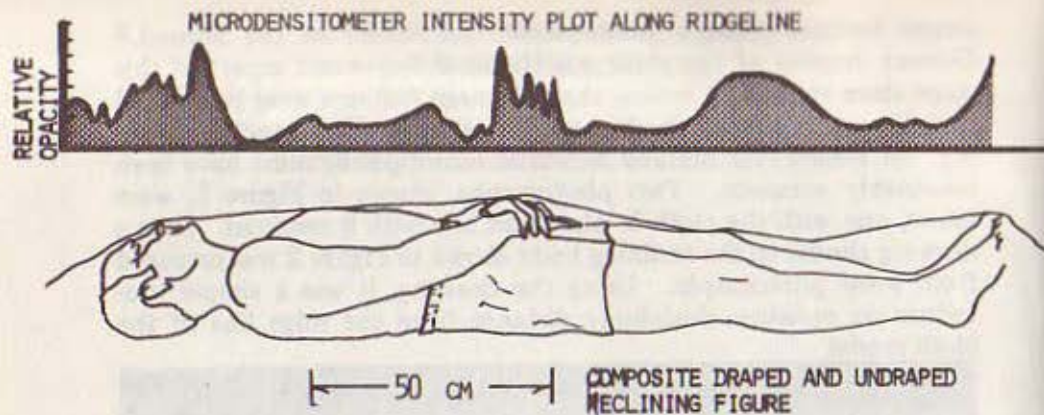


Fig. 1. Draped and undraped subject in body position



SCAN NOMENCLATURE FOR FIGURE 3

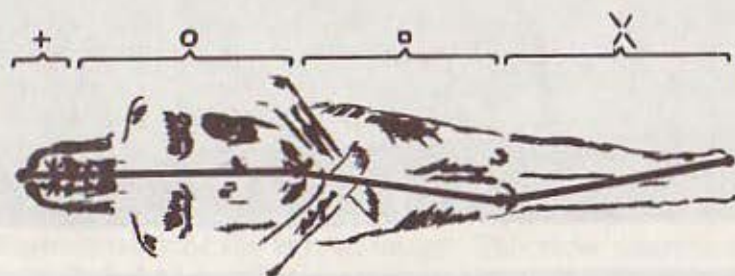


Fig. 2. Microdensitometer Plot, composite draped and undraped reclining figure, and microdensitometer scan identification nomenclature for ridgeline.

To accomplish the next step, measurement of image intensity,  $I$ , we used a microdensitometer to scan the image on the Shroud along the path of the ridge line. (The ridge line indicates the body's highest points of contact with the Shroud). See Figure 2. This step allowed us to correlate measured image intensity with cloth-body distance at known points on the Shroud, in this case along the well defined ridge line. We then plotted image intensity versus cloth-body distance and established a relationship between the two. A plot of this relationship is shown in Figure 3. From Figure 3 it is apparent that a definite correlation between image intensity and cloth-body distance exists.

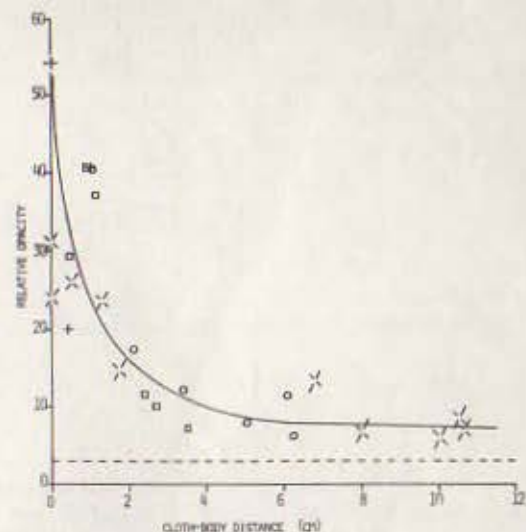


Fig. 3. Relative opacity (image intensity on the Shroud) versus cloth-body distance. Symbol nomenclature given in Figure 2.

It is therefore apparent that the image on the Shroud must be equivalent to a three dimensional surface of Jesus' body. Moreover, Figure 3 can then be used to translate image intensity into three dimensional relief. In fact, the microdensitometer plot of image intensity alone provides a distorted profile of Jesus' body. Much of the distortion, however, can be removed if image intensity,  $I$ , is converted directly to cloth-body distance,  $d$ , by our single, experimentally determined fall-off curve. This transformation is depicted in Figure 4 and shows that a nearly correct body surface profile with vertical relief can be generated merely from image intensity infor-



mation present on the Shroud.\* The only remaining step was to mathematically construct a fully three dimensional image of Jesus.

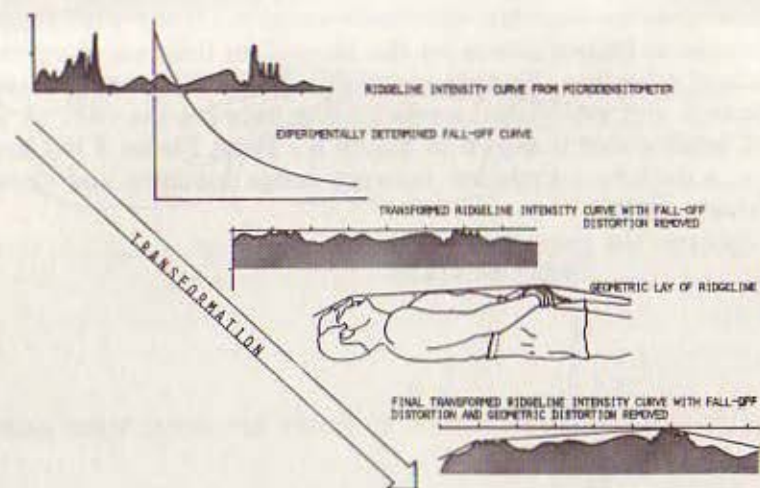


Fig. 4. Transformation Process to remove fall-off and geometric distortions for ridgeline intensity plot.

To accomplish the construction of the three-dimensional image, we converted all image points to vertical relief rather than just those image points of the ridge line. Using Interpretation System's VP-8 Image Analyzer, a device which plots shades of image intensity as adjustable levels of vertical relief, we were able to form a three dimensional brightness surface of the Shroud image. The wide versatility of this instrument also allowed us to test varying amounts of relief (which helped to approximate our experimental falloff curve) as well as to rotate the resulting image and thereby view it from various angles. Figure 5 shows a computer generated relief surface of the entire body image, front (left) and back (right).

\* Additional distortion due to cloth drape is present, but this can be removed by proper mathematical techniques as illustrated further in Figure 4. What we are concerned with in this paper, however, is only the transformation of image intensity into cloth-body distance (i.e. vertical relief).



Fig. 5. Computer generated three dimensional relief surface of the body image. (Front-left; Back-right)

In perspective, a three dimensional relief of the image on the Shroud is not as insignificant as it might seem. It should be pointed out that ordinary photographic images cannot usually be converted to true three dimensional reliefs. The photographic process does not cause the objects filmed to become exposed in inverse relationship to distance from the camera; hence, three dimensional information is not usually recorded onto film. Only when the degree of illumination received from an object depends, in some way, upon its distance (for example in a stellar photograph), would three dimensional analysis and reconstruction be possible (by the VP-8 Image Analyzer). Ordinary photographs of persons transformed into vertical relief showed obvious distortion; noses were pushed into faces, arms into chests, and entire reliefs appeared flat and unnatural. See Figures 6 and 7. Figure 6 is a normal photograph both positive and negative of



Fig. 6. Normal photograph of Pope Pius XI, positive and negative.



Fig. 7. Computer generated three dimensional relief of Figure 6.

Pope Pius 11th. Since the Shroud is a negative, we optimized the negative of the photograph to develop the three dimensional image in Figure 7. Compare the flattened nose, contorted mouth and deeply depressed eyes to the correctly defined image in Figure 8. Clearly this three dimensionality is a newly established, distinctive characteristic of the Shroud.



Fig. 8. Computer generated three dimensional relief of face on the Shroud.

#### A. Implication to the Understanding of Image Formation and Preservation.

There are several aspects of the Shroud three dimensional relief of Figure 5 which we feel are significant in understanding image formation and alteration processes. First, since the body form is natural, proportioned, and lacks any blatant distortion it would seem that: (1) the process of image formation, as it acted in varying degrees of intensity depending upon how far the cloth was from the body, was uniform and independent of body surface qualities, (2) the lay of the Shroud was relatively flat,\* and (3) other historical processes tending to change image intensity acted uniformly or not at all. This last point implies that the Shroud image has probably not been altered appreciably by random degradative bacterial, chemical, or thermal agents; for then, anomalies in vertical relief would be present in affected areas. However, any reactions induced by full-length daylight expositions, possibly being boiled in oil, etc. which act uniformly over the image may have caused changes in levels of intensity to occur homogeneously. These latter effects would not alter the overall three dimensionality of the Shroud image, only the falloff curve I(d). Other sets of more complicated explanations for the three dimensional image on the Shroud could be proposed. One, for example, is that the Shroud lay over a small body and the resulting irregularities in the drape of the cloth were somehow compensated for by inhomogeneities of the image forming process. This explanation like many others requires special "ad hoc" assumptions to account for the completely natural image and therefore seem unlikely to us. Second, it would appear that the image forming process acted in the same manner on the bottom side of the body as on the top because the characteristics of the bottom relief seem similar to those of the top relief. For example, (1) the hair on the front image stands out in natural relief but on the back image it appears compressed against the head, as it would for a reclining body on a hard surface, (2) the calf area of the back image seems proportionally rounded with respect to the ankle area of the front image, and (3) both the front and back images have nearly the same maximum vertical elevation implying equal contact intensities. These three

\* For otherwise, the relief image, which is mathematically built on an already flat surface, would show blatant distortions in vertical relief.

characteristics of the front and back images of the Shroud are compatible with the image forming process acting similarly on the top and bottom sides of the body. Third, the relief image implies that the process of image generation did not depend on pressure between the body and the cloth since, as just noted, equal contact intensities occurred on the top and bottom images where pressures at contact are greatly different. Fourth, if chemicals were responsible for producing the image, they were not completely used up as evidenced by the lack of "saturation," i.e. flat, level areas, anywhere on the three dimensional image. Fifth, it may be observed that, although cloth-body distance was a factor affecting the intensity of the image, this factor did not appear to affect the resolution of the image implying that the transference of body surface information to the cloth must have been along nearly straight-line paths essentially perpendicular to the Shroud.\* Sixth, on the basis of the relief picture, it is possible to conclude that the Shroud image was not produced by direct contact where a specific level of discoloration of the cloth occurred only where the Shroud touched the body and nowhere else. For if the mechanism had been by direct contact, the relief image created by the VP-8 Image Analyzer would appear flattopped with areas of contact having the same vertical elevation. See for example Figure 9 where we constructed three dimensional reliefs from experimental direct contact images made by Cordiglia and Rodante.<sup>3</sup> The three dimensional characteristics of these images eliminate the direct contact mechanism as a viable image forming candidate. In short, a direct contact mechanism, while it might account for the Shroud's negative property, does not explain its three dimensional quality.

\* That the transference was nearly perpendicular can be shown by the way in which the three dimensional image was created by the VP-8 Image Analyzer. All image points were projected perpendicular to the "zero intensity surface." This "zero intensity surface" is the intensity of the Shroud cloth which, as noted previously, must have been relatively flat over the body. Thus, since a consistent three dimensional image can be formed by perpendicular projection from the "zero intensity surface," which is equivalent to the cloth's surface in space, it follows that the image forming process must have acted perpendicular to the Shroud; for otherwise, an undistorted image surface of the body would be impossible to construct with the VP-8 Image Analyzer.

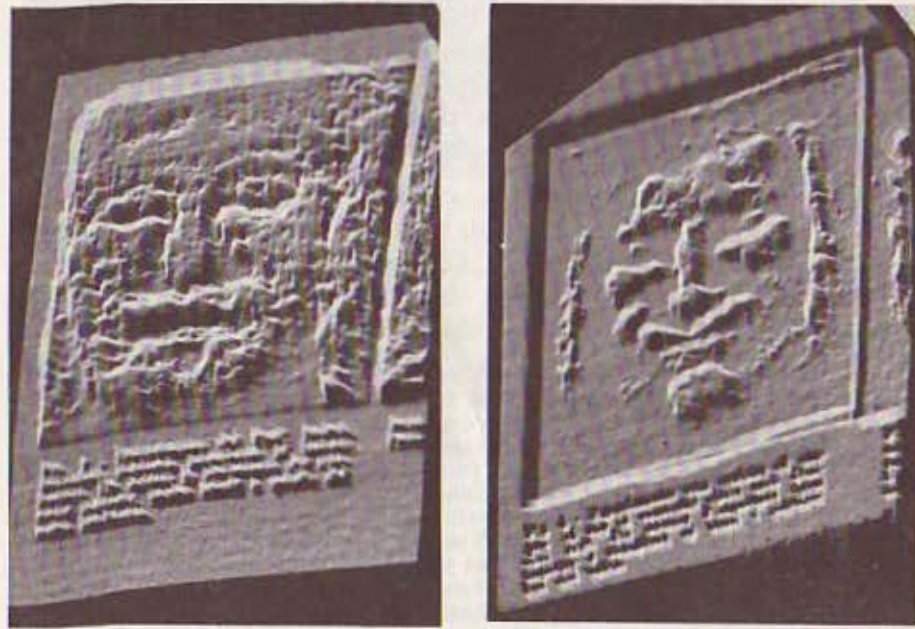


Fig. 9. Contact images of Cordiglia and Rodante and their respective three dimensional reliefs.

## B. Implications to Authenticity

All of these results have a profound impact on the authenticity of the Shroud. A well-known argument has been that an artist, who must have lived prior to the Fourteenth Century\* could not have produced a consistent negative image without the capability of checking his work by photographic inversion.<sup>4</sup> Similarly, we submit that an artist or forger living then would not have been able to encode three dimensional information by adjusting the intensity levels of his work to everywhere correspond to actual cloth-body separations. To demonstrate this point, we performed an experiment. We obtained photographs of Shroud paintings by two competent artists who had been commissioned to copy the Shroud as exactly as possible.<sup>5</sup> Then, we transformed these pictures into relief images to see how well each artist had captured the three dimensionality of the Shroud onto his painting. At the time, both artists were not aware of the three dimensional property. The results are shown in Figures 10 and 11. In Figure 10, that of Cussetti, obvious distortion occurred, for example at the nose which appears to be bent inward. The attempt of Reffo, in Figure 11 is likewise distorted; for instance, the face appears to be depressed inward and the entire composition seems flat. Varying the degree of relief did not help the situation because the abnormalities of these pictures were only altered proportionally, but not eliminated. Since two competent artists who had the Shroud itself to copy were unable to flawlessly produce a three dimensional image from the Shroud, it would seem remote that some medieval artist could have achieved such an accomplishment with no Shroud available for reference. In fact, we consider it a challenge for pre-twentieth century technology to have placed a clear three dimensional image of a human body onto a cloth either by artistry or any other means available.

\* For the history of the Turin Shroud is known with certainty from that time on.

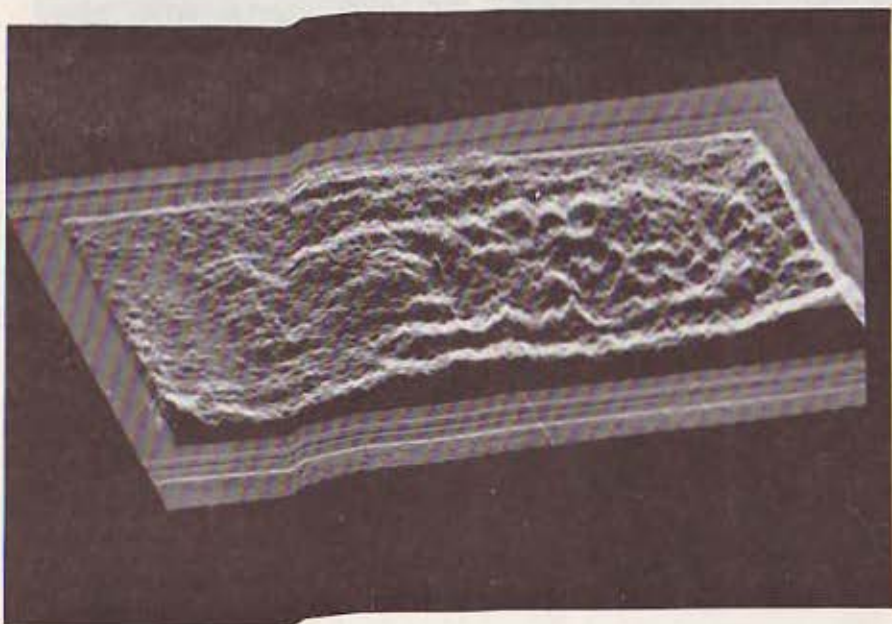


Fig. 10. Cusseti's painting — positive, negative, and three dimensional.



Fig. 11. Reffo's painting — positive, negative, and three dimensional.

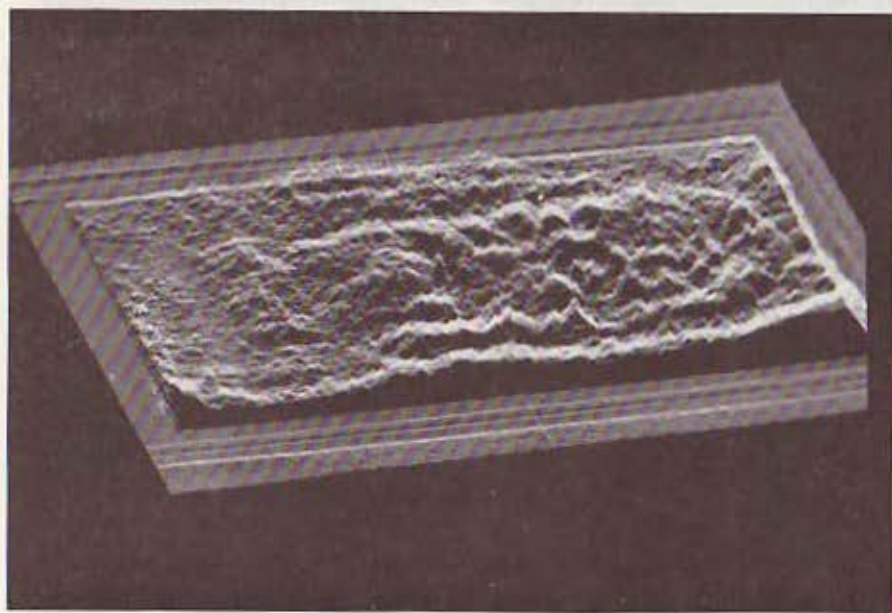


Fig. 10. Cusseti's painting — positive, negative, and three dimensional.

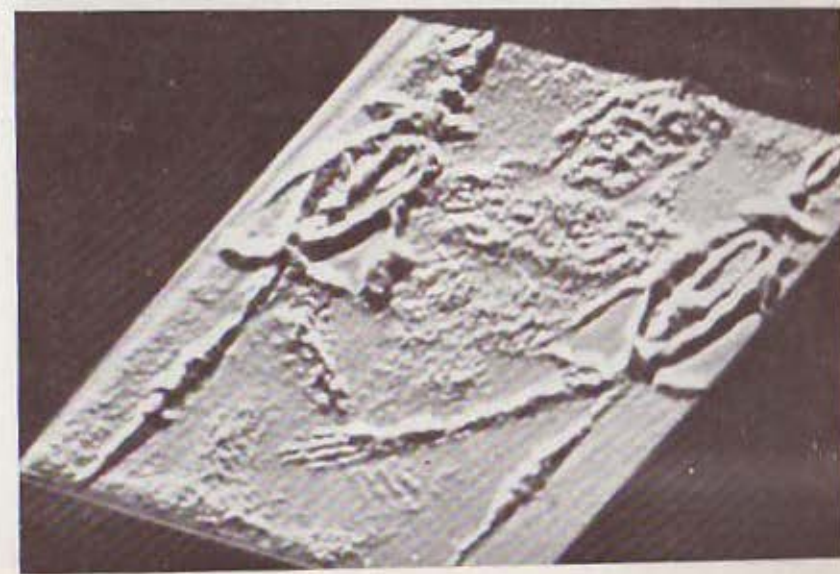


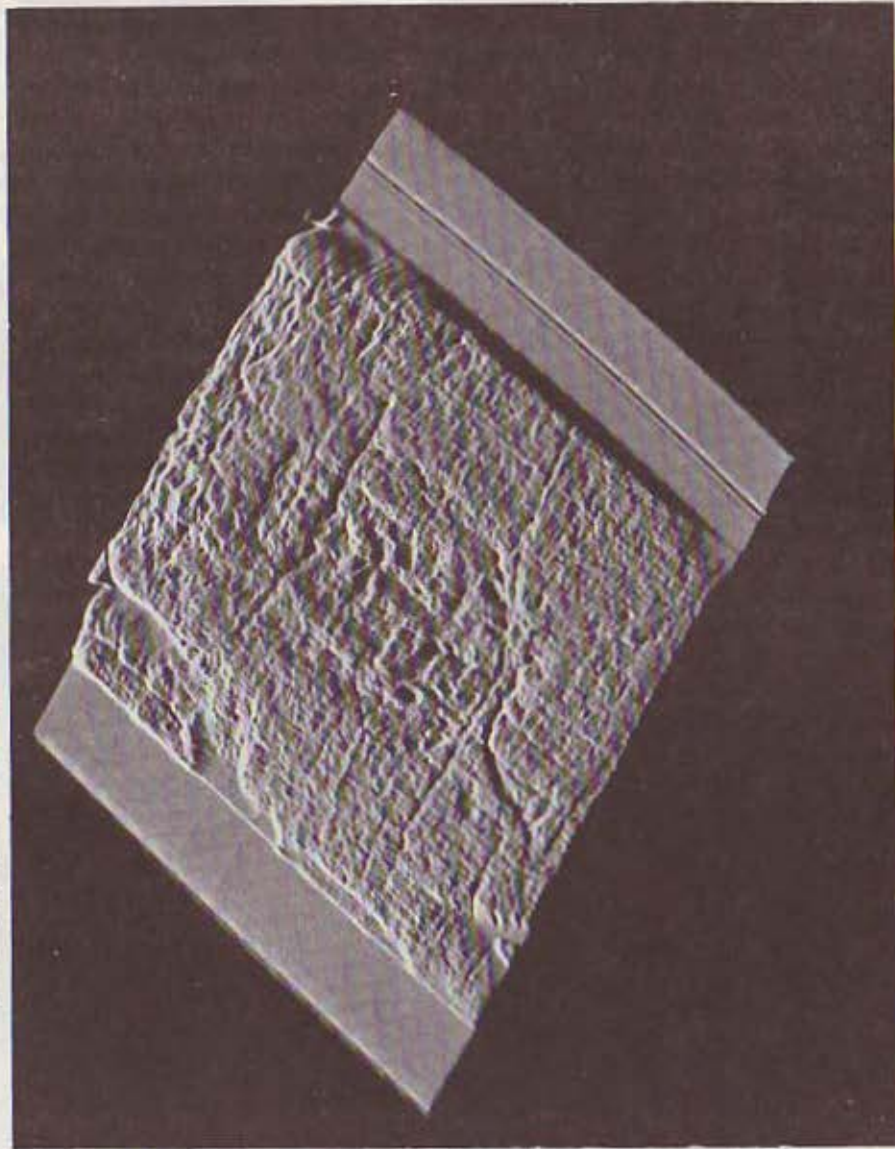
Fig. 11. Reffo's painting — positive, negative, and three dimensional.

### C. Implications to Archeology

Another photograph of the Shroud which we subjected to relief enhancement with the relief purposefully somewhat suppressed was a close up of the face. See Figure 12. The suppression revealed something unexpected — over each eye appeared objects resembling small buttons. Though it seemed natural on the basis of the computer generated picture to interpret these features as objects resting atop closed eyelids, we felt compelled to consider several alternative explanations: these “objects” (1) represent a nonuniformity in the image forming process, (2) were caused by the cloth hanging close to the eyelids, nearly touching them, (3) were produced by a local biological, chemical, or thermal reaction during the history of the Shroud, (4) were added by an artist to give the effect of eyes on the image, and (5) were swellings of both eyelids due to physical abuse. We rejected Explanations (1) and (3) since they seemed unlikely; over the entire fourteen foot Shroud image, no other anomalies of the three dimensional quality are apparent and thus the probability that the image forming process or possible random degradive processes acted on both eyes and nowhere else is insignificantly small. Explanation (2) we rejected for two reasons. First, if the cloth had been draped close to the eyelids, then an upward distortion for the nasal region between the eyes would be observed in the relief pictures.\* But upon examining Figure 8, it is apparent that this did not occur since a well-formed nasal structure was produced from the original Shroud image. Indeed, the direct contact image of Figure 9, which reveals protrusions in the eye region, also shows evidence that the cloth sagged towards and touched the bridge of the nose since an image of equal intensity over that area was also formed. Second, the edges of the “objects” fall off much too sharply to be accounted for by a simple sag in the cloth over the eyes or as swelling of the eyelids (which also eliminates 5.) Finally, Explanation (4) also had to be discarded. Since the color and character of the image in the eye regions are indistinguishable from other parts of the Shroud image, an artist or forger would have had to come up with a process which could mimic the Shroud image formation process to a high degree.<sup>6</sup> We believe this would be very difficult, even using modern technology. So we were left with but one conclusion — that the buttonlike features are what they seem to be, namely solid objects resting upon

\* For the cloth would have sagged close to that area also.

Fig. 12. Closeup of the three dimensional face with suppressed relief. Note the buttons.



the eyelids.\* This identification agrees with ancient Jewish burial custom where objects (potsherd fragments or coins) were apparently sometimes placed over the eyes.<sup>7</sup>

Detailed identification is not possible without further investigation, but we propose that they may be some kind of coins since: (1) they are both nearly circular and approximately the same size, and (2) scriptural accounts indicate that Joseph of Arimathaea, a wealthy man, was responsible for burying Jesus.<sup>8</sup> He obviously had money on his person at the time of Jesus' burial for he was able to purchase a linen burial cloth.<sup>9</sup> Thus, if Joseph followed Jewish burial custom to cover the eyes, then it is not unreasonable that the most natural and convenient thing for him to use would have been coins rather than pottery fragments.

If our conjecture is true that these images are of coins, then we may have a truly unique method of dating the image. Computer enhancement of high quality closeup photographs of the eye region followed by a statistical correlation with known coinage of a given era and locality may be able to: (1) identify the objects as coins and (2) date and locate the probable time and place the image and not just the cloth was formed. Indeed, we have some computer enhancements which, though lacking sufficient resolution for positive identification, indicate a possible structure on the surface of the objects. In addition, Ian Wilson has suggested several Judean Bronze Lepton coins which are about the correct size as the buttonlike images. In particular, a Lepton of Pontius Pilate coined in A.D. 30-31 seems to agree especially well. On the other hand, a silver Denarius of Tiberius, coined in A.D. 14-37 was entirely too large. According to Wilson, a Lepton would probably be a likely candidate for Joseph of Arimathaea, an orthodox Jew, to use since it was acceptable as a Temple offering.<sup>10, 11</sup>

It should be noted in passing that the fact that objects are found on the eyes indicates that the head of Jesus must have been in a nearly horizontal position, for otherwise they would have fallen off the eyelids. It is interesting to note further that these objects might have been mistaken for open eyes at one time; for example, Ian Wilson points out that the image on the Mandylion cloth (possibly the Shroud) was thought to be a face with the eyes open.<sup>12</sup>

\* These objects could not be liquid because in that case they could not be supported upon the convex curvature of the eyelids; they would have necessarily formed in concave regions of curvature in the eye socket.

If the identification of these images as solid objects over the eyes is correct, then another significant aspect of the image forming process comes to light: whatever process formed the image had to have acted the same way not only over the body and hair, but also over presumably organically inert fragments situated atop the eyes. This conclusion, we believe, is of significance, for it places great restrictions on the possible image formation processes. In short, three dimensionality implies that the image forming process, acted uniformly through space over the body, front and back, and even seemed to act independently of the type of surface, organic and inorganic, from which the image was generated. In addition, this identification of the "objects" seems to strengthen the authenticity of the Shroud. For what artist or forger in the Fourteenth Century would have thought to place objects on the eyes of Jesus?

Another aspect of the three dimensional image which is of archeological interest concerns the probable existence of a chin bandage. It would appear that this was used in Jesus' burial, for the hair on the left side of the face seems to drape over the edge of some invisible object, possibly a bandage used to bind the mouth closed. (See Figures 5 and 8). Additionally, a long beard seems to be divided by this invisible bandage.\*

#### D. Implications to Art and Forensic Medicine

As scientists, our main interest is to understand the image forming process. However, here, as in many forms of scientific research, there are certain fallouts which have values in other fields as well. Such is the case with the three dimensional property as it might impact the field of religious art. For instance, it is now technically feasible to construct a lifesize sculpture of Jesus, with a high degree of reliability and accuracy. The Shroud image could drive a computerized milling machine like those used in industrial applications involving three dimensional shaping. Available filtering techniques could be applied to clean the image of noise which accounts for the "roughness" of the pictures presented in this paper. Additionally, an exact image intensity versus cloth-body distance curve could be used rather than the approximate one which formed the three dimensional relief images of this paper. Furthermore, if it is true as has been stated by various artists of renown that the artistic impact of the Shroud surpasses the best known human portrayals of

\* This also aligns with Jewish burial customs and the gospel narrative.<sup>13</sup>



Jesus, then surely such a sculpture would bring similar acclaim to that domain of religious art. And only such a sculpture could claim to be an accurate and faithful depiction of the physical, historical Jesus.

Another use for the three dimensional image would be as an aid in forensic medical studies of Jesus' body after crucifixion. For example, as seen in Figures 5 and 8, the degree of swelling of the right cheek or extension of the chest and abdomen can now be accurately evaluated. Also, a slight forward lean of the body, as suggested by Mons. Ricci, can be detected in the Figure 5 relief image; this could be of value in characterizing the Rigor Mortis of Jesus' body. In fact, we believe that after death the body, suspended by the arms on the cross, assumed a forward lean which was held by Rigor Mortis.<sup>14</sup> If further research confirms this belief, another argument for the authenticity exists, for it seems quite unlikely that a forger could have encoded into the intensity levels of his composition information which would accurately depict the correct forward lean of a crucified man.

### III. Conclusion

The history of science shows that whenever a subject can be placed in a mathematical context, increased knowledge of that subject quickly follows. After all, mathematics is the language of science. In Astronomy, for example, only after Johannes Kepler formulated his three mathematical descriptions of planetary motion was Sir Isaac Newton able to deduce the basic principle of his Law of Gravitation by which planets orbit the Sun.

Perhaps, in this perspective, we would be remiss not to observe that the relationship between image intensity and cloth-body distance  $I(d)$  is a mathematical characterization of the Shroud image. And so, we can only hope that such a mathematical description will help bring about a clearer understanding of the principles by which the image on the Shroud was formed. Obviously, for this to happen, further research on the Shroud is desperately needed; however, we feel that the impact of the three dimensional quality on the authenticity of the Shroud, not to mention dating, archeology, image formation, art and forensic medicine cannot be underestimated or denied.

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## CLOTH-BODY DISTANCE OF THE HOLY SHROUD OF TURIN

By Thomas M. McCown

### Introduction

#### Purpose

The purpose of this experiment is to determine if the image of a man on the Holy Shroud of Turin can be accurately described by a function relating image darkness at any given point on the image to a certain distance. This distance is the cloth-body distance formed by draping the Shroud over a body so that the anatomical features of the image cover the corresponding features of the body.

#### Problem

The Holy Shroud of Turin is the purported burial cloth of Jesus Christ and by implication it is His image on the Shroud. The history of the Shroud is veiled in mystery and intrigue; there are no definitive historical contradictions to the authenticity of the Shroud, yet there is no outright historical confirmation either. From the historical debate on the Shroud arise two questions; what formed the image, and whom is the image of?

In his pamphlet, "The Holy Shroud," Reverend Edward Wuenschel examines the image on the Shroud. Through painstaking analysis Wuenschel clearly demonstrates that the man in the image has suffered severe scourging all over his body, has worn something that deeply scratched his head, and has suffered puncture wounds in his wrists, feet, and side. Christ suffered all of these tortures, and no record exists of any other man suffering all of them. Reverend Wuenschel concludes that image, whether man-made or not, definitely depicts Jesus Christ.<sup>1</sup>

The major question today about the Shroud is what formed the image on the Shroud. If the image is a painting or the result of some other process applied by hand then the Shroud may be a historical forgery. However, if a process that acted without intervention by man formed the image, then the Shroud image is probably an authentic replica of the actual body of Christ.

Two characteristics of the image on the Shroud lend credibility to the thought that the image is not man-made. The first of these has already been demonstrated by Secondo Pia who photographed the Shroud in 1898 (figure 1). When Pia developed the photographs of the Shroud he found that negatives from the Shroud photographs possessed the lighting and shading characteristics the "positives" would. A positive has the natural highlights and shades of a man when seen in sunlight. Since the negative of a negative is a positive, Pia concluded that the Shroud image itself is a negative image of a man. Pia's conclusion is corroborated by the Report of the Commission of Experts which viewed the Shroud in 1969 and published its conclusions in 1976.<sup>2</sup> Since it is highly unlikely that anyone conceived of negative imagery before the advent of photography, it is hard to imagine anyone painting a negative image before the invention of photography, and the Shroud and its image are easily traced back to the 14th century. This alone undermines the man-made theories of image formation, but there is more.

A second unusual characteristic of the image is the shading variation from point to point on the image. Pia's photographs reveal that the image darkness varies from point to point in a way that suggests to many that a process acting across a distance formed the image. If image formation occurred with the Shroud draped across the body of Christ, the image-forming process would act across the distance that separated the Shroud from the body. This distance, called the cloth-body distance, would vary from point to point and cause the varying darkness of the image.

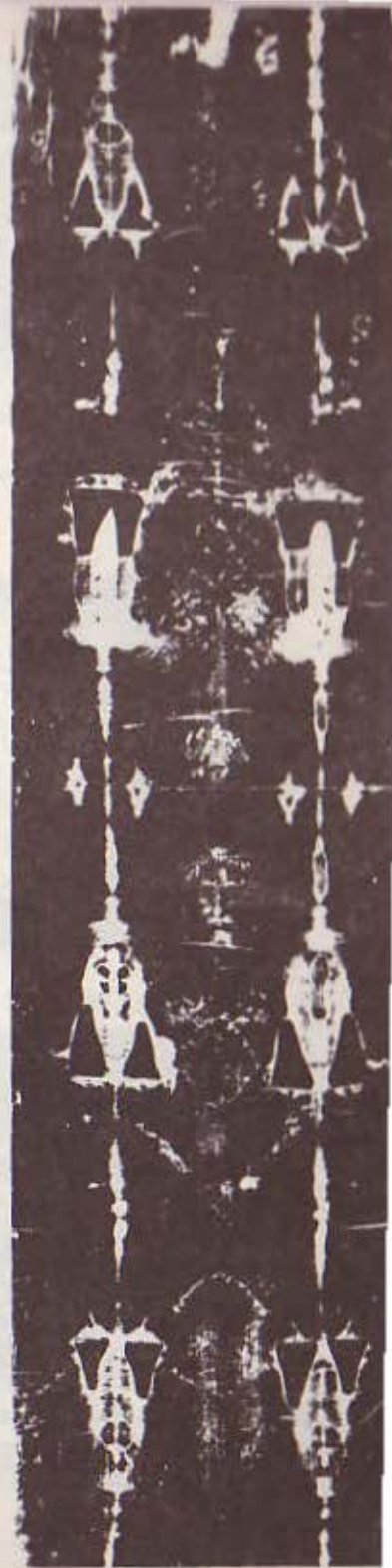
Dr. John Jackson and Dr. Eric Jumper have found a function that approximately relates image darkness to cloth-body distance. On advice from Bill Mottern they used this function and Interpretation System's VP-8 Image Analyzer on Pia's photographs of the Shroud to create a three dimensional "body-surface" from the image of the man. They hoped to make a surface that looked like a body from the image, with their function, and thereby demonstrate that the image darkness is related to cloth-body distance. The superb results from Dr. Jackson's and Dr. Jumper's experiment clearly show that the Shroud image possesses a three-dimensional quality unheard of in art. For comparison, a similar analysis was performed on normal

\* Enrie's



As the Holy Shroud appears on a photographic plate. The negative images on the cloth are now reversed into positive images revealing the true appearance of the Face and Body of Christ, as He lay in the tomb awaiting Easter.

As the Holy Shroud looks to the eye. The little triangles along either side are patches sewn over the portions burned in the fire of 1532. The figures along the center are negative images of the back (right) and the front (left) of the Body of Christ.



paintings, and the results show that normal paintings do not possess the same three-dimensional characteristics like those of the Shroud (figure 2).<sup>3</sup> The three-dimensional quality of the Shroud reinforces the conjecture that the image is not man-made. Despite the excellent work by Dr. Jackson and Dr. Jumper, there is a need for further analysis of the three-dimensional characteristics of the Shroud image. Such an analysis should more accurately determine the function relating cloth-body distance to image darkness and define the error bounds of that function. Precise knowledge of the functional relationship between cloth-body distance and image darkness will greatly aid the scientific determination of what process formed the Shroud image.

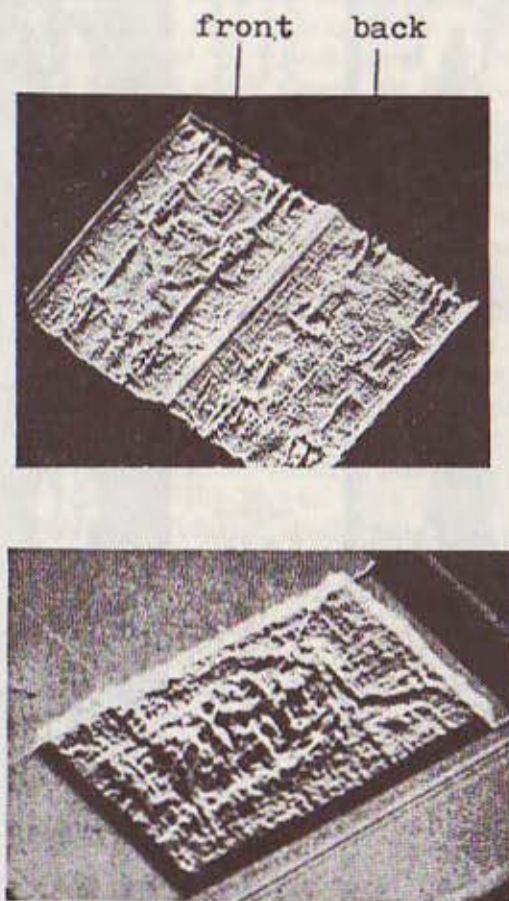


Fig. 2a 3-D Relief of Image

Note hand  
sunk into  
chest



Fig. 2b 3-D Relief of Normal Painting

Fig. 2. Dr. Jackson's and Dr. Jumper's Results

### Scope

This report shall analyze an experiment to determine if that experiment will yield an accurate function relating cloth-body distance to image darkness. The analysis of the experiment consists of error analysis of the cloth-body distance data and the function relating cloth-body distance to image darkness. Finally the report comments on the current progress of the experiment.

### Apparatus

With the exception of a computer, which analyzes the data to determine the function relating cloth-body distance to image darkness, the equipment for this experiment may be found in any classroom. The rest of the equipment consists of three tables, an overhead projector, a mirror, a mirror stand, a camera, a camera stand, a cloth model of the Shroud, and someone to act as a body under the cloth. Reference to Figure 3 will help the reader visualize the experimental arrangement.

### Procedure

First, because the Holy Shroud of Turin is extremely old and fragile, I obtained a cloth model of the Shroud that can be handled. Dr. Jackson and Dr. Jumper have already made such a replica of the Shroud. To make this cloth model they projected a life-size picture of the Shroud onto a cloth hanging on a wall. Then they traced the

## Data Analysis

The data analysis presents how measurements off the photographs yield the cloth-body distance and how this information and image darkness data will allow a computer to derive a function relating cloth-body distance to image darkness. Then the report discusses how the derived function will make a three-dimensional "body surface" from photographs of the Holy Shroud of Turin.

The coordinate system for the experiment shown in Figure 4 is a convenient reference system for making measurements off the photographs. Without the coordinate system, measurements made off the photographs would have no meaning. Looking down on table 2 (figure 4) one sees that the x-direction extends from the camera to table 2, and that the x-value of a point gives how far away a point is from the camera. The y-direction extends along the edge of table 2. The x- and y-values together give the exact location of a point in relation to the camera. Therefore, if the location of the Shroud model is known, then the x- and y-values give the location of a point on the image on the Shroud model. Since the Shroud model accurately represents the Shroud, the exact point on the Shroud model is the same point on the original Shroud. Thus, the x- and y-values determine an exact point on the image. The z-direction extends vertically from table 2 upwards, and the z-value gives the height of a point above table 2.

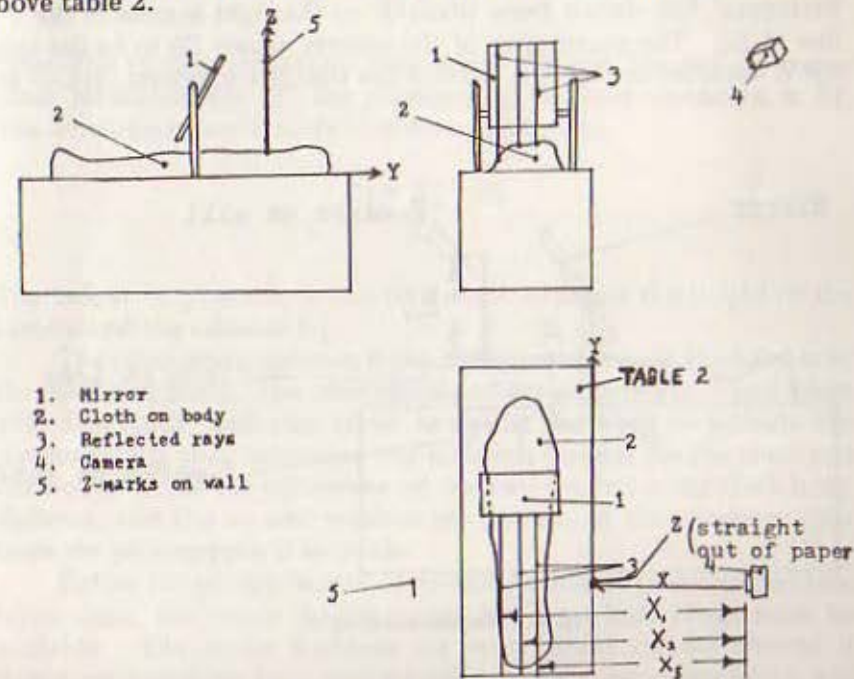


Fig. 4. Coordinate System

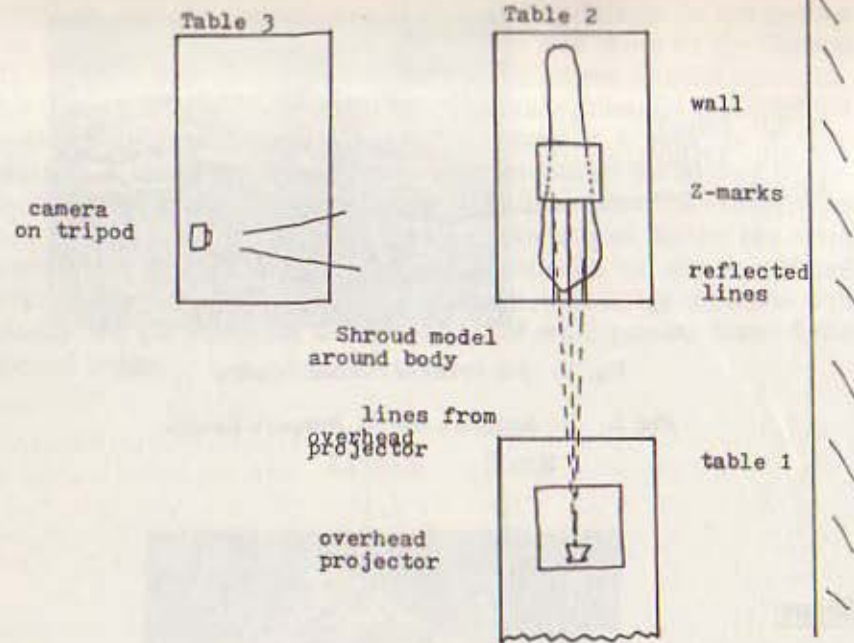


Fig. 3. Experimental Apparatus

image onto the cloth and included such extraneous marks as the burn marks sustained by the Shroud in a fire.<sup>4</sup> Dr. Jackson and Dr. Jumper have granted permission to use their Shroud model for this experiment.

After laying the Shroud model on table 2, someone about 5 ft. 10 in. and weighing about 175 lbs. lies on the cloth. Then the cloth folds over the person so that the features of the image on the Shroud model cover corresponding features on the person. The overhead projector projects three thin lines to the mirror on table 2, and the mirror reflects them down to the table. There the lines fall across the person and the cloth. Then a camera takes three pictures; one with the lines falling on the cloth covering the person, one with the lines falling directly on the person, and a last picture with the table bare and the lines falling on the table. The last picture is for calibration purposes; without a picture for calibration, accurate measurements could not be made on the first two photographs.

Measurements off the photographs are easier to take and inherently more accurate when the photographs are projected on a wall and the measuring is done on the enlarged photographs than when the measuring is done directly off the photographs. Also, superposition of the calibration photograph over the other two photographs allows measurement off the photographs in reference to the assumed coordinate system. As mentioned before, measuring in reference to the coordinate system gives the measurements scientific value.

The x-, y-, and z-values for a point are easy to determine. The lines projected onto table 2 are known distances from the camera; this gives the x-value for any point on those lines. The y-value of a point is the distance from that point to the y=0 line; however, due to distortion in the photograph from perspective the y-value cannot be measured directly from the photograph. Referring to Figure 5 for this discussion is essential. The vertical line drawn from point A crosses the horizontal line at point B. The horizontal line is the line from the calibration photograph that lies on table 2. Y-value markings on the horizontal line have built-in correction for distortion due to perspective because they are spaced a known distance apart and were taken in the calibration photograph. Thus, the y-value mark for point B is the y-value for point A. So far the analysis has established the x- and y-values for point A.

The height of a point is the z-value; finding the z-value of point A is more complicated than finding the x- and y-values. The horizontal line drawn from point A to the right intersects the y=0 line at Z<sub>0</sub>. The perspective of the camera causes Z<sub>0</sub> to be the value for Z depicted in Figure 6. Notice the triangles at points Z<sub>0</sub>-C-D and

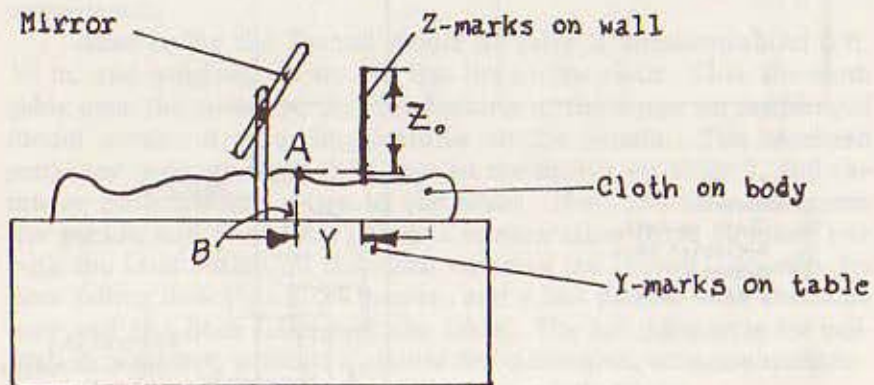


Fig. 5. Measurement of Y

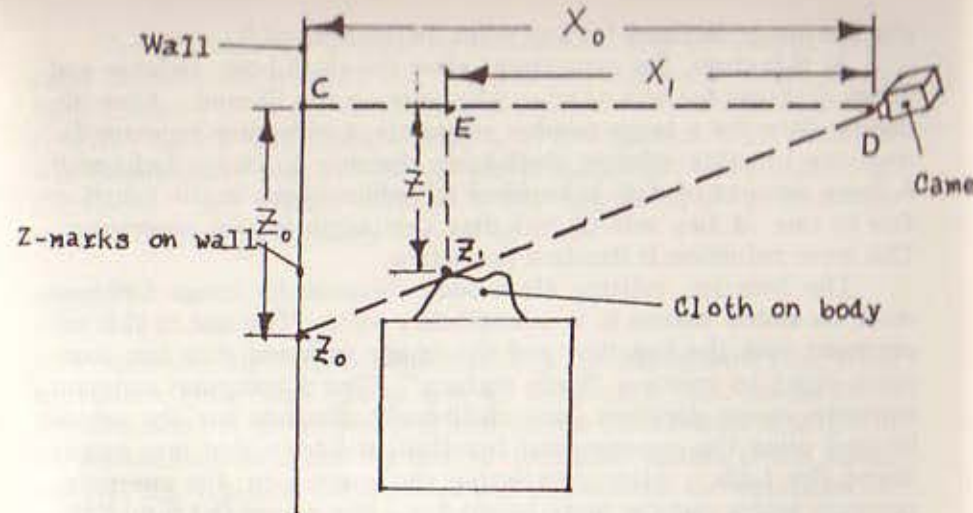


Fig. 6. Measurement of Z

Z<sub>1</sub>-E-D. These triangles are similar, which means their corresponding sides are proportional. The following expression is a consequence of the similarity of the triangles:

$$Z_1 = Z_0$$

$$X_1 = X_0$$

Since the experiment set-up determines X<sub>1</sub> and X<sub>0</sub>, and Z<sub>0</sub> comes from measurements off the photograph, the only unknown is Z<sub>1</sub>. The equation below is useful for determining Z<sub>1</sub>:

$$Z_1 = \frac{X_1}{X_0} Z_0.$$

The height of point A is the difference between the height of the camera and the value of Z<sub>1</sub>.

The cloth-body distance is the difference between the heights of the cloth and body. The photographs of the experiment — one taken with the cloth, and one taken with just the body — provide the measurements that determine the different heights for the cloth and the body. Since the difference of the two heights is the cloth-body distance, and the x- and y-values are known, all the necessary data from the photographs is available.

Before the comparison of cloth-body distance to image darkness takes place, the image darkness data for the whole image must be available. The image darkness for every point on the Shroud is stored on computer tape, and a computer program exists which will

give the image darkness for any point on the Shroud.<sup>5</sup>

At this stage, the experiment gives the cloth-body distance and image darkness for any number of points on the Shroud. After obtaining data for a large number of points, a computer program derives the function relating cloth-body distance to image darkness.<sup>6</sup> A large amount of data is required to reduce errors in the function due to one or two sets of bad data that occur in any experiment. This error reduction is standard procedure.

The function relating cloth-body distance to image darkness must be tested before it is scientifically valid. The test in this experiment uses the function and the image darkness data (on computer tape) to create a "body surface." First a computer program converts image darkness into cloth-body distance for the whole Shroud using the experimental function, and from that into height above the table. After completing the conversion, the computer program prints out the body height for a line across the top of the Shroud (figure 7). Then the program prints out similar data plots for a line across the Shroud at every 1/8th of an inch. These height printouts are then pasted to cardboard and the cardboard pieces are cut along the printouts. When these cut pieces of cardboard are pasted together in order, they form a surface as in figure 8. If the cardboard pieces form a surface that looks like a body then the function that relates cloth-body distance to image darkness is consistently accurate throughout the image. This would prove that the function relating cloth-body distance to image darkness is scientifically valid.

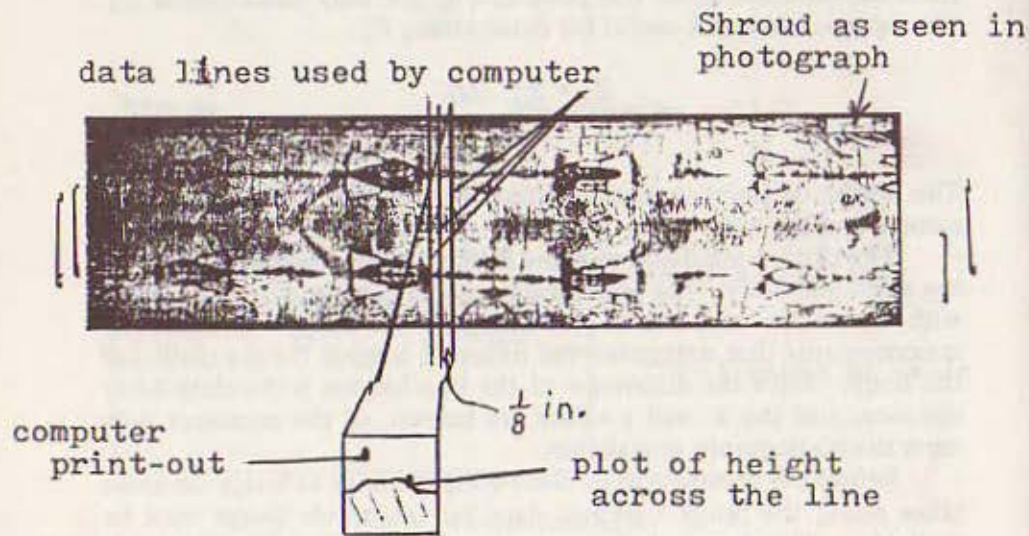


Fig. 7. Computer Test of Experiment

The previous work done by Dr. Jackson and Dr. Jumper indicates that the experiment will establish the function relating cloth-body distance to image darkness within error bounds that make the function useful for scientific analysis of the Shroud. This function will demonstrate that the image was probably not hand applied to the Shroud, and will aid scientists in their search for the process that made the image on the Holy Shroud of Turin.

### Errors

Errors in the data and the results in the experiment arise from systematic errors and human errors. Systematic error results from imperfections in the experiment and human errors cause mistakes in the measurements taken off the photographs. Errors in the values for  $X_1$ ,  $X_2$ ,  $X_3$ ,  $X_0$ , the alignment of the camera, the equations for cloth-body distance, and the function relating cloth-body distance to image darkness are all sources of systematic error. The derivation of systematic errors for the experiment are in Appendix A.

Human errors occur if the lines drawn on the photographs for determining the y- and z-values are not perfect or if the measurements off those lines are not perfect. Human errors resulting from inaccurate lines and measurements are rendered insignificant in this experiment by projecting the photographs on a large screen. Therefore, only systematic errors affect the data and results for this experiment. Systematic errors are listed in Table 1.

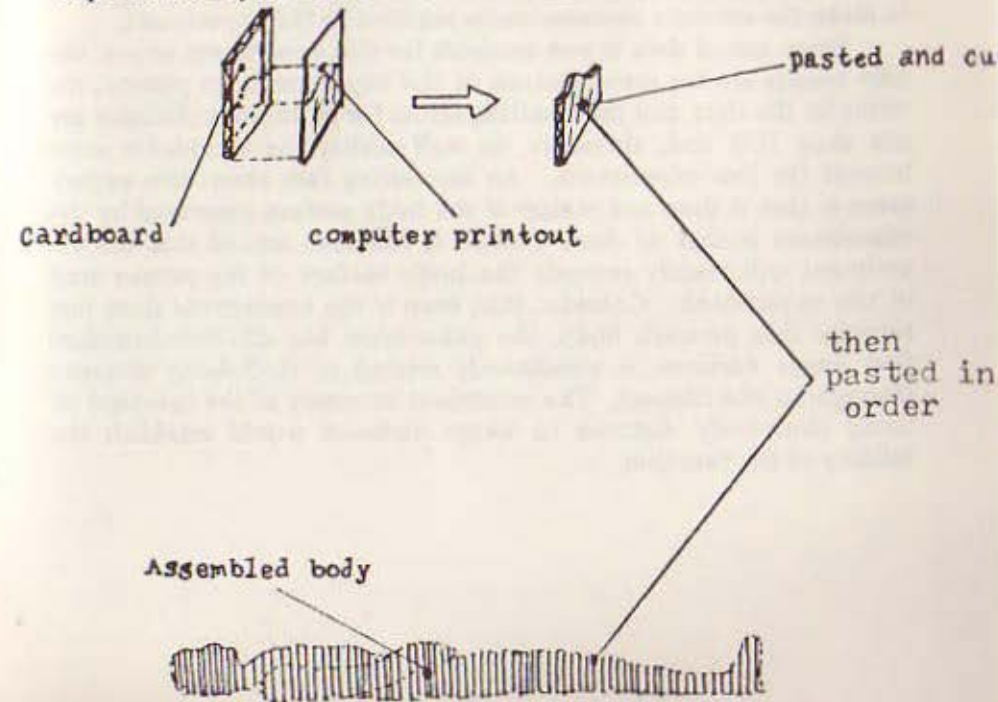


TABLE 1  
SYSTEMATIC ERRORS

value	error (mm)
X <sub>0</sub>	2.0
X <sub>1</sub>	3.5
X <sub>2</sub>	3.5
X <sub>3</sub>	3.5
Y	1.0
Z <sub>1</sub>	1.76
cloth-body distance	2.52

Table 1 Systematic Errors

### Results

To date, only trial photographs of the cloth and body exist. However, they are encouraging because they show that it is feasible to make the accurate measurements required in the experiment.

Since actual data is not available for this experiment as yet, the only results are for error analysis of the experiment. In general, the errors in the data and the resulting errors for cloth-body distance are less than 10% and, therefore, lie well within the acceptable error bounds for this experiment. An interesting fact about this experiment is that it does not matter if the body surface generated by the experiment is that of Jesus Christ. It has been argued that the experiment will merely recreate the body surface of the person used in the experiment. Consider this; even if the experiment does just recreate that person's body, the experiment has still demonstrated that image darkness is consistently related to cloth-body distance throughout the Shroud. The consistent accuracy of the function relating cloth-body distance to image darkness would establish the validity of the function.

### Conclusion

The experiment has sufficiently small errors in it that it will yield an accurate function relating cloth-body distance to image darkness.

### Recommendation

The experiment should be continued because the results of the experiment will be helpful in determining the nature of the process that formed the image on the Holy Shroud of Turin.



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- 4 Jackson and Jumper, p. 1
- 5 Jackson and Jumper, p. 1
- 6 Computer program is courtesy of Jackson and Jumper.

## APPENDIX A

### Error in X (error in meter-stick measurements)

$$\Sigma_O = \text{error in } X_0 \text{ due to equipment} = 2.0 \text{ mm}$$

$$\Sigma_x = \text{error in } X_1, X_2, \text{ and } X_3 \text{ due to equipment} = 3.5 \text{ mm}$$

### Error in Y (error in alignment of y=0 line)

$$\Sigma_y = \text{error in } y \text{ due to equipment} = 1.0 \text{ mm}$$

### Error in Z

The following error analysis is based on concepts found in Phillip R. Bevington's *Data Reduction and Error Analysis*. From the equation for  $Z_1$ ,

$$Z_1 = (X_1/X_0) Z_0$$

The error in  $Z_0$  is 1.0 mm and is due to error in the alignment of the apparatus. When the calculation for  $Z_1$  is performed, the error in  $Z_1$  is found to be 1.76 mm.

### Error in Cloth-Body Distance

Since the cloth-body distance is the difference of two values for  $Z_1$ , the error in cloth-body distance is twice the error for  $Z_1$ . Therefore, the error in  $Z_1$  is 2.52 mm.

### Percentage Errors

Because of the size of the experiment, the only significant percentage is in the cloth-body distance. Since the average cloth-body distance is more than 3 cm on the percentage error (ave.) is 10% for each measurement for cloth-body distance.

# X-RAY FLUORESCENCE ANALYSIS WITH APPLICATIONS TO THE SHROUD OF TURIN

By J. S. Accetta

Air Force Weapons Laboratory

## I. Theory of X-Ray Fluorescence Analysis

X-Ray Fluorescence Analysis is a subset of a general category of experimental techniques known as spectroscopy which has been fundamental to advances in physics for several hundred years. A number of experimental techniques are available to the investigator interested in identification of constituent elements in an unknown sample by examination of the characteristic emission spectra under suitable excitation. A series of characteristic emission lines exists in the x-ray region of the spectrum and is the subject to which this paper is addressed.

Figure 1 shows a typical energy level diagram of an atom with some of the possible transitions so labeled. Standard spectroscopic notation is used.

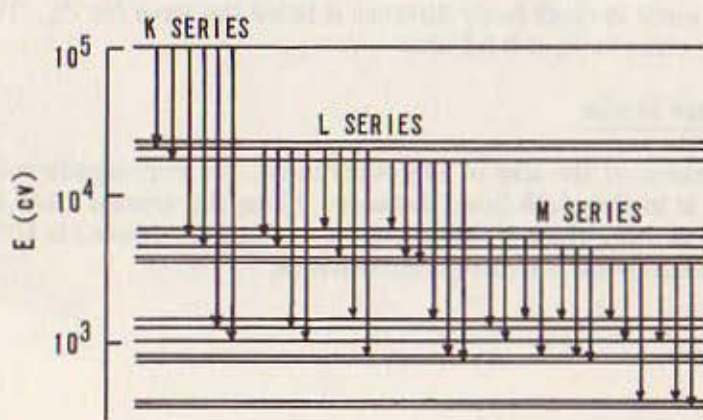


Fig. 1. Energy level diagram of an atom with transitions.

The removal of a K shell electron for example increases the energy of the atom. The "hole" created can be filled by an electron transition from one of the other shells. In general the most probable transition will be from the L shell whose hole can be filled in turn by one of the M shell electrons etc., resulting in a "cascade" of transitions giving rise to a characteristic spectra.

The particular technique, suggested by Delorenzi,<sup>1</sup> which appears to be most amenable to investigation of the Shroud is based upon the x-ray photoelectric effect whereby an atomic electron bound to its parent nucleus may be ejected by an incident x-ray photon whose energy  $h\nu$  is comparable to the electrons binding energy  $E_b$ . In contrast to the optical photoelectric effect which leads to ejection of electrons with small binding energies, the x-ray photoelectric effect for large  $h\nu$  can lead to the ejection of any electron. The incident photon is completely absorbed by the atom and since the electron is bound to the nucleus by electrostatic forces, the nucleus participates in such a way as to conserve momentum.

The probability of a given photon inducing photoelectric ejection, measured in terms of cross-section, is a function of the incident photon energy and atomic number of the target atom.

An expression for the K shell probability, which is derivable from quantum electrodynamics is given as:<sup>2</sup>

$$\sigma_{pE} = 1.61 \times 10^{-28} \sigma_T Z^5 \left( \frac{E_e}{h\nu} \right)^{7/2}$$

where  $\sigma_T$  = classical Thomson cross-section of the electron  
 $Z$  = atomic number of the target atom  
 $E_e$  = rest mass energy of the electron  
 $h\nu$  = energy of the incident photon

The general trend is that the photoelectric absorption probability increases with decreasing photon energy. This comes about because the electron, in a relative sense, is more tightly bound for lower energy photons and hence it is somewhat easier for the nucleus to absorb the required momentum. When the energy of the photon falls below the binding energy of an electron, the probability of absorption drops abruptly to zero simply because there is insufficient energy for ejection. Typical variation of this cross section for K-shell ejection is shown in Figure 2 for  $h\nu = 22$  KeV.

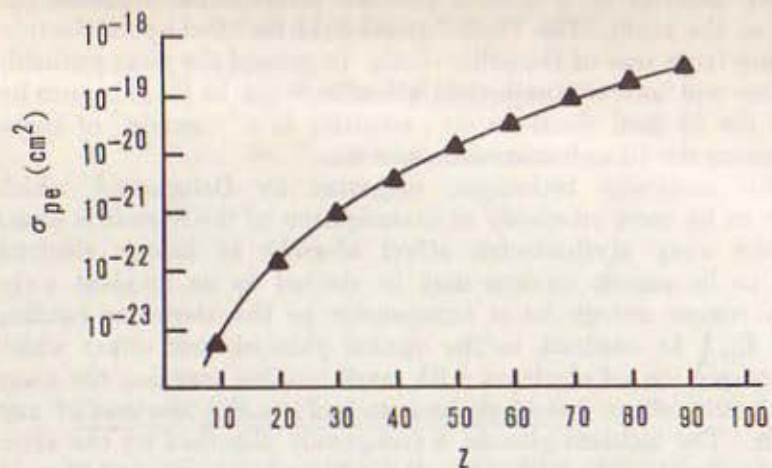


Fig. 2. K-shell ejection cross-section variation.

The onset of photoelectric absorption for a particular electron shell is denoted as the "edge" and is often expressed as "K edge," "L edge" etc. The approximate K and L edge energies are given in Figure 3 as a function of atomic number.<sup>3</sup>

Ejection of a K or L electron results in a cascade of transitions giving rise to the characteristic x-ray spectrum.

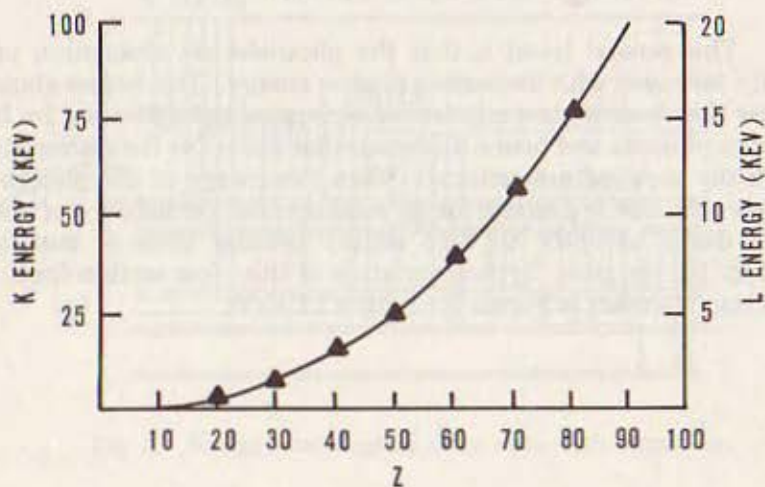


Fig. 3. K and L edge energies as a function of atomic number.

## II. Experimental Configuration

Although conventional x-ray sources may be used, a particular method that lends itself well to field work is the utilization of radioisotopes as x-ray excitation sources. Isotopes that are commonly used for this purpose are listed in Table I.<sup>4</sup>

Table I

Radioisotope	Half Life	X-Ray Energy (KeV)
<sup>55</sup> Fe	2.7 y	5.9
<sup>109</sup> Cd	470 d	22
<sup>145</sup> Sm	1.9 y	39

Some of these sources also emit  $\gamma$  radiation of higher energy. One possible field experimental configuration is shown in Figure 4.

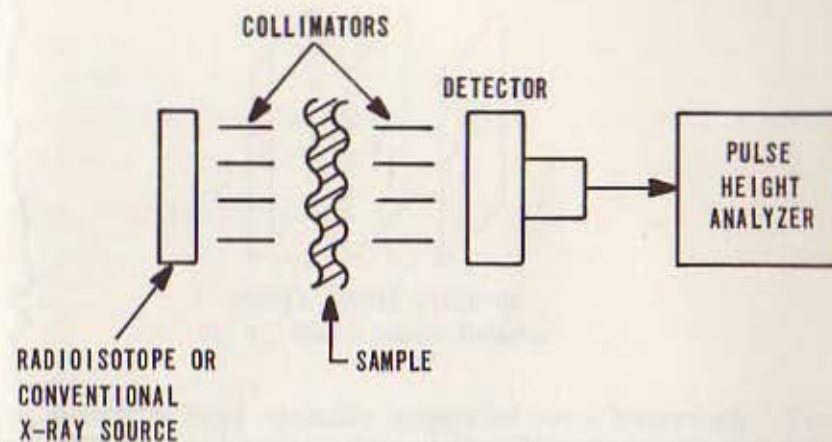


Fig. 4. Possible field configuration for experiment.

Complete systems of this kind are available commercially. A typical arrangement might consist of a <sup>109</sup>Cd excitation source, a cooled Ge(Li) detector, a 4096 channel analyzer and display unit. The sensitivity of the technique is dependent on a number of variables such as the energy and flux of the excitation source, unknown concentration, counting time, background levels and sample thickness. A typical spectra using an arrangement of this kind is shown in Figure 55.

Sensitivities of 50 parts per million or better corresponding to a few  $\mu\text{g}/\text{cm}^2$  in concentration levels are not uncommon.

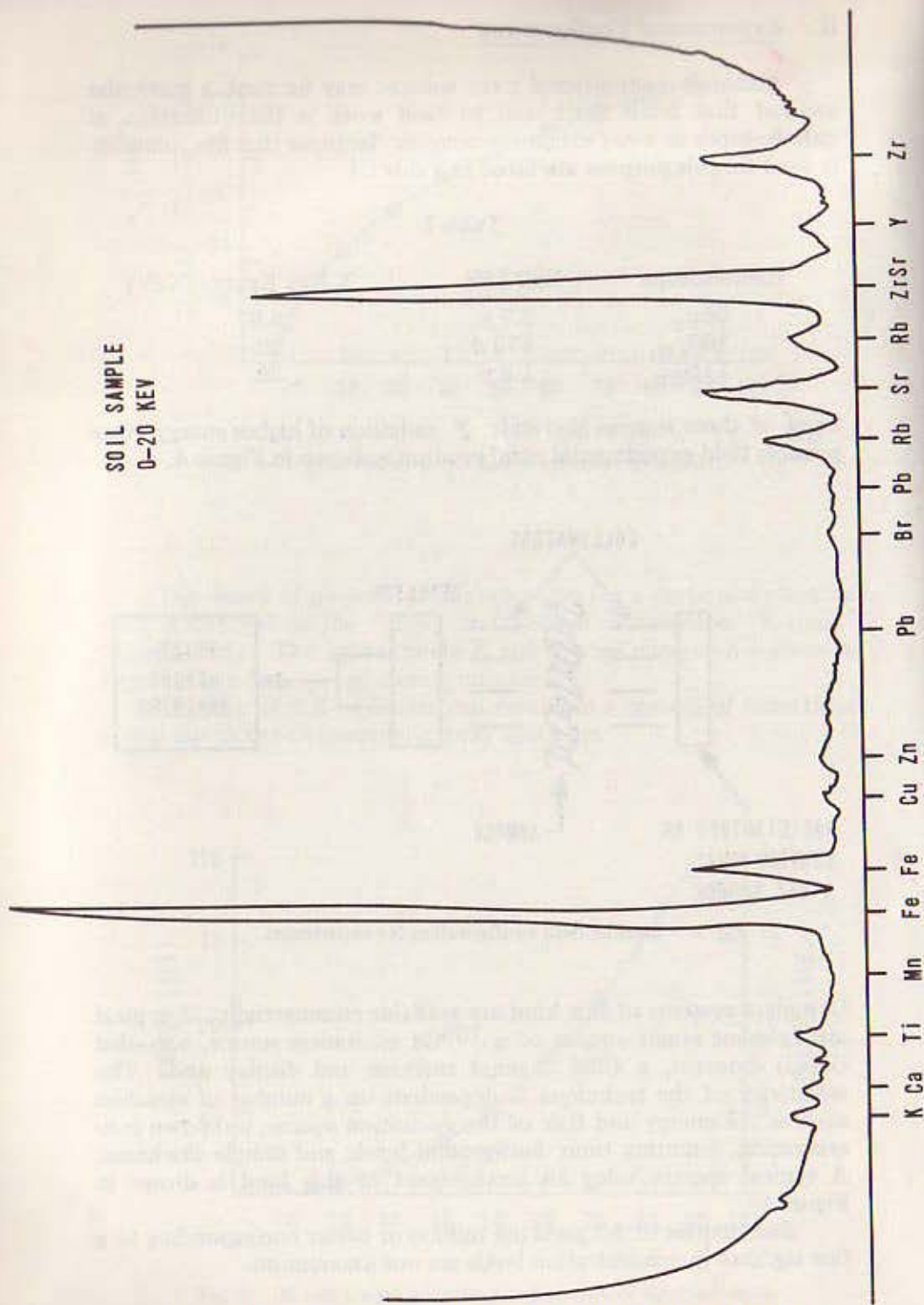
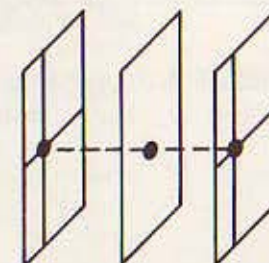


Fig. 5. Typical spectra sample using the proposed test arrangement.

### III. Investigation of the Shroud

The objective of the application of this technique is to characterize the Shroud in terms of trace element concentration as a function of some spatial coordinates. If we presume a counting time of 10 min for each 10 cm<sup>2</sup> of cloth, one might be able to characterize some 40 cm<sup>2</sup> per hr of effort. Since time would be somewhat limited, only certain preselected portions would be investigated. As pointed out before, the probability of absorption is dependent on source excitation energy for a given atom so the sensitivity can be optimized to some extent by choosing the proper excitation source; however, in this instance, since there is little apriori reason to suspect the presence of any particular element, the options are: (1) choose a source that will excite the widest possible range of elements with some sacrifice of sensitivity. (2) do several characterizations with different sources, considerably lengthening the time required.

An experimental configuration that appears feasible for this investigation is shown in Figure 6.



SOURCE SAMPLE DETECTOR

Fig. 6. Source Sample Detector.

The Shroud is hung vertically suspended on a framework. Two identical frameworks are positioned directly in front of and behind the Shroud. Each framework would be equipped with a positioning system such that source and detector are always axially coincident during examinations of any segment of cloth.

An alternate approach is to position both source and detector on one side of the sample only. The optimum experimental approach should be the subject of a preliminary investigation.

Some questions to be answered with this technique.

1. Does the image have a characteristically higher concentration of one or more elements?

2. Does the Shroud in general have an abnormal concentration of any trace element?
3. What is the effect of the backing material on the measurement?
4. Can trace elements of blood be identified?



The author wishes to acknowledge the contributions of H. J. Fullbright, R. Morris, and R. Rogers of the Los Alamos Scientific Laboratories.

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# INFRARED THERMOGRAPHY WITH APPLICATIONS TO THE SHROUD OF TURIN

By J. S. Accetta

Air Force Weapons Laboratory

## I. Theory of Infrared Thermography

All objects whose absolute temperatures exceed 0°K emit radiation over some portion of the electromagnetic spectrum. The infrared region of the spectrum roughly encompasses the wavelength range of 1-1000 $\mu$ m. An entire distinct technology has evolved over the years as a result of the need for information in this region.

The total energy of a molecule can be subdivided into electronic, translational, rotational and vibrational energies. In the region of 2-30 $\mu$ m, the emission spectra of a radiating object consists principally of vibrational transitions between states induced by random thermal energy. Thermal radiators are sources whose spectra consists of a distribution of very closely spaced emission lines forming an apparent continua when observed with instruments of moderate resolution. Most solids and liquids can be classed as thermal radiators at reasonable temperatures.

Planck showed that the distribution of radiation from a perfect radiator termed "blackbody," could be described by the following expression.<sup>1</sup>

$$W = \frac{2\pi hc^2}{\lambda^5} \left( \frac{1}{e^{hc/\lambda KT} - 1} \right)$$

where  $W$  = spectral radiant emittance in watts  $\text{cm}^{-2} \mu\text{m}^{-1}$  radiated into a hemisphere, and  $T$  = absolute temperature in °K. The other symbols have their usual meaning.  $W_\lambda$  is shown in figure 1<sup>2</sup> for various temperatures of the radiating object.

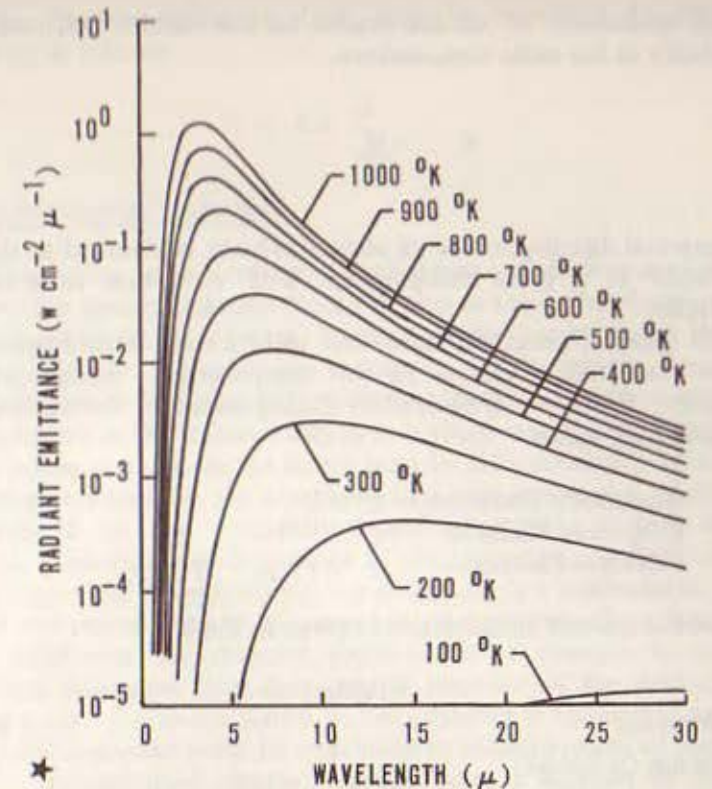


Fig. 1. Distribution of Radiation.

The total radiated flux of any subset of the region can be found by integration of the above expression over the appropriate wavelength limits.

$$W = \int_{\lambda_1}^{\lambda_2} W(\lambda) d\lambda \text{ (w cm}^{-2}\text{)}$$

If the integration is carried out over all wavelengths, the result is the total radiated flux.

$$W = \int_0^{\infty} W(\lambda) d\lambda = \sigma T^4$$

where  $\sigma$  = constant

This classic result is the Stephan-Boltzman law.

A correction term to describe non-blackbody radiators, termed "greybodies" is defined as emissivity  $\epsilon$  and is given by the ratio of

radiant emittance  $W'$  of the source to the radiant emittance of a blackbody at the same temperature.

$$\epsilon = \frac{W'}{W}$$

The spectral distribution of an ideal greybody is identical to that of a blackbody at a given temperature with exception of a reduced amplitude.

In general, emissivity turns out to be a complicated function of source material, surface finish, temperature, wavelength and geometry. Sources can be crudely distinguished by the way in which the emissivity varies.

Blackbody Radiator	$\epsilon = 1$
Greybody Radiator	$\epsilon < 1$
Selective Radiator	$\epsilon = f(\lambda, T, \dots)$

Some total normal emissivities are given in Table 13.

Table 1

Material	Emissivity
Aluminum (polished)	.05
Aluminum (anodized)	.55
Gold (highly polished)	.03
Steel (oxidized)	.79
Brick (red common)	.93
Glass (polished)	.94
Lacquer (white)	.92
Nickel	.05
Oil on Nickel base (.001 inch layer)	.27
Oil on Nickel base (thick)	.82
Paint (oil average)	.94
Skin (human)	.98
Soil (average)	.92
Water	.96
Snow	.85

From the table we may conclude that emissivity cannot be estimated from visual appearances.

The Stephan-Boltzman Law may be rewritten to consider emissivity as follows:

$$W = \epsilon \sigma T^4$$

## II. Experimental Technique

There are a large number of techniques and devices available to measure the energy radiated from a source in the infrared region. Of particular interest are thermal imaging devices operating in the 3-5  $\mu\text{m}$  and 8-14  $\mu\text{m}$  region of the spectrum. These devices, known as thermographs or scanning radiometers, convert the radiant emission from a source in the infrared region to a visual image. The brightness of any scene element in the image may be radiometrically related to the energy emitted by the corresponding source element which is in turn related to the temperature and emissivity of that source element. Resolution is dependent of the instantaneous field of view of the device and is typically on the order of a few milliradians.

If the entire scene is at a constant temperature then changes in scene brightness are directly attributable to changes in average emissivity integrated over the spectral response of the device. For precise work, the visual acuity of the observer is unreliable and the instrument response must be converted to absolute units of measurement. Sophisticated imaging devices have a number of built-in features that enable quantitative measurement of a thermally radiating object.

## III. Application to the Shroud

Some relevant questions are:

1. Does an image exist in the infrared?
2. Since the image would depend on surface emissivity, can something of the surface properties be deduced?
3. Can the emissivity changes, if any, be related to a chemical change in the cloth?

To answer the foregoing questions, the following experiments are suggested:

a) The simplest method to obtain infrared information is controlled photography using commercial infrared film. Properly handled, the spectral response of this film is extendable to about 1.2

$\mu\text{m}$ . The purpose of this procedure is to possibly reveal some heretofore undiscovered gross features in the Shroud and secondly to contribute further spectral information to the image analysis effort.

b) To further the extent of spectral image information, it is recommended that the Shroud be scanned in the 3-5  $\mu\text{m}$  and/or the 8-14  $\mu\text{m}$  regions of the spectrum using scanning thermographs. The purpose of this effort is identical to the above.

c) Lastly, it is recommended that spectral image data be obtained to identify variations in spectral emissivity across the image. This information is crucial in any attempt to identify the chemical composition of the image forming material.

The experimental implementation of these techniques are quite straightforward. The only precaution necessary is to enclose the Shroud in a small chamber to prevent changes in temperature due to convection. Data may be digitized and recorded for subsequent quantitative reduction. For calibration, a passive blackbody cavity at the same temperature of the Shroud would be inserted into the scene measurement. The entire procedure should take no longer than 4 to 6 hours.

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## AUTHENTICATION OF THE TURIN SHROUD

By Walter C. McCrone

For centuries the Turin Shroud has been a holy relic of the Catholic Church owned by the Italian House of Savoy. The Shroud rests in a silver case in the Cathedral of Turin, Italy. The provenance of the Shroud is known dependably for more than 600 years with considerable evidence extending this date back to the time of Christ.

It would be a tremendous accomplishment if the Shroud could be dated, and a date near the time of Christ would certainly lend considerable weight to the evidence that it is indeed the Shroud of Christ Himself. It is also important to determine the nature of the image on the linen. If the mechanism of image formation and the chemical nature of the image can be determined and if the stains which form a part of that image can be shown to have been caused by body fluids, this would be further authentication. Finally, success in these areas would lend strong credence to the evidence gained from the image itself. It would then be very difficult not to conclude that the Shroud was indeed that of Christ.

We believe there is an excellent chance that the Shroud can be dated, using very new techniques, and that the chemical nature of the visible markings can be established. We further believe this can be done without removing additional samples from the Shroud. We will discuss each of these analytical problems in turn, beginning with the problem of dating very small samples of organic materials such as linen.

### Carbon Dating

Carbon dating has become an established technique for the archeologist. To a lesser extent it has been used to date art objects and other historical materials. The procedure was pioneered by W.F. Libby who was able to determine the amount of residual  $C^{14}$  and re-

late this to the aging of carbon-containing materials. His method used several grams of carbon placed in a Geiger counter to record beta tracks from the radioactive  $C^{14}$  present in all carbon samples.

This method originally required 20-25 gram samples of wood, paper, cloth, etc., but this has been progressively reduced. Prof. Codegone in his report did not reflect this progress. Even though his report is dated April 1971, a variety of laboratories were able in 1971 to analyze 5-6 gram samples. This figure was further reduced to 2-3 grams, then to 0.5-1.0 grams and now at least two laboratories in the U. S. are building equipment able to date 0.05 g (50 mg) samples.

Expressing these figures in terms of weight of the Shroud linen, 1 m<sup>2</sup> of which weighs 234 g, we find the area of linen required per test:

<u>Date</u>	<u>Sample weight</u>	<u>Sample area</u>
1950	40 grams	40 x 40 cm (1600 cm <sup>2</sup> )
1970	20 grams	30 x 30 cm (900 cm <sup>2</sup> )
1971	5 grams	14 x 14 cm (196 cm <sup>2</sup> )
1973	2.5 grams	10 x 10 cm (100 cm <sup>2</sup> )
1974	600 mg	5 x 5 cm (25 cm <sup>2</sup> )
1977	50 mg	1.4 x 1.4 cm (2.0 cm <sup>2</sup> )

X These improvements can be attributed to steady improvements in both equipment and techniques. The rapid progress in the past ten years has been due to the art conservationists who wish to date art objects but cannot spare more than slivers of wood, paper or canvas. The project now nearing fruition with the listed 1977 area requirement of  $1.4 \times 1.4 = 2.0 \text{ cm}^2$  is sponsored by the Smithsonian Institution. As a Fellow of the International Institute of Conservators I have followed this work with interest. We know very well the scientists involved. We would be able to arrange to have the Shroud samples dated probably during the summer of 1977 under conditions of the highest security, and our closest supervision to ensure a secure "chain of evidence" and utmost secrecy.

Note that the smaller of the two Shroud linen samples previously examined by Prof. Raes (pp. 78-83 of the Commission's report "La S. Sindone") (70 mg, 3 cm<sup>2</sup>) more than meets in area and weight the minimum required and the larger (110 mg, 5 cm<sup>2</sup>) exceeds the minimum by more than a factor of two. Several analyses for date can, therefore, be determined on these two samples.

### Identification of the Stains and Image

A second phase of an ultramicroanalytical program would in-

volve the stains and the image. There is evidence from the Commission's report that the stains, at least, are visible on only one side of individual fibers and the cellulose fiber itself is white. The significance of this lies in the palpability of the stains; they are physically tangible. The ion microprobe is an ideal tool for this task. It identifies all elements and even organic compounds. It is able to identify samples invisible even with the light microscope. It detects, on one tiny spot on one of my scalp hairs, for example, more than 30 trace elements attesting to the fact that such a hair can only have come from my head, the calcium level ensures good cell membrane equilibria, the iron level that I am not anaemic, the potassium level that my hyperactivity is under reasonably good control, the zinc that I need not fear schizophrenia and the lithium is protection against manic depressive behavior. Finally, the vanadium and chromium levels announce that I am 60 + 2-3 years. Only three years ago such analyses were impossible and no other analytical method can make such analyses. It will enable us to tell which of all the 104 chemical elements are present in blood stains, in any other stained area and in the image and qualitatively, at least, the amount of each. We have ready access to blood-stained linen from Egyptian mummies and even from other burials in the Middle East for comparison. The trace elements in blood are similar to those in hair since, of course, the trace elements in the hair came from the blood stream. We feel that there is a good chance of success in relating the apparent stains to blood by means of the trace elements found.

The organic components of blood are also distinctive in composition and some are particularly stable chemically, e.g., porphyrins. The ion microprobe shows molecular organic fragments as well as inorganic ions and molecular fragments, hence the organic components of blood should also be identifiable in blood-stained areas. There is yet another ultramicroanalytical tool capable of characterizing and identifying organic and inorganic molecules — micro Raman spectroscopy. This instrument which became available commercially only in March 1977 yields information equivalent to infrared absorption, but on samples nearly 1,000,000 times smaller, i.e.,  $10^{-12}$  g. It should also be able to identify blood and other stains, image, etc.

We feel confident that no more sensitive or appropriate analytical instruments could be found for this project. We are also confident that the results will answer the question of blood and give us new and useful, hopefully definitive, information on the image. We are pleased that only single fibers are required. The actual portion analyzed will be 10 times smaller than the human eye can see.

There are other very sensitive microchemical tests for blood often carried out on a single stained fiber. Interestingly enough, old blood stains often react more strongly than fresh with some of the reagents used. The most sensitive blood tests involve catalytic color or luminescence development. The oxidation of certain substances such as phenolphthalein, benzidine or luminol is catalyzed by hemoglobin. The most minute amounts of blood contain enough hemoglobin to produce by catalysis a great deal of reaction product. The most sensitive of these tests is probably the phenolphthalein test.

As a result of the Albuquerque meeting I have decided to add the following material. Although somewhat repetitious it is more general with respect to chemical analytical possibilities.

Suggestions with respect to analysis —

Introduction: There have been many developments in microanalysis in the past 1-5 years and, indeed, they are continuing today. In fact, two highly significant microanalytical tools are only now in the final stages of development: 1. Carbon-dating of 50 mg (3 cm<sup>2</sup>) samples and 2. Micro Raman spectroscopy on picogram samples.

Samples needed: Some analytical tests can be carried out on the Shroud as a whole:

- reflection x-ray fluorescence
- photography at different wavelengths
- x-ray radiography (soft x-rays)
- infrared thermography

Other tests require milligram samples, i.e. carbon dating (50-100 mg). Two such samples are already available (60 and 110 mg) and should be used for carbon dating.

Finally, some tests are extremely micro in terms of sensitivity, i.e., pollens and single fibers. These include light and electron microscopy, micro Raman, electron and ion microprobes. Again, a number of threads have been taken already (p. 23-25 of Sindone).

Among the very micro tests is single particle identification. "Dust" from the Shroud should be collected and characterized. Specific areas such as folds and creases should be sampled individually. Once this is completed the dust from the entire Shroud should be collected. Both sampling operations would be done with a "micro vacuum cleaner" (figure 1). The particles thus recovered will include 2000 years of biological and mineral substances as well as particles associated with people and their activities: flyash, industrial, etc. These particles can be individually identified and many (biological and mineral) are characteristic of specific locations.

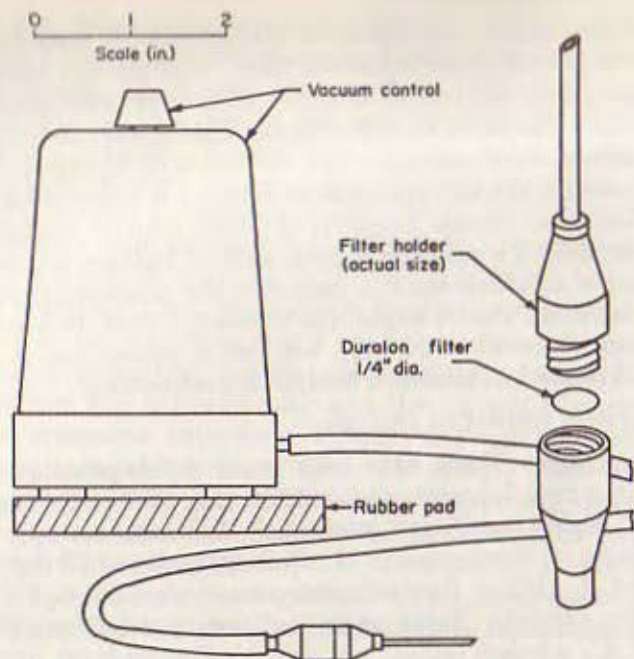


Fig. 1. A small particle collector made up of a small vacuum pump and a probe tip holding a 6 mm membrane filter (from Particle Atlas Two, Ann Arbor Science Publishers, 1973).

#### Analyses to be recommended:

Reflection x-ray fluorescence — At least three different areas should be examined: background, body image area with stains absent; blood stained area. This examination will show elements above about sodium if the amount of the element is high enough.

X-ray radiography\* — This should cover the full Shroud using soft x-rays.

Infrared thermography\* — As usually used this is a method of temperature mapping. For example, breast tumors can be located by a slightly higher skin temperature over the tumor itself. This makes the tumor site visible on an infrared thermogram. The Shroud would normally show a uniform temperature over the entire surface but if irradiated for a minute or two with IR radiation some areas due to absorption of IR would become warm compared with other areas that do not absorb IR. The absorption is composition dependent. Although the resulting image would not be very helpful in telling

what the chemical composition is in different areas it might give enhanced contrast in the Shroud image.

Photography at different wavelengths\* — Good photographs should be taken in UV, visible and IR, preferably to be at sufficiently close wavelength intervals to show variations in light absorption. Fluorescence (UV) should be recorded separately.

Carbon dating — This is a destructive method. The sample must be purified, then burned to CO<sub>2</sub> for  $\beta$ -counting in a small proportional counter. This equipment becomes available during the summer 1977. The counting time is 2-3 months.

Micro Raman — This is a very micro method (picogram; 1  $\mu$ m<sup>2</sup>) capable of identifying organic and inorganic compounds. It should identify blood components, e.g., porphyrins; compounds in different stained areas and the presence of aloes, other spices, incense, etc. if enough is present.

Microprobes — The electron microprobe will detect 10<sup>-15</sup>g of most elements with atomic numbers above beryllium. The 10<sup>-15</sup>g must be in 50-100 ppm concentration. Spot size or size of analysis site is 0.01  $\mu$ m<sup>2</sup>. The results are quantitative.

The ion microprobe is much more sensitive: 10<sup>-20</sup>g and ppb-ppm. All elements in the periodic table can be detected although quantitation is difficult. Recently, the ion probe has been showing considerable success for the identification of organic compounds. It is still best considered a finger-print method with comparison of patterns obtained from the Shroud fibers with patterns from known substances.

Light and electron microscopy (PLM & SEM) — The principal area of application for PLM and SEM is for sample site selection, i.e., choosing the areas for microprobe and/or micro Raman study. PLM has, however, been very successfully applied by Dr. Max Frei to the identification of pollens obtained by applying sticky tape to the Shroud surface. This study should be continued and extended to include SEM by Dr. Frei with dust removed from the Shroud by "micro-vacuum cleaner" or equivalent (figure 1). He should attempt to relate the types of pollen observed to the portion of the Shroud from which it was taken, i.e., face area vs other areas. This might show that the face area has pollens characteristic of the Edessa period when it was thought to have been folded for showing only the head.

\* These are lower priority recommendations.

The light microscope will also identify any dust particles whether mineral, industrial or flyash. These samples should be taken cooperatively with Dr. Max Frei who is an acknowledged expert in the identification of plant materials (fibers, pollens, seed and leaf hairs etc.). A density separation would give Dr. Frei the biological particles in the lighter fraction and McCrone Associates the heavier mineral, industrial and flyash fraction.

### Conclusion

The interest of McCrone Associates personnel lies in two areas and we would hope to participate actively, or cooperatively, in these areas:

1. Carbon dating
2. Untramicroanalysis
  - a. Shroud image
  - b. stains
  - c. extraneous organic substances, i.e., aloes, incense, myrrh, etc.
  - d. particle analysis

Some samples are already available, e.g., carbon dating and blood stains but, if future events prove propitious, it would be highly desirable to obtain additional samples under each of the above categories especially of fibers showing the Shroud image, background fibers (no obvious stains or image) and particles vacuumed from the linen fibers.

Any scientist working on this project will be aware of his own personal emotional involvement. Although still a scientist committed to elucidating the truth, he will feel impelled to do his utmost to learn the final answer. At the same time, we must all be aware of the sensitive nature of the information we may learn. The protection of this information and its transmission through proper channels must remain uppermost in our minds.

## CHEMICAL CONSIDERATIONS CONCERNING THE SHROUD OF TURIN

By R. N. Rogers

I believe that the excellent work and observations of the Turin Commission and the fact that the Shroud has been through a fire make it possible to propose what may be nearly definitive experiments for the future. However, in order to make a truly scientific study we should start by applying Scientific Method. We should consider all possible hypotheses; all of the hypotheses should be expressed as clearly and concisely as possible; each should be given an adequate test, and no preconceived ideas should be defended. Three possible hypotheses are considered below.

(1) Hypothesis: the image was painted on the cloth. What facts do we have or lack to prove or disprove this hypothesis? The following observations can be mentioned: the coloration appears on one side of the cloth only, the cloth does not appear within the fiber bundles (it was not absorbed by the fibers), and no direct test for hemoglobin was positive.

However, if the image were painted, it had to be painted with a colored material; otherwise the artist could not observe the progress of his work. What colored materials could have been used prior to the known history of the Shroud? Most would have been inorganic in an organic vehicle or water, ~~egg~~<sup>egg</sup> yolk in oil or egg white. More unlikely would have been natural organic pigments or stains; however, many of them would have been plant or animal porphyrins, all of which contain characteristic metals. Purely organic materials can be rejected on obvious grounds. Purely inorganic pigments may not have been changed by the heating received at the time of the fire, but all organic colors should have suffered a change in proportion to the severity of the heating they received. The closer the organic vehicle or dye to a heated area, the greater should be its change of color or

density. No variation of color with position is observed on the Shroud: shading is accomplished by variation of density not color. Tone remains constant with position. I believe that the obvious thermal gradient that existed at the time of the fire eliminates the possibility that any organic vehicle was used for an inorganic pigment, that any organic pigment, dye, or stain was used, or that any common porphyrin pigment was used. The lack of observed capillary flow or absorption seems to eliminate most water-based (ink-like) inorganic systems from consideration.

The only conclusion that can be reached is that, if the image were painted, a stable, particulate inorganic pigment in a water base had to have been used. Painting could not conclusively be proved by detection of one or more of the expected pigment metals; however, the hypothesis could be conclusively disproved by demonstration of the absence of any inorganic pigment.

I believe that the best way to test nondestructively for the presence or absence of inorganic pigments would be by x-ray fluorescence, and I consider this analysis to be the most important nondestructive test that can be run during the 1978 viewing.

Multiple x-ray fluorescence analyses should be made, including analyses of the base cloth, charred areas, blood stains, and image areas. A somewhat variable background concentration of heavy metals can be expected as a result of the fire and the heating of the silver cask used to store the Shroud; however, it should be possible to detect discontinuous distributions of specific metals, if they are there. Note that it should be possible simultaneously to detect sodium depositions at zones of expected body fluid or tear deposits.

It is unlikely that much sodium would be contributed by the cask, and I doubt that the area of the image has been handled sufficiently to mask a heavy sweat impregnation. Therefore, a discontinuous distribution of salt on the Shroud, without a concomitant distribution of pigment metals, would serve to indicate a natural cause for the image. The colorless crystals observed by the Commission suggest the possibility that salt is present; they should be identified.

(2) Hypothesis: the image was produced naturally by reactions between volatile products from a body and the cellulose of the Shroud or spices or by direct absorption of vapors or fluids produced by the body by a combination of processes involving organic reactions and/or materials.

No capillary flow evidence has been observed microscopically, the image is largely on the front surface of the material, and shading

appears to eliminate direct imprinting by body contact. Again, however, the expected thermal gradient during the fire appears to eliminate conclusively the possibility that any expected organic colorants or reaction products could be responsible for the image.

Pure cellulose begins to produce gaseous products at an appreciable rate shortly before 590°F (310°C); unprocessed cotton batting and newsprint begin to pyrolyze rapidly at about 446°F (230°C). Parts of the Shroud were, then, subjected to temperatures sufficient to produce darkening for some unspecified time. The thermal conductivity of flax fiber is about  $1 \times 10^{-3} \text{ cal cm}^{-1} \text{ s}^{-1} \text{ } ^\circ\text{C}^{-1}$ . Not all of the Shroud was darkened by the fire; therefore, a rather steep thermal gradient had to exist. However, parts of the image that are essentially in contact with darkened areas have as nearly as can be observed identical color tone and density as parts of the image at maximum distance from a discolored area. If large, complicated, natural-product organic molecules were responsible for the image, they should have decomposed, changed color, or volatilized at different rates depending on their distance from a high-temperature zone during the fire. There is no evidence for any variations at all.

In addition to basic, simple thermal stability, we must consider reactions between organic deposits (or, indeed any deposits) in the image and pyrolysis products of the cloth in a closed (or nearly closed) cask.

At 200 to 300°C, cellulose and residual hemicellulose pyrolyzes to produce hydroxymethyl furfural, water, furfural, formaldehyde, formic acid, levulinic acid, 3-pentenoic- $\gamma$ -anhydride, and many lesser products. Oxygen would be quickly depleted within the cask, allowing true combustion to occur only at a zone open to communication with the air. Pyrolysis products would, however, quickly permeate the cloth. Most of the major products are extremely reactive — they could, for example, quickly reduce the iron of an ochre pigment to black iron oxide (a reaction used by potters). Formaldehyde denatures proteins, reacts with ammonia and amines, couples with phenolic compounds, reacts with alcohols and sterols, and acts as a potent reducing agent. Some relatively simple porphyrins might survive the heat and reactive products, but it should be absolutely useless to look for characteristic reactive body exudates, eg, I would not expect to observe any of the normal constituents of sebum. The sulfur of any sulfur organics should be gone as  $\text{H}_2\text{S}$ .

The fire seems to preclude the possibility that the original image was composed of natural organic materials or reaction products, be-

cause the present image does not vary in color tone or density as a function of the thermal gradient during the fire.

Note also that, if the present image were the result of a catalyzed thermal degradation of the cellulose during the fire, it should vary in color tone and density as a function of position: it does not.

Absence of hemoglobin is not surprising: it would have been badly degraded by heat and reactive pyrolysis products of the cloth during the fire. Fluorescence observed in the ultraviolet photographs may indicate derivative porphyrins from blood, however. X-ray fluorescence should still detect iron in blood-stain areas. Ion microprobe analysis may detect parent peaks of blood-derived porphyrins, because they are very stable molecules. Similar ion microprobe fragmentation patterns from charred and image areas or absence of any expected natural organic compounds would help disprove this hypothesis; however, I believe it is largely disproved by absence of expected variations in color as a result of the fire.

(3) Hypothesis: the similarity of color between the image and heat-damaged areas, the existence of the image on one side of the cloth only, and the roughly  $1/r^2$  dependence of image density with expected separation between body and cloth suggest rapid heating as the cause of the image.

An image originally formed by thermal discoloration of the cloth would not change color or density significantly with any additional heating that did not discolor the surrounding cloth. If x-ray fluorescence does not identify any pigment on the cloth and no thermally stable organic pigment can be suggested, this appears to be the only hypothesis left.

An ESCA (electron spectroscopy for chemical analysis) study of the image compared with control cloth and thermally darkened cloth might yield some information; however, such analysis would require removing a sample of cloth from the image area, and I doubt that results would ever be definitive. Reflectance spectrometry might prove identity of the image and thermally darkened cloth, but photographs taken with different filters may provide the required data as well. It may not be possible to prove conclusively that the image is the result of thermal degradation of the cloth, but a very strong circumstantial case could be made.

The following additional observations may be made.

(a) The crimson, mentioned in the Commission report as probably being the result of painting, could be an iron derivative produced during the fire.

(b) The porphyrins could best be detected by fluorescence spectrometry, but such testing would probably require sampling the Shroud. Porphyrin resolution should be considered in planning photographic efforts.

(c)  $^{14}\text{C}$  dating should be done; however, great care should be observed in the purification of the sample. Simple washing and extraction may be sufficient, but control samples should be saved.

# PHOTOGRAPHY OF THE TURIN SHROUD FOR USE IN IMAGE ANALYSIS EXPERIMENTS

By Don Devan

## Introduction

In this paper, the problem is addressed of designing a photographic experiment for the Shroud of Turin from the point of view of the ultimate use of those photographs as elements of a multifaceted structure of physical evidence, historical record, conjecture and deduction which has been under construction by secular and theological scholars, over the years, to establish the true place of this relic in church history. The paper is written with the realization that many excellent and carefully conceived photographs have been taken in the past for the purpose of documenting the physical appearance of the Shroud and for the purpose of making accurate records of the Shroud's visual presence available to the scholars who pursue its understanding.

It is not intended, in suggesting that a new set of photographic images is necessary, to in any way detract from the value of the existing images or the diligence and expertise of previous photographers. On the contrary, the expertness, care and consideration which was indicated (for example) by the documentation supporting the photography performed during the most recent scientific examination of the shroud in 1973 was both gratifying and impressive. Instead, what will be outlined below are the guidelines for a set of Shroud photographic images specifically oriented toward subsequent image analysis, evaluation and enhancement techniques, many of which involve the use of digital computer technology.

The nature of such images, and in particular the supporting information describing the conditions under which the images were obtained and developed, is in most particulars different (and more

demanding) for images with this intended use than it is for images whose intended use is for human visualization. Thus, given the broad range of possibilities for the realization of new information about the Shroud by the use of contemporary image processing techniques (information such as that relating the intensity of staining to cloth/body separation — as reported in several papers by John Jackson and Eric Jumper), it would seem that there is high potential for the continued realization of factual "building blocks" for the structure of Shroud scholarship through the use of such image analysis concepts and capabilities. Further, this potential can be made manifest by the availability of photographic images of the Shroud which were specifically created in the light of the requirements pre-imposed by the conceptual and mathematical nature of the image processing techniques and by the operational requirements of devices which are used to convert the Shroud images from visual form to a form suitable for computer input and manipulation.

In the light of the above principle, the body of this paper will first outline the basic requirements for images intended for subsequent manipulation by image processing techniques. Following this, in a more or less "grab bag" fashion, the nature of several aspects of the Shroud image will be sketched out, where image enhancement and analysis processes might be of value in the crystallization of specific information or the resolution of specific questions about the Shroud.

## Creating Photographs for Subsequent Image Analysis

In the design of a photographic experiment whose results will be subsequently analyzed by various image analysis techniques, three basic characteristics of the obtained photographic negatives must be considered in the light of the functional requirements of the contemplated analysis concepts: (1) The spatial resolution must be optimized; (2) the photographic (silver) density vs. intensity of reflected light contrast resolution of the developed image must be optimized; and (3) there must be a reliable, accurate and consistent way to quantitatively relate the point-by-point photographic density to the reflected light intensity — ideally as a function of the spectral content of the reflected energy.

With regard to the first factor listed above, (spatial resolution), the maximum resolution possible, in principle, to obtain from the Shroud image can be considered to be limited by the diameter (about 0.01 inches) of the threads used to weave the Shroud cloth. For image enhancement techniques which seek to filter out or mitigate

the interference and distortions of fine details imposed by the weave pattern, on the order of ten samples of the spatial reflectivity profile across a single thread will be required in order to adequately describe this profile (so that its light modulation pattern can be eliminated). A reasonable value for the sampling aperture size of a device used to convert the photographic image into computer compatible form is 0.001 inches; noise problems due to film grain begin to arise for apertures smaller than this. Thus, it would appear, that one-to-one closeups should be optimum for resolving the maximum possible detail present in the Shroud image; i.e., at this one-to-one magnification, an aperture 0.001 inches in diameter, sampled every 0.001 inches across the film, will resolve a single thread of 0.01 inches in diameter into the required ten discrete measurements across its diameter.

The second factor (contrast resolution) listed above involves the ability to quantitatively distinguish small changes in the reflectivity of the Shroud's surface. Two major areas are involved in optimizing this factor. The first involves the spectral characteristics of the light reflected, point-by-point, by the Shroud itself; while the second involves the response of the film to that light in terms of the formation of photographic (silver grain) density, as governed by the exposure and processing (development) of the exposed photographic emulsion. It is recommended that the Shroud be photographed with black and white film, using filters for spectral differentiation, rather than with color film. The reasons for this have to do with the difficulty of determining density/reflected light intensity relationships from color film; they will not be discussed in this paper.

To optimize the inherent contrast-quality of the light spectrum reflected by the Shroud image, it is very useful to perform a spectral-radiometric analysis of the light reflected by the Shroud from various regions of interest, given that the light incident on the Shroud is that light under which it will be photographed. This analysis will indicate the spectral content of the light reflected by the Shroud — i.e., the intensity of reflected energy as a function of wavelength from the background (unstained cloth), from regions containing the body image, and from bloodstain regions. With this information, the characteristics can be inferred for spectral bandpass filters which will selectively block or attenuate light from the body image or bloodstain regions while passing light reflected from the background. (In essence, the required filters will transmit primarily the spectral complements, or "opposites" of the spectra of the regions under investigation. This technique is akin to using a yellow filter (the complement of blue) when attempting to enhance the contrast of whitish

clouds against a blue sky background; the background light is attenuated relative to light from the cloud regions, thus increasing the cloud/background contrast in a black and white photograph).

To assist processing the exposed films, it would be useful to have readings of the maximum and minimum amount of light, after the filters, from the region in the camera field of view. This information, coupled with sensitometric step wedges, will expedite the determination of film development parameters which place the densities created by film response to light reflected by the image in the optimal (linear) portion of the film density/log (exposure) response range.

The third factor listed above (density/reflected light intensity calibration) is in some respects the most important in that no steps were taken in previous photographic coverages of the Shroud to permit recovery of this very important kind of information. It is a relatively straight forward process to obtain the required calibration information, and it is an essential ingredient for many subsequent image analyses, including the determination of the existence of a consistent relationship between the intensity of body image or bloodstain coloration (as manifest by the intensity of light reflected from the image) and the cloth/body separation of a shroud presumed to be draped over a prone body — per the initial research of John Jackson and Eric Jumper, for example.

To accomplish the required calibration, with a reasonable degree of precision, it is simply required to focus the camera, with any filters in place, on a background region of the cloth that is free from spots, stains, blemishes, etc., and to make an exposure that is identical to the exposure which has been determined for the image itself. The (high) film density created by this exposure corresponds to 100% transmission — i.e., no attenuation due to body image or bloodstain. Following this exposure, a series of known shorter exposures (varying either exposure time, f-stop or both) should be taken, dividing the dynamic range (of reflected light intensity) of the selected image region into 10-20 increments on a logarithmic scale. The (lower) film densities (after development) corresponding to these exposures thus determine the reflection of an image point of the same density: The reflection ratio is simply the ratio of the effective exposure time to achieve the same calibration density as the image point density, divided by the exposure time for the actual image (which was also the time for the 100% transmission calibration exposure). It should be noted that this simple calibration technique depends, in principle, on the assumption that the body image or bloodstain image is everywhere the same "color" in the sense that



relative spectral light profiles are constant from one point to another. Thus, the visually observed shadings are due essentially to variations in intensity of staining which are not accompanied by significant changes in the spectral content.

It should be reiterated that the parameter resulting from the calibration process described above is related to the intensity of light (energy/area) reflected by the (cloth) background itself. This kind of information must ultimately be related to the microscopic characteristics of the image (concentration of light absorbing substance, etc.) which actually determine the point-by-point reflectivity of the Shroud material. Thus, the reflectivity calibration process provides an important means to link the visually observable macro-scale image to the micro-scale structure which determines the observed appearance. It is through the very process of relating the observed image to the physical characteristics of a contemplated micro-scale staining or coloration mechanism that the actual nature of the formation of the image on the Shroud may perhaps be understood. From this point of view, the overall process of understanding the formation of the Shroud image has three basic elements: a mechanism for modifying the light reflecting properties of the cloth fibers; a means for creating a spatial-intensity pattern of such modification; and the response of this spatial-intensity pattern to incident light (i.e., the visually observed or photographically recorded image).

#### Image Analysis Possibilities

Photographic images obtained as described above will admit to a wide variety of subsequent image processing techniques designed to extract or enhance various aspects of the Shroud image. To begin with, comparison of film density measured (by digital microdensitometric systems) between points on the Shroud image and equivalent density measured on a calibration exposure will permit direct conversion from photographic density to the physically meaningful parameter, cloth image reflectivity. A quantitative transformation of the point-by-point photographic density of the Shroud, to the point-by-point reflectivity should be a valuable data base for researches (such as those of Jackson and Jumper) seeking to understand the mechanism by which the Shroud imprint occurred.

On another level, the photographic data should facilitate attempts to enhance the most fine detail of the Shroud image by making possible the use of techniques which will eliminate the weave pattern from close up images, while leaving intact other information now distorted by the reflected light modulation introduced by the

weave. Techniques to achieve this enhancement involve a mathematical approach known as digital filtering. The most common implementation of this approach involves operations on the two-dimensional Fourier transform of the image. (For those not knowledgeable of Fourier transform techniques, the Fourier transform in essence treats an image as though it were composed of a superimposed sequence of spatial waves of different frequencies — whose crests and troughs either augment or counteract each other at each image point, in such a way that the net wave amplitude (light intensity) at each point is that seen by the eye or measured by an instrument.) To achieve elimination of the weave pattern modulation, the Fourier transform of this pattern is obtained (from a photograph of a non-imaged portion of the Shroud) and the spatial frequency pattern due to the weave is then eliminated from the Fourier transform of the image region whose enhancement is desired. The filtered Fourier transform of the image can then be converted back to the normal spatial representation resulting in an image with the weave effects eliminated or diminished.

One candidate region for the enhancement operation is the region around the eyes. According to Jackson, the eye region shows the image of what may perhaps be coins placed over the closed eyes according to ancient Jewish burial custom. If this region could be clarified, perhaps sufficient detail could be seen to permit a pattern recognition experiment to be performed to determine if the disc-shaped objects over the eyes were indeed similar to coins known to have existed during the time of Christ's life. At the very least, if the edges of the disc-like objects over the eyes can be clarified by removal of the weave distortion, it may be possible to determine whether they are smoothly round (suggesting coins) or more irregular (suggesting potsherds perhaps).

In addition to the technique described above, there are a variety of other methods for "sharpening" images which can act either in conjunction with or independently from digital filtering methods. For example, a powerful class of edge enhancement processes involve super-imposing the so-called Laplacian\* of the image on the original image. The Laplacian is a measure of how quickly the spatial intensity gradient of the image changes; thus it has a sudden extreme wherever the image has a local minimum or maximum in intensity. Physiological research on the eye indicates that its response to image fields is similar to the Laplacian response; thus images processed by

\*  $\frac{\partial^2 R}{\partial X^2} + \frac{\partial^2 R}{\partial Y^2}$ , where R is the image reflectivity.

the Laplacian operation tend to have a visually crisp but natural appearance, particularly when the Laplacian image is super-imposed on the original.

There are obviously many portions of the image which would benefit from removal of the visual "interference" of the weave texture and from edge enhancement or sharpening operations. Thus, it would appear that a serious effort along this line would have potentially high value if it could be brought to fruition.

Another large class of image enhancement techniques involves the enhancement of contrast in regions where intensity variations are subtle. Previously reported work by Devan, Jackson and Jumper has shown some examples of contrast enhancement designed to improve the visual information quality of the image. An interesting opportunity for another form of contrast manipulation exists in the light of establishment of a relationship between image intensity and cloth/body separation. If such a relationship can be quantitatively established, it will then be possible to systematically modify the measured Shroud reflectivities so that they visually highlight any existing sculptural quality of the image in a manner similar to the natural reflection of light from a three-dimensional surface.

Still another type of analysis would seem to be interesting in the light of questions about the mechanism of image formation on the Shroud. This analysis is termed texture analysis since it is related to what the eye generally calls texture. More technically, texture analysis involves the determination of certain statistics of an image in terms of the spatial arrangement of different levels of reflectivity. To compute these statistics, the image is thresholded (each point on the image is assigned either a "yes" or a "no" value depending on whether its intensity is above or below the threshold level) at various levels. The thresholded image is then analyzed to determine the statistical distribution of "run lengths" — i.e., of the total image, how many "yes" values occur one in a row, two in a row, three in a row, etc. The statistics of these run length distributions then permit subtle distinctions to be made between surface texture qualities such as roughness/smoothness, regularity/irregularity, etc.

Texture analysis can be used to shed light on such questions as: Were the bloodstained regions formed by the same process that formed the body image? How does the side image relate to the front and back images? Are the textural distinctions between hair, beard and flesh regions consistent with true characteristics, or are the textures "artificial" (implying some form of imprinting)? As in the case of Fourier transform techniques, the texture analysis must be performed independently of the overriding texture imposed by the

weave. This is readily accomplished by using the texture statistics of a background portion of the cloth as a basis from which to measure those statistics for the image region under study.

The "grab bag" of image enhancement techniques summarized above represents, of course, only a general indication of the range of possibilities for the extraction of new visual clues to the true nature of the Shroud of Turin. This paper has attempted to outline some of the design criteria for a photographic experiment whose results will facilitate the search for such clues through the use of image analysis techniques. It is intended that the thoughts and concepts discussed above serve as a skeleton — one which will be "fleshed out" by the interaction of these ideas and those of others interested in continuing progress toward the solution of the puzzle of the Shroud of Turin.

By way of assistance to Shroud researchers contemplating the ways in which improved knowledge of the visual properties of the Shroud might be related to their hypotheses, it may be beneficial to establish the conceptual distinction between two terms sometimes used (imprecisely) synonymously within the image processing vocabulary. These two terms are image enhancement (often referred to as image processing), and image analysis.

The operational differences between the two phrases are actually considerable: Image enhancement refers to the creation of a new image, following operations on the original image, which is in some respect more suitable for human visualization — typically through the removal of distracting, non-informative features (generically referred to as “noise”), the sharpening of blurred or indistinct edges, or the exaggeration of subtle differences in grey shade or color value. The digital filtering (Fourier transform) process and the Laplacian edge sharpening process discussed above are examples of image enhancement operations. Image analysis, on the other hand, involves the measurement of some property of the image, often in relationship to the physical process which created that property. The result of an image-analytic operation is therefore generally a measurement or number. In some cases, this number may quantize an image feature which has a qualitative visual counterpart. For example, the eye distinguishes between sharp or blurred edges; image analysis measures how sharp an edge is in terms of how quickly the grey shade or color value which defines the “visual” edge changes over a given spatial distance on the photograph. Similarly, as discussed above, the eye qualifies textures as rough or smooth, regular or irregular, etc; image analysis permits comparative measurement of how rough, regular, etc. one image region is with respect to another region.

It would perhaps be beneficial in terms of clarifying the communication between scholars of other disciplines and those involved in image processing and analysis to keep the above distinction in mind. Thus, as hypotheses are developed which have possible manifestations in the visual properties of the Shroud image, it would be helpful for the author of such a hypothesis to ask the self-directed question, “would it help me to see something in the image more clearly, and/or do I require that some characteristic of the image be in some manner established quantitatively (even though I’m not sure what form that quantization might take)?” It is this author’s opinion that the image processing scientists will be better able to

serve the Shroud research community if the concepts outlined above are applied when the reproductions of the Shroud image to be kindly provided by Msgr. Ricci and Ms. Patrizi are reviewed to establish specific areas of interest for high resolution photography intended for subsequent image enhancement and/or analysis.

By D. H. Janney

The entire world has been fascinated by the photographs returned to earth from the unmanned landing on Mars. In clarity these pictures rival those obtainable by conventional photography of terrestrial landscapes. The casual viewer may not realize that the photographic data as originally returned to earth lacked this clarity. The clarity was restored on earth by the use of digital image processing. This processing operation can include many types of manipulations of the photographic image, all performed in the digital computer. Some of the simpler operations produce results similar to those obtainable with standard darkroom techniques; others require a detailed analysis of the image data in order to determine a suitable processing routine.

Figure 1 shows the fundamental components of a digital image processing system. An input image must be reduced to digital form, i.e., a series of numbers within the computer, and finally redisplayed as a picture for visual perception. Figure 1 shows the initial reduction of an image to a series of numbers being performed with a densitometer. This device measures the photographic darkness, or density, of the image at a very large number of points spaced on a rectangular grid in the manner of a checkerboard. The density value of each checkerboard square is often known as a pixel (picture element). The pixels which cover the entire image become the series of numbers which are manipulated within the computer during digital image processing. The series may be transported to the computer by any convenient method, but is shown here as being carried on a magnetic tape. Once the data series is in the computer, the possible operations on it are limited only by the imagination of the computer programmer. Following the numerical operations a new series of pixels is written on a second magnetic tape. This new series

represents the processed image which can then be displayed for visual perception. The display, or reconstruction, may take place on any of a number of different types of hardware. The images to be considered in this report were all displayed using the graytone option of a computer output microfilm device. These devices accept numerical data (pixels in this instance) and display the data as a picture on a tube similar to a television picture tube. This picture is photographed in order to obtain a permanent record of the processed image.

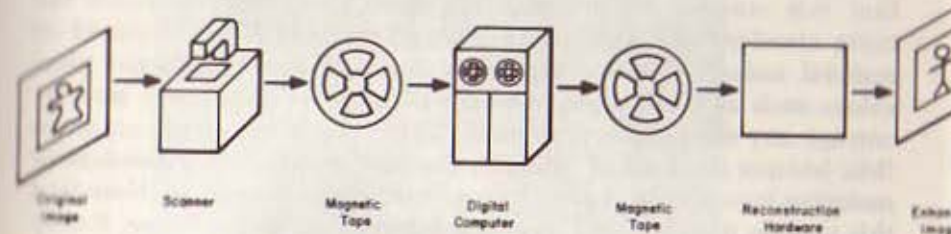


Figure 1. Schematic of data flow in digital image processing.

It is to be noted that the hypothetical image being processed in Figure 1 begins as a ghost-like shape with rounded corners and becomes a stick figure with sharp features. At one time this type of operation was considered universally useful for making obscure features readily visible. A qualitative description of this process, often known as a "high-frequency boost" can be found elsewhere.<sup>1</sup>

Unfortunately, virtually all practical experience tells us that though there are some dramatic successes with a simple high-frequency boost, more often it is necessary to control image noise in some manner prior to the boost or possibly simultaneously with it. The term "noise" is used here to mean any of several undesirable image features. In the case of the Shroud, two obvious types of noise from the viewpoint of the image processor are the image of the fabric weave and the prominent "scars" such as the line across the bottom of the chin. Since these features are extraneous to the desired information content of the image, we consider them to be noise. Further, since they are of the same general size as the obscure

details which we might wish to make visible (or to "enhance"), it is known both theoretically and from experience that a high-frequency boost will accentuate them along with any obscure features which are being sought. This accentuation of noise is not only undesirable from an aesthetic viewpoint, it may totally obscure desired features. There are standard methods for preferentially enhancing desired features while attempting to suppress noise structure. These have yet to be tried extensively at LASL on the Shroud images.

The work by this writer at the Los Alamos Scientific Laboratory has been devoted primarily to nonstandard methods of removing the most gross noise features from the image, in the belief that this removal by preprocessing would be required before the more standard methods could be used successfully for control of residual noise. It is known that a sharp change in adjacent pixel values such as occur along the edge of the chin "scar" will severely corrupt any enhancement process. This writer's immediate objective thus became the task of filling in the scar regions by a procedure of smearing into it typical pixel values from adjacent regions. Note that this process does not add any new information to the image, it only smooths disturbingly abrupt changes in pixel values so that subsequent processing can proceed more satisfactorily.

One can think of many ways of performing the smearing into the scar region. It was desired to develop a method which would require no modification for use on different parts of the Shroud, but which would not excessively smear the desired image at any position.

The method reported here involved first smearing the entire image. Note that this can be done as the reverse of a high-frequency boost; that is, it can be done as a high-frequency suppression. The smeared image is then compared pixel by pixel with the original image. If the pixel values differ by more than an empirically selected factor, the pixel of the original is defined as belonging to the scar and is replaced with a pixel from the smeared image. If the difference is less than this factor, the original pixel is left unaltered. Thus it was believed that much of the image would not be changed, but that the regions of scars and similar appearing image defects would be filled in with pixels representative of a small surrounding region. This procedure has not been entirely successful. Either a new procedure is needed, or "smarter" tests to differentiate acceptable image regions from defective image regions are needed. If the criterion of pixel-by-pixel similarity is made too stringent, all pixels look like noise to this procedure and the entire original image is replaced by the smeared image. If the criterion is relaxed, the acceptable portions of the original image are preserved, but the boundaries of

the scars are also preserved. Examples of work with this procedure are shown in Figures 2 through 4. Specifics concerning the numerical analysis of these figures follow.



Figure 2. Image after Tukey filtering and histogram equalization.



Figure 3. Blurred version of image.



Figure 4. Image with Limited Nonstandard Noise Control.

Figure 2 differs only slightly from the original. Standard methods only of noise control and contrast enhancement have been applied. Noise control at this point was with a Tukey, or medial value, filter. In this filter, each pixel is examined along with its eight nearest neighbor pixels. The median value from the total of nine pixels is assigned to the pixel position being processed. This routine is sometimes useful for removing isolated noisy pixels, but did very little for this image. Next, the Tukey-filtered image has had its contrast stretched with a routine of histogram equalization. This routine is based on a statistical analysis of the distribution of pixel values from the entire image. For an image of the type considered here, it is sufficient to note that this procedure stretches most of the range of photographic densities, but compresses the extremely high and extremely low densities into very narrow ranges. Thus, most of the image is contrast-stretched, but at the expense of the extremes of the original. For the Shroud image this procedure has served to give increased contrast to image and noise alike. Figure 2 is the result of Tukey filtering followed by histogram equalization.

Figure 3 is a blurred image created from Figure 2. For creating the blur, each pixel of Figure 2 was replaced by the sum of itself and a fraction of each of many neighborhood pixels. As each neighborhood pixel is further removed from the pixel being replaced, a smaller fraction of the neighborhood pixel is added into the summation. The reader versed in optics will recognize this operation as being similar to photographing Figure 2 with a camera which has a large point spread function. For convenience, the fraction of each

the pixel being replaced. Again, the camera-oriented reader will note that this operation is equivalent to assuming that the camera has a Gaussian point spread function. For Figure 3, the Gaussian was assumed to have a standard deviation of approximately 1/4 mm. In considering the meaning of this number, note that the entire scanned image was 15.4 mm square on 35 mm film.

Figure 4 is the image formed from the pixel-to-pixel comparison of Figures 2 and 3. Where the two images differed by more than 30%, the pixel of Figure 2 was replaced by a pixel from Figure 3. Otherwise it was not altered. As noted previously, this procedure needs substantial improvement as a preprocessor to image enhancement.

It is of interest to speculate upon the future of image processing for work on the Shroud images. Previous work by Jumper<sup>2</sup> has demonstrated that computer image enhancement can be used to make obscure features of the image more readily visible. The present work was directed toward noise reduction in the empirically founded belief that further enhancement without a major noise control effort would be doomed to failure. Though the present work was only partially successful, it is certain that more clever schemes could be devised. Some schemes would be intuitive, based on plausibility arguments, others would be based on statistical analyses of the image. Following successful noise control, it is believed that further enhancement for the finding of faint details would be possible.

Any new photography of the Shroud should be done with photographic materials of very wide latitude; i.e., a wide range of brightness values should be recorded, even though the entire image then sometimes appears "flat." Once the wide range is on film the information can be extracted by computer-aided techniques or by clever darkroom techniques. This statement leads to ideas concerning data extraction from the image which are not related to classical enhancement. Once the complete brightness information is in the computer it is possible not only to process it for purposes of enhancement, it is also possible to extract quantitative measurements at selected points, or along selected lines. This information obtained at various positions relative to the anatomical features of the image would be added data with which various hypotheses concerning initial image formation could be tested.

Lastly, it must be noted that color image analysis may have a useful role in any investigation of the Shroud image. One extreme of color analysis would require obtaining data in a number of carefully chosen narrow color bands from which it would be possible to deduce the molecular properties of the image material. If this study

were to be undertaken, considerable care should be exercised in measuring the spectral characteristics of both the illuminating light and the reflected light. Another potentially useful form of color photography would use colored filters for photography on black and white film. This family of photographs would have a more limited potential for use in molecular analyses, but it is known from other work that sometimes appropriate combinations of images taken with different colors of light can be useful for making obscure details more readily visible. These combinations can be formed in the computer from the individual photographs.

Conventional colored photography, though of great value as a popular record of the Shroud image, is probably of limited utility in the scientific extraction of image data. A notable exception to this statement might be possible if the colored film were to have spectral characteristics matched to the light reflected by the Shroud image. For this reason, it could be useful to photograph the Shroud with a large number of commercially available color films during its exposure to view. Except for the value of such images for public appreciation, this study should be given lower priority than the others noted above.

In summary, computer treatment of photographs of the Shroud image can be expected to yield added image detail. Unfortunately, the image defects arising from the weave of the Shroud itself, as well as centuries of abuse, will limit the gains in image quality which can be made. Simply photographing the image under carefully controlled conditions of lighting and photographic technique will give images from which much potentially useful data can be extracted, aside from any consideration of enhancement possibilities.

## REFERENCES

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<sup>2</sup>Eric Jumper, private communication.

# DIGITAL ENHANCEMENT OF IMAGES OF THE SHROUD OF TURIN

By J. J. Lorre and D. J. Lynn

## I. Background

In the Spring of 1976, we were approached by Tom Dolle of the Christ Brotherhood of Santa Fe, New Mexico and introduced to the subject of the Shroud of Turin. He was wondering whether some of the same techniques which had been used here at the Image Processing Laboratory of the Jet Propulsion Laboratory to enhance and analyze images of Earth, Mars, Venus, Mercury and other celestial objects might be successfully applied to images of the Shroud. We were interested and expressed a desire to see if there was something we might do.

Subsequent correspondence with Father Peter Rinaldi of the Holy Shroud Guild and Dr. John Jackson resulted in a visit with us by Dr. Jackson. After discussions regarding the availability of data and what might be done, Dr. Jackson provided us with photographic negatives and slides of the Shroud. These photographs were scanned and put into digital form for subsequent computer enhancement and analysis.

It should be noted that this was an effort undertaken by the authors in their spare time and was not supported or endorsed by the Jet Propulsion Laboratory or NASA. However, because of the potential scientific and historic significance of the Shroud, we were able to use existing facilities on a non-interference basis. This effort was also undertaken at a time when we were deeply involved in the Viking Mission to Mars, so there was not much spare time available. Thus, the results presented here represent a very limited investigation.

## II. Introduction

Digital image processing deals with the manipulation by computer of two dimensional arrays of data. Visual imagery, because it is comprised of spatially organized information, is ideally suited for management in a computer. This does not mean however, that the computer appreciates the subject in question or that it is able to recognize an event or characteristic which a person, for a variety of reasons, might consider significant. It is thus important to realize that the human eye-brain processor is the key ingredient in the interpretive process and that the computer is merely an aid in presenting information to the eye.

The above is noted to point out that the computer investigation described herein was in no way concerned with the authenticity, origin or even the subject of the Shroud. Our efforts were solely aimed at extracting and displaying as much information about the image on the Shroud as we could.

Specifically the objectives of the investigation can be divided into two categories:

- A. To enhance various characteristics of the image in order to present to the eye as much detailed structure of the image on the Shroud as possible, and
- B. To reveal any information about the intrinsic structure of the image which might indicate the way in which it was formed.

## III. Processing Environment

There were three distinct steps in producing the pictures presented here. The first step consisted of transforming the photographic images to an array of numbers which could be read and manipulated by the digital computer. This transformation was accomplished by scanning each film using a Boller and Chivens PDS scanning microdensitometer, and recording the resulting digital image on magnetic tape. The scans produced images up to 2000x2000 picture elements (pixels) with the transmittance or density of the film digitized to 8 bits (256 discreet levels).

The second step consisted of processing the images on the IBM 360/65 computer of the Image Processing Laboratory (IPL). This computer hardware and software system was developed by IPL to support the Planetary Exploration Program of NASA, and is totally dedicated to digital image processing. In this system, a digital image can be modified serially by any number of different algorithms at



the experimenter's discretion until the cumulative desired effect on the image is achieved.

The third step consisted of recording the output digital image on film. In this process, each display element on the film is exposed in proportion to the digital value of the corresponding digital picture element. This film image is then developed and printed in standard photographic fashion. Color images required a fourth step wherein black and white separation transparencies were combined with colored light to produce an additive color image.

Each picture is bordered by tic marks which represent five pixels. Large marks indicate 100 pixel intervals. At the bottom of each picture is a descriptive label which indicates what the image represents, something about the way it was scanned and the various algorithms used to produce the output image.

The algorithms chosen for the various enhancements presented here were spatially invariant, i.e., they were impartial algorithms which performed the same logical process on the data irrespective of location in the image. Using these types of algorithms, certain regions of an image might be modified more than other picture regions, but this would be due solely to the local nature of the data and not to any bias on the part of the analyst. This constraint was applied in order to prevent the analyst from biasing the results based on a prejudgement as to what structure was important and what was not.

Each of the algorithms used is described in the Appendix. Those who wish a more technical description of a process may refer to that section.

#### IV. Results

##### A. Simple Enhancements

Figure 1 shows the entire body impression on the Shroud. The left half of the picture shows the back of the figure and the right half shows the front of the figure. In an attempt to bring out fine detail, the image of Figure 1 was high pass filtered to enhance features smaller than about 31 picture elements. The resulting version can be seen as Figure 2.

Only fine detail is enhanced by this filter. Especially noticeable are short linear marks, often with small spots along them which appear on the back of the figure and long linear features which run the entire length of the Shroud. These latter appear to follow the weave of the cloth and are evident both on and off the figure.

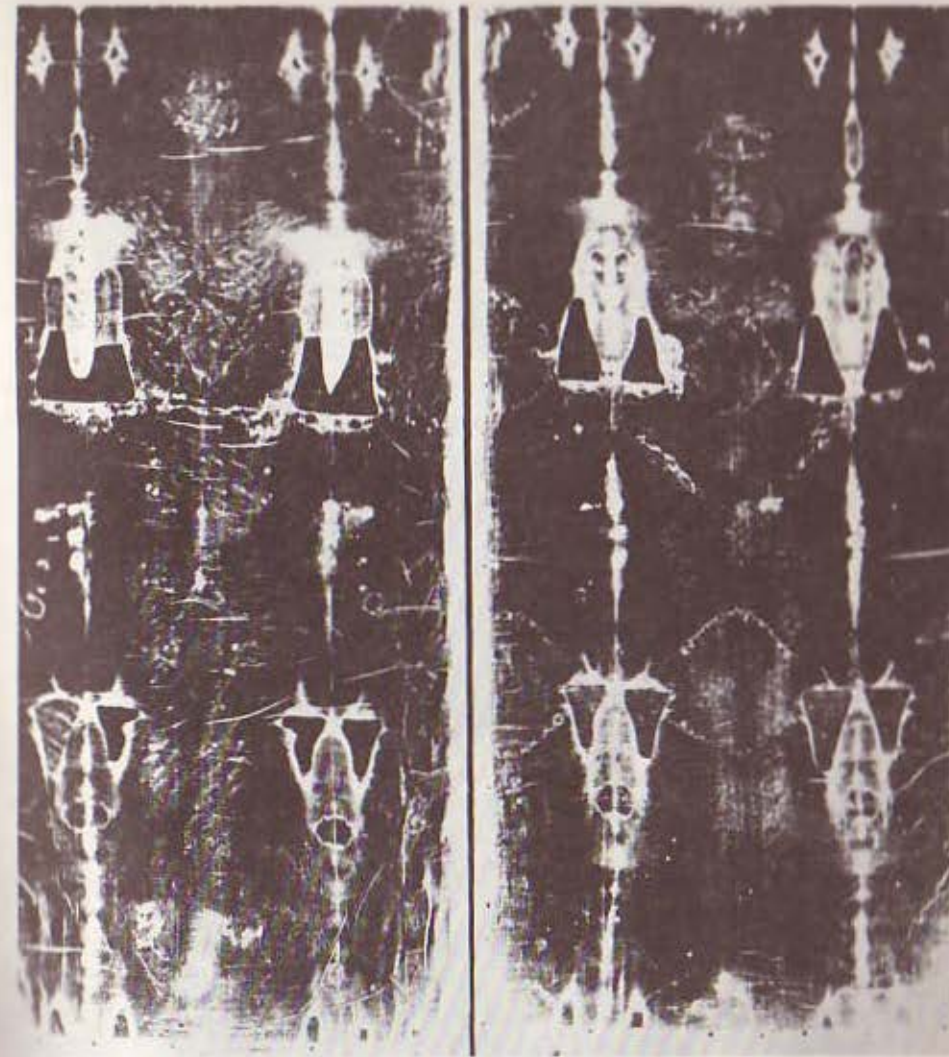


Figure 1. Slightly contrast enhanced version of the scanned and digitized image of the Shroud.

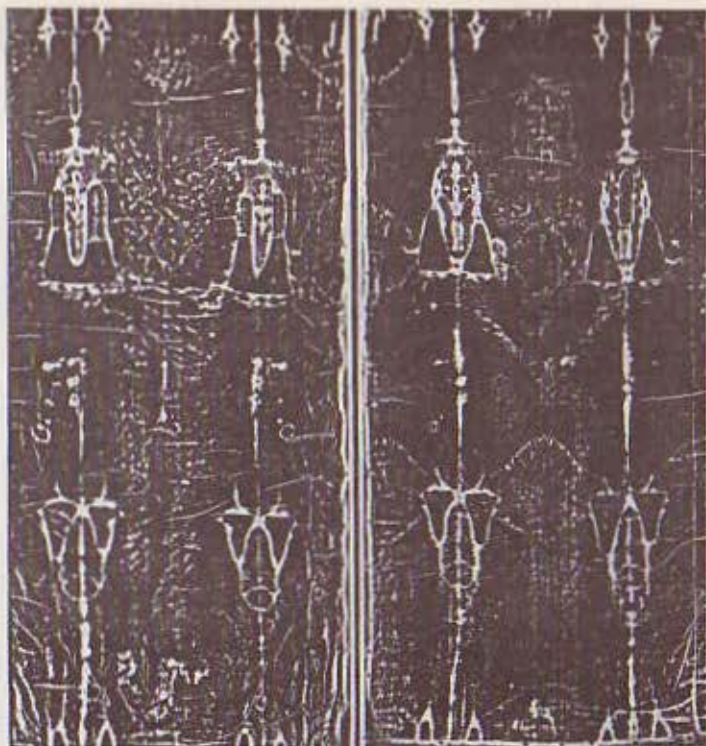


Figure 2. High pass filtered and contrast enhanced version of the image in figure 1. This enhancement brings out features of the dimensions of the filter (31x31 pixels) or smaller.

In addition, it appears that the massive blemishes due to burn marks have a soft density fall-off. This is important because the many dense, small features in the water marks and the figure are well-defined and do not have soft edges. This would tend to indicate a different mechanism of formation.

Figures 3 and 4 show a false relief map which is produced by replacing the image with its directional derivative. This type of directional filter displays the gradients in intensity in one direction and gives the illusion of side-lighting. The two figures differ in that the orientation of the derivative is  $45^\circ$  clockwise from horizontal in Figure 3 and  $45^\circ$  counterclockwise from horizontal in Figure 4. Thus, each image can be expected to contain detail which the other does not have, as can be seen by the image of the hands in each. These two figures probably contain the best display of fine structure produced in this investigation. It is interesting to note that except for structure such as the hands, Figures 3 and 4 contain about the same amount of information. Thus, the data does not appear to be directionally oriented.

N.B. ||

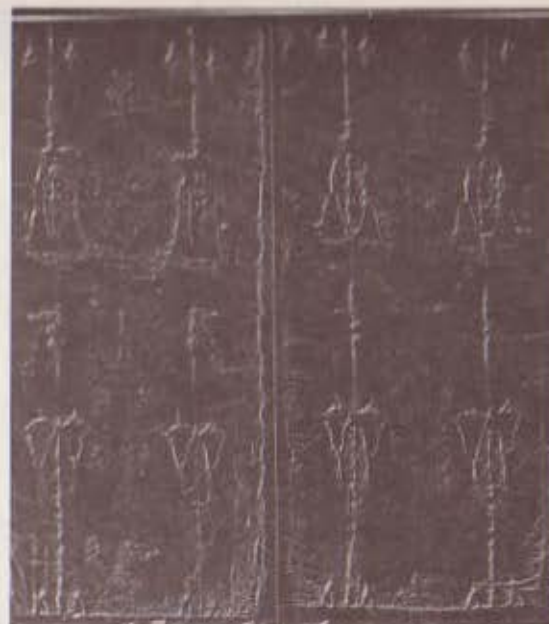


Figure 3. The result of applying a Derivative Filter in a direction  $45^\circ$  clockwise from horizontal; the magnitude of the gradient is displayed as increasing intensity. In this version, features which tend to be normal to the direction of the gradient are displayed; features which are parallel to the direction of the gradient are suppressed.



Figure 4. The same as figure 3 except the direction of the derivative was  $45^\circ$  counterclockwise from horizontal (i.e., perpendicular to the direction of the filter of figure 3).

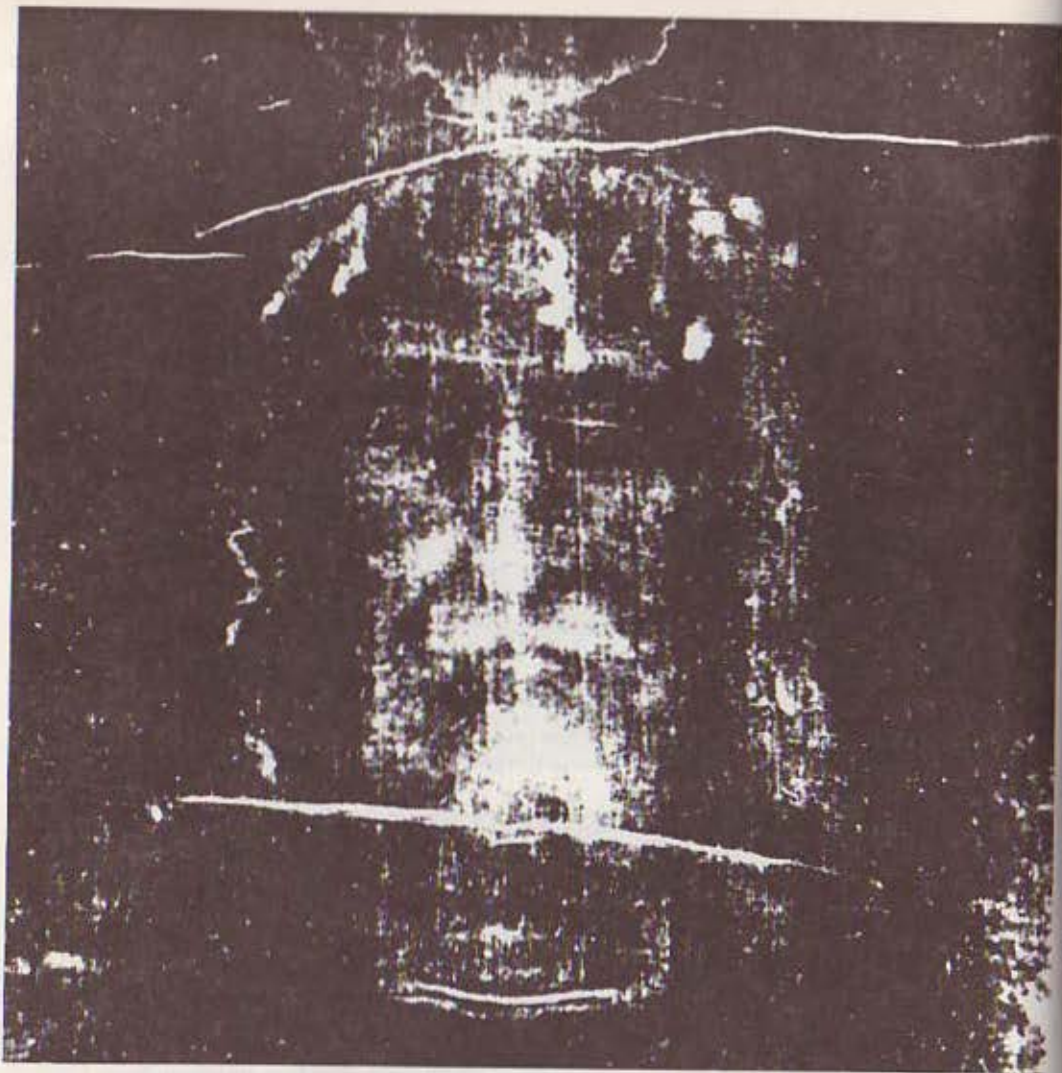


Figure 5. A magnified and slightly enhanced version of the facial region of figure 1. The vertical and horizontal structure of the weave of the cloth can be seen.

#### B. Removal of Artifacts and Undesired Data

The following describes processing which was directed towards enhancement of the face by the removal of artifacts and data which distract the eye from more relevant structure. This type of enhancement is potentially dangerous because some data must be discarded in order to emphasize other data. The danger lies in that good information may also be discarded, or that the data which remains is improperly biased and subject to misinterpretation. However, it was felt that as long as most of the information removed was not directly associated with facial structure, the result was an improvement.

Figure 5 is the image of the facial region which was used. Figure 6 is a picture of the log amplitude of the Fourier Transform of the image in Figure 5. Figure 6 reveals a smooth transform with two bars in the shape of a cross passing through the center of the transform. The bars are caused by parallel, nonperiodic, linear features in the original image. Close inspection of Figure 5 shows the cause to be due to the fabric weave which introduced lines horizontally and vertically in the image. These lines in the image are normal to the bars in the transform.

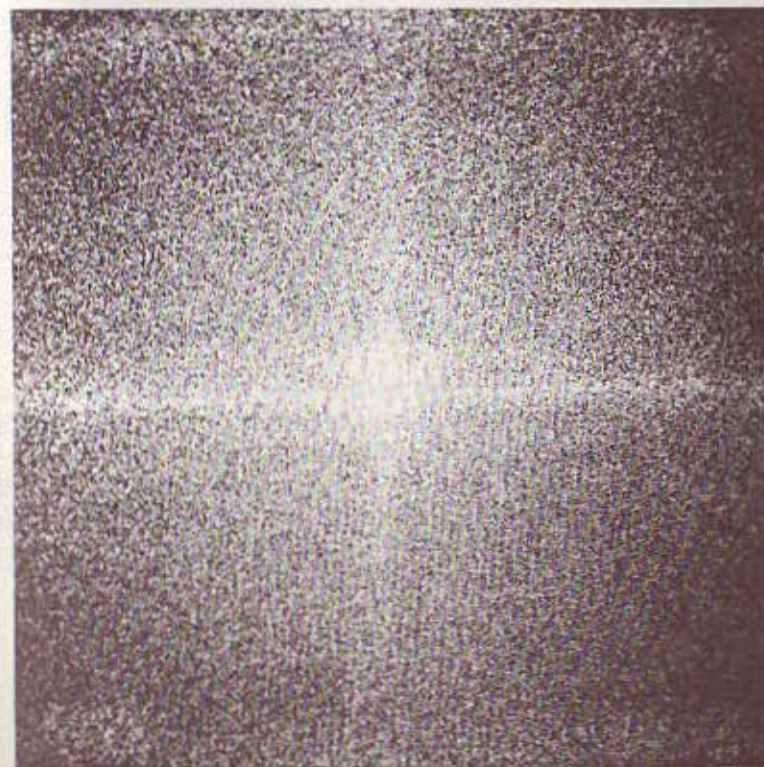


Figure 6. The log amplitude of the Fourier Transform of the image in figure 5. This picture displays the spatial frequency distribution of information in the image of the facial region. Zero frequency is at the center. The bars are caused by the directionality of the cloth weave.

Because these lines were considered to not be part of the face itself, they were suppressed by reducing the amplitude of those frequency components lying along the bars in the Fourier Transform. The modified Fourier Transform is shown in Figure 7. To obtain the modified image of the face, the inverse Fourier Transform was computed.

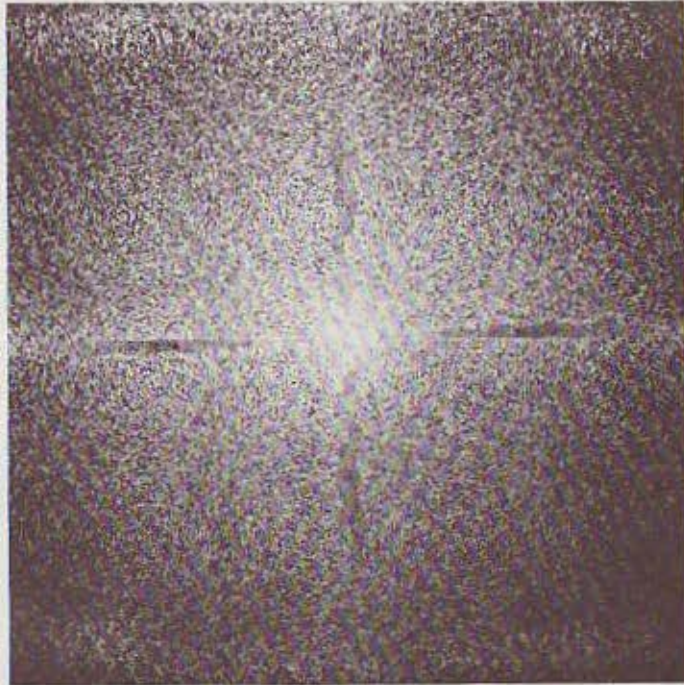


Figure 7. The log amplitude of the Fourier Transform after being modified by suppressing the bars caused by the cloth weave.

Figure 8 contains the image of the face with most of the cloth weave removed. Figure 9 contains the information which was removed from Figure 5; it is the difference between the image of Figure 5 and the image of Figure 8. A very slight resemblance to the face can be seen in Figure 9 indicating that some true facial information was removed as well. Fortunately however, the majority of Figure 9 appears to be unwelcome artifact.



Figure 8. The inverse transform of figure 7. The cloth weave has been suppressed.

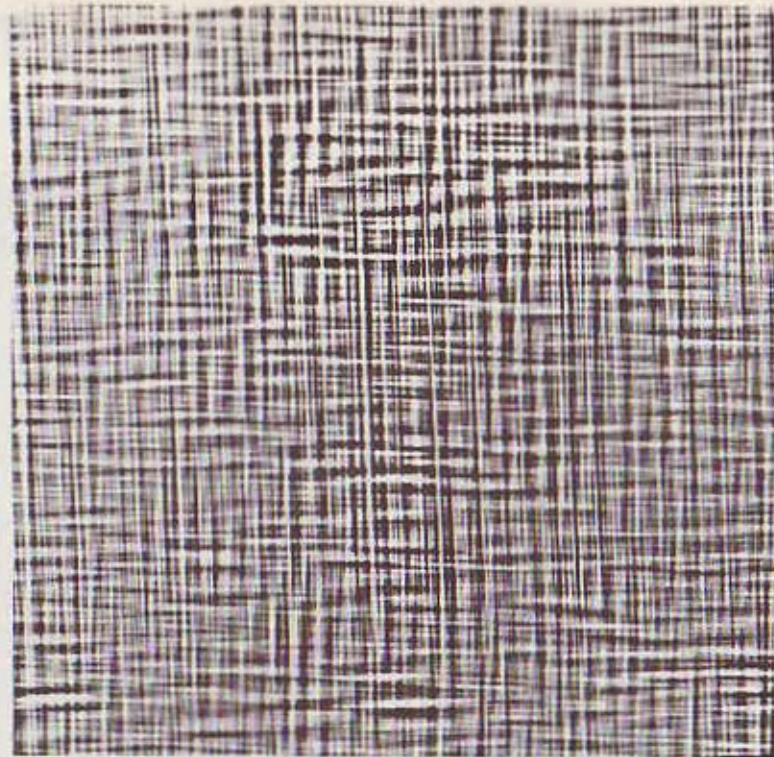


Figure 9. The difference between the images in figure 5 and figure 8. It displays the data which was removed by the step shown in figure 7. The lack of recognizable facial detail in this picture indicates that very little of the facial image information was removed in this process.

An additional operation which was applied was the removal of the large jagged crease marks above and below the face. This was done because they interfered with removal of the cloth weave.

It should be noted at this stage that the uniform nature of the Fourier Transform is another indication that whatever the mechanism was which caused the impression upon the Shroud, it was not directionally oriented, i.e., there was no preference for applying the impression from any direction.

The previous description dealt with removal of structured linear features from the image. It was also desired to remove random structure from the image. This step of the enhancement used the image shown in Figure 8 as the input. It is very difficult to say what is artifact and what is true information. All of the structure in Figure 8 is on the Shroud but much of it is visually distracting. Because we are faced with an ambiguous problem, two Median Filters (see Appendix for definition) were run on Figure 8, each having different properties. The Median Filters were used to suppress non-monotonic structure in the image.

Figures 10 and 12 show the results of two Median Filters whose neighborhoods were  $7 \times 7$  picture elements and  $17 \times 17$  picture elements respectively. Figures 11 and 13 show the information removed from Figure 8 by these filters. In Figure 11 it appears that most of the information removed is not significant in an evaluation of the human characteristics of the face. In the case of the  $17$  element filter, some facial data has been removed because clearly it is apparent in Figure 13. However, larger scale features such as the overall bone structure and facial proportions are more evident in Figure 12. This indicates that low spatial frequencies are primarily responsible for the recognizable facial features.



Figure 10. The result of applying a Median Filter of dimensions  $7 \times 7$ . Only features which are smaller than this and which differ greatly from the surrounding pixels are altered.

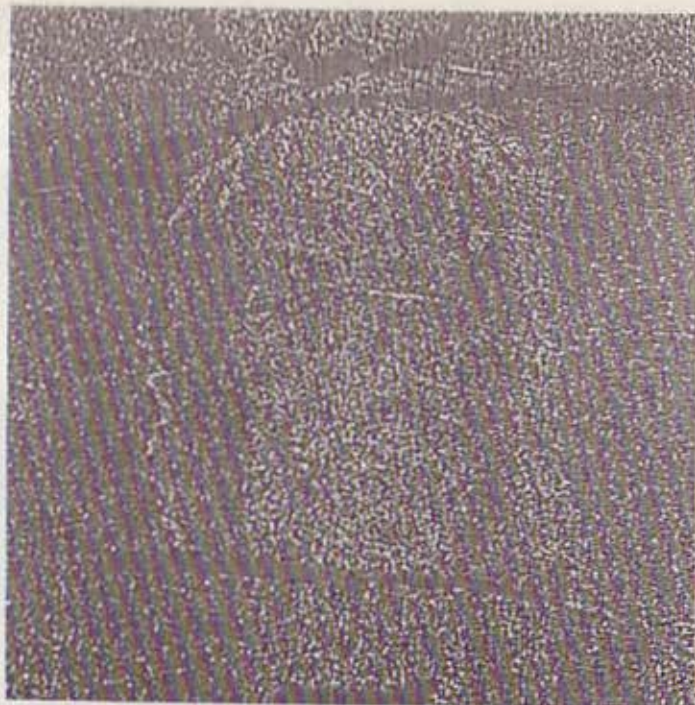


Figure 11. The difference between figure 10 and figure 8. It displays the data which was removed by the 7x7 Median Filter.



Figure 12. The result of applying a 17x17 Median Filter. This operation tended to remove larger features and artifacts than the 7x7 filter.

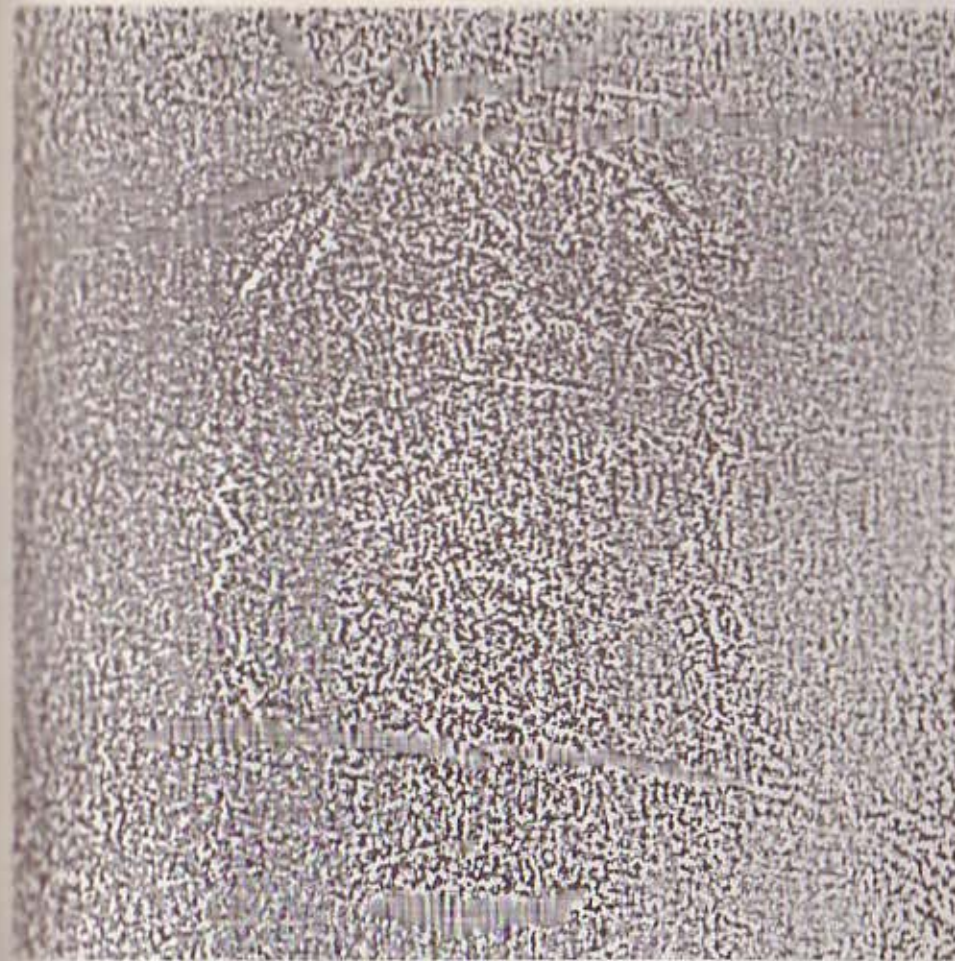


Figure 13. The difference between figure 12 and figure 8. This shows that detailed facial characteristics have been removed by the larger Median Filter, but the overall facial structure was retained.

### C. Color Composition

Several of the film products provided by Dr. Jackson were taken either on color film or through color filters. Two color transparencies were scanned through the red and the blue filters on the scanner and digitized to generate separate color images. Because the slides were of limited quality, it was felt that more than two colors would not provide additional information.

In addition, infrared and ultraviolet pictures were provided. These were not of suitable quality to be useful, but they are included here for completeness. Figures 14 and 15 are pictures made from scans of the ultraviolet and infrared pictures. Figure 16 shows the ratio of infrared/ultraviolet images but the quality of these pictures is such that the noise level predominates.



Figure 14. Strongly contrast enhanced version of the image produced by scanning and digitizing the ultraviolet photograph.



Figure 15. Strongly contrast enhanced version of the image produced by scanning and digitizing the infrared photograph.

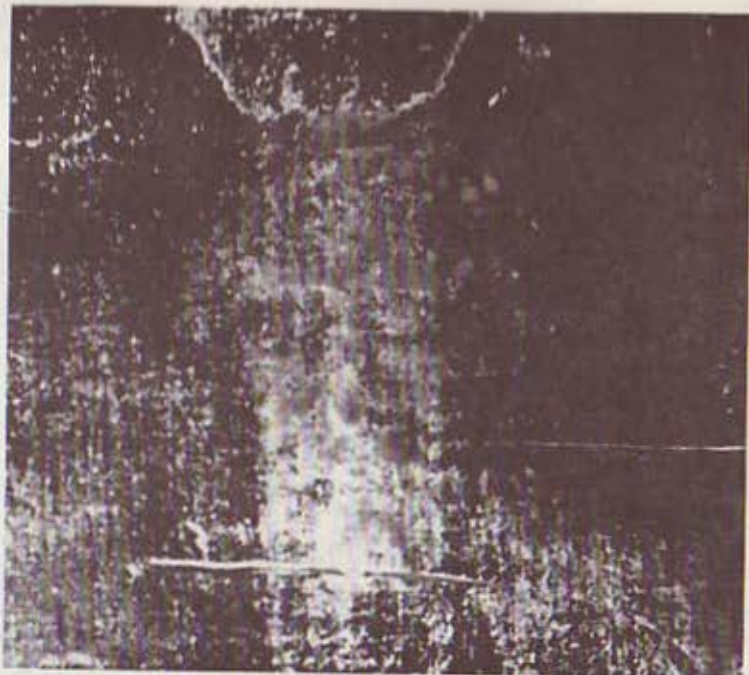


Figure 16. The ratio of the infrared to the ultraviolet images.

More success was achieved with the color film scans. Figures 17 and 18 show images from the blue and the red scans of the facial



Figure 17. The blue component of the scanned and digitized image from color transparency No. 1.

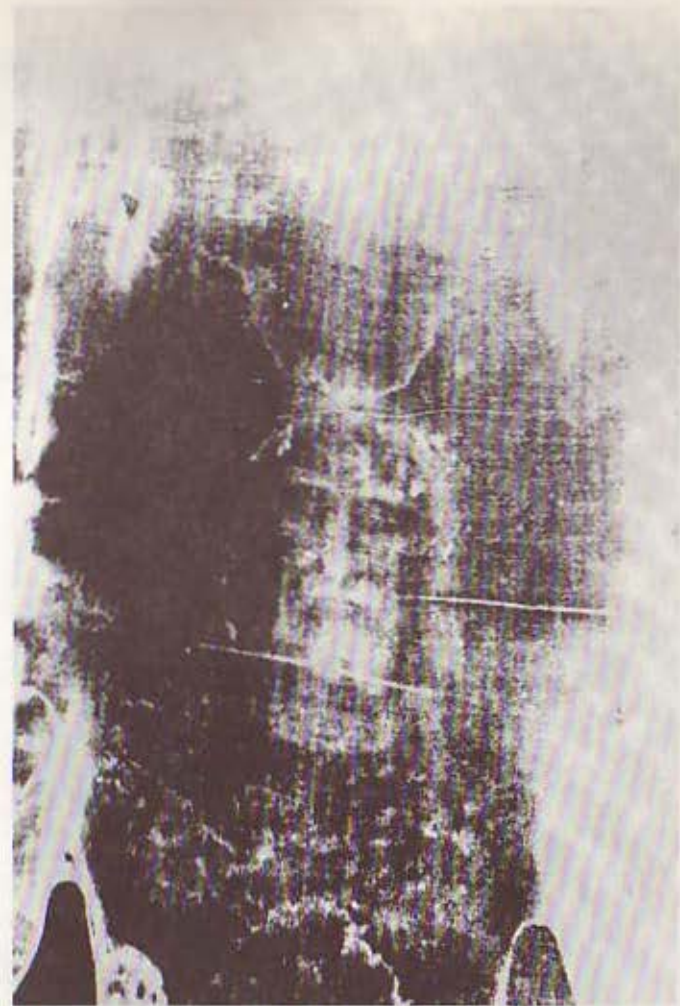


Figure 18. The red component of the image from color transparency No. 1.

region. The data was adjusted so that each picture would have the same dynamic range in the area of most interest. Two ratios were produced, one red/blue and the other blue/red. The red/blue ratio image is illustrated in Figure 19 (high values are shown as white, low values as black). A color ratio map was produced by recording the red/blue ratio image with red light and the blue/red ratio image with blue light. The results are presented in Figure 20. This figure illustrates that most of the features on the cloth are predominantly redder whereas the unmarked cloth is relative bluer.



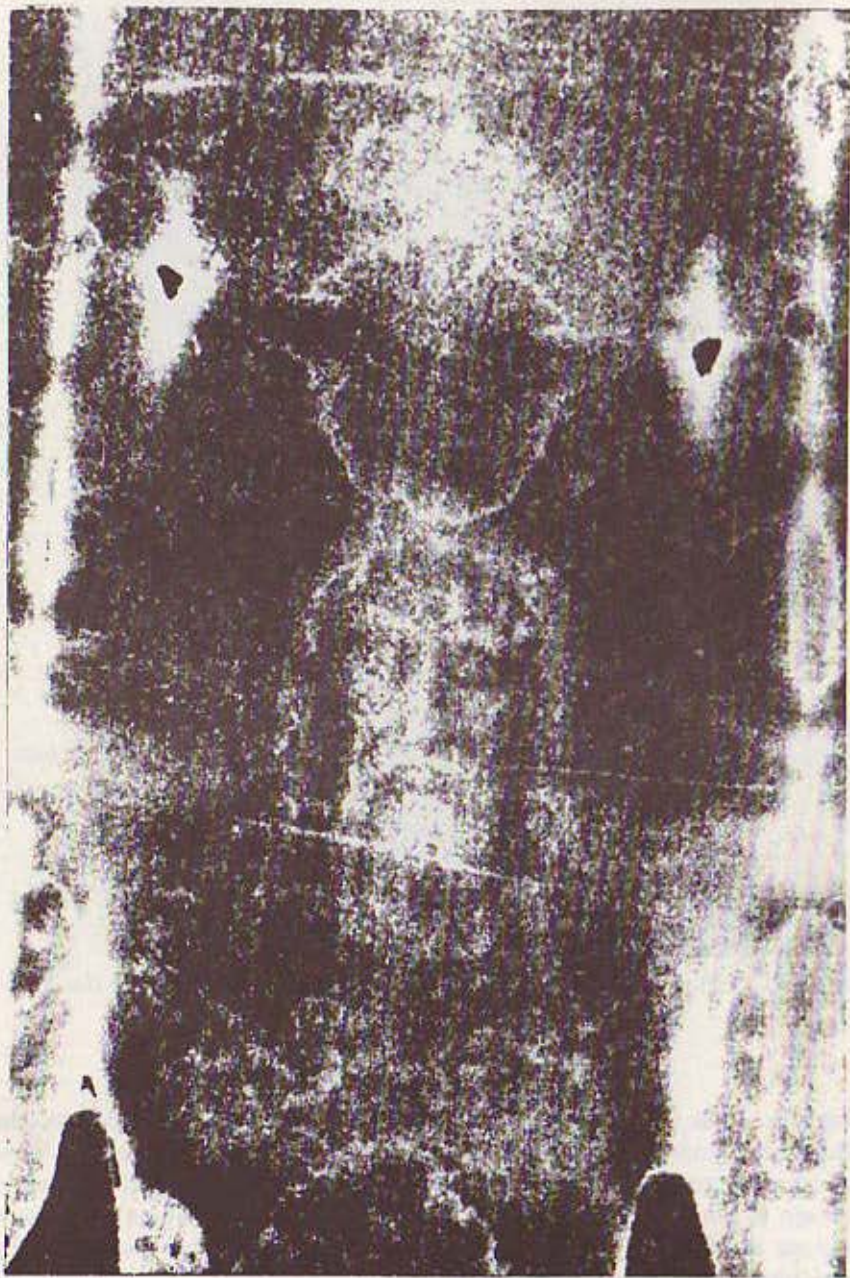


Figure 19. The ratio of the red component shown in figure 18 to the blue component shown in figure 17.



Figure 20. A pseudocolor exaggeration of the ratio of the red and blue components from color transparency No. 1. In this picture the red-to-blue ratio is displayed as red and the blue-to-red ratio is displayed as blue. This picture indicates that the unmodified cloth appears to be uniformly bluer and the modified cloth redder.

The same procedure was run on the color images of the overall figure. Figures 21-24 illustrate the same sequence as Figures 17-20, and show the same trend in the result for most of the body impression.



Figure 21. The blue component from the scanned and digitized image from color transparency No. 2.



Figure 22. The red component from color transparency No. 2.

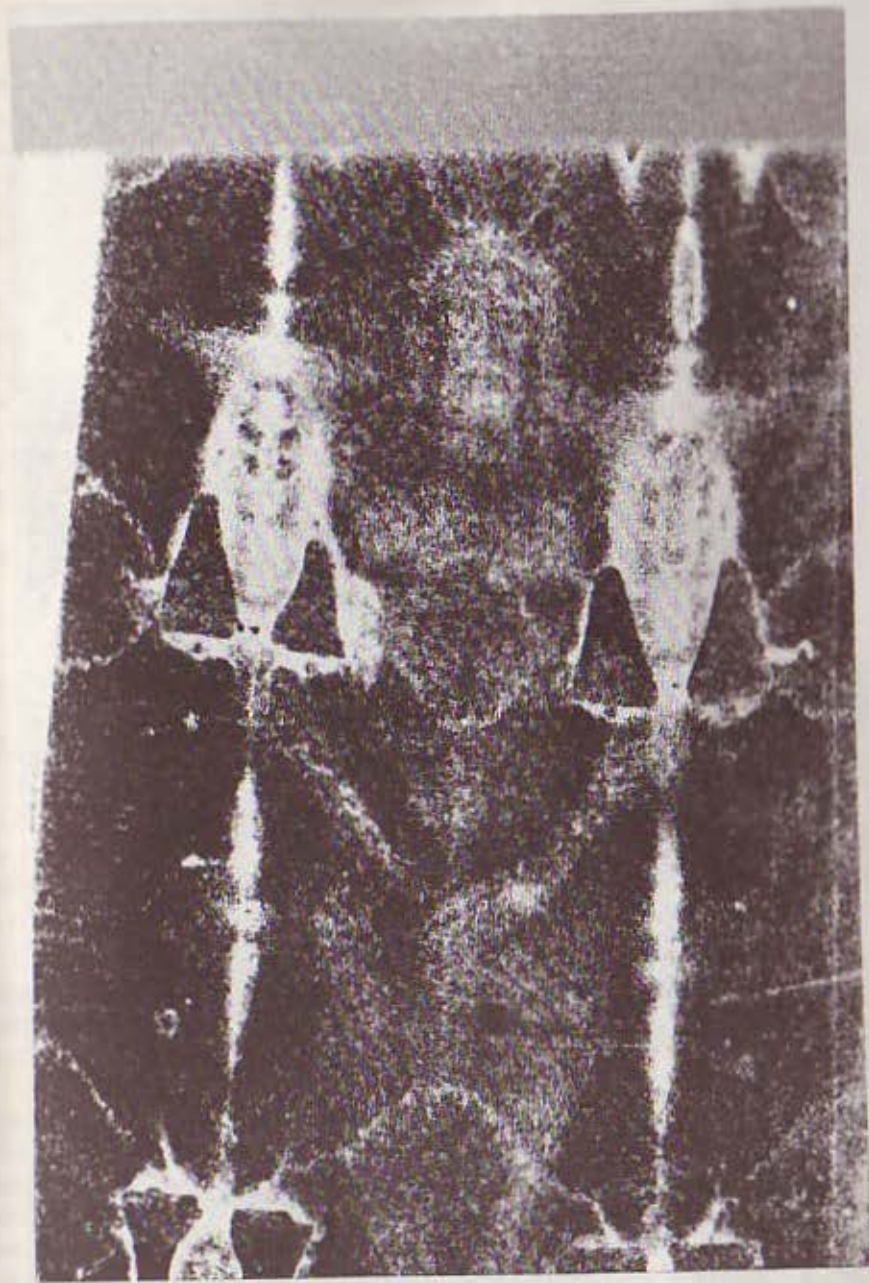


Figure 23. The ratio of the red component shown in figure 22 to the blue component shown in figure 21.

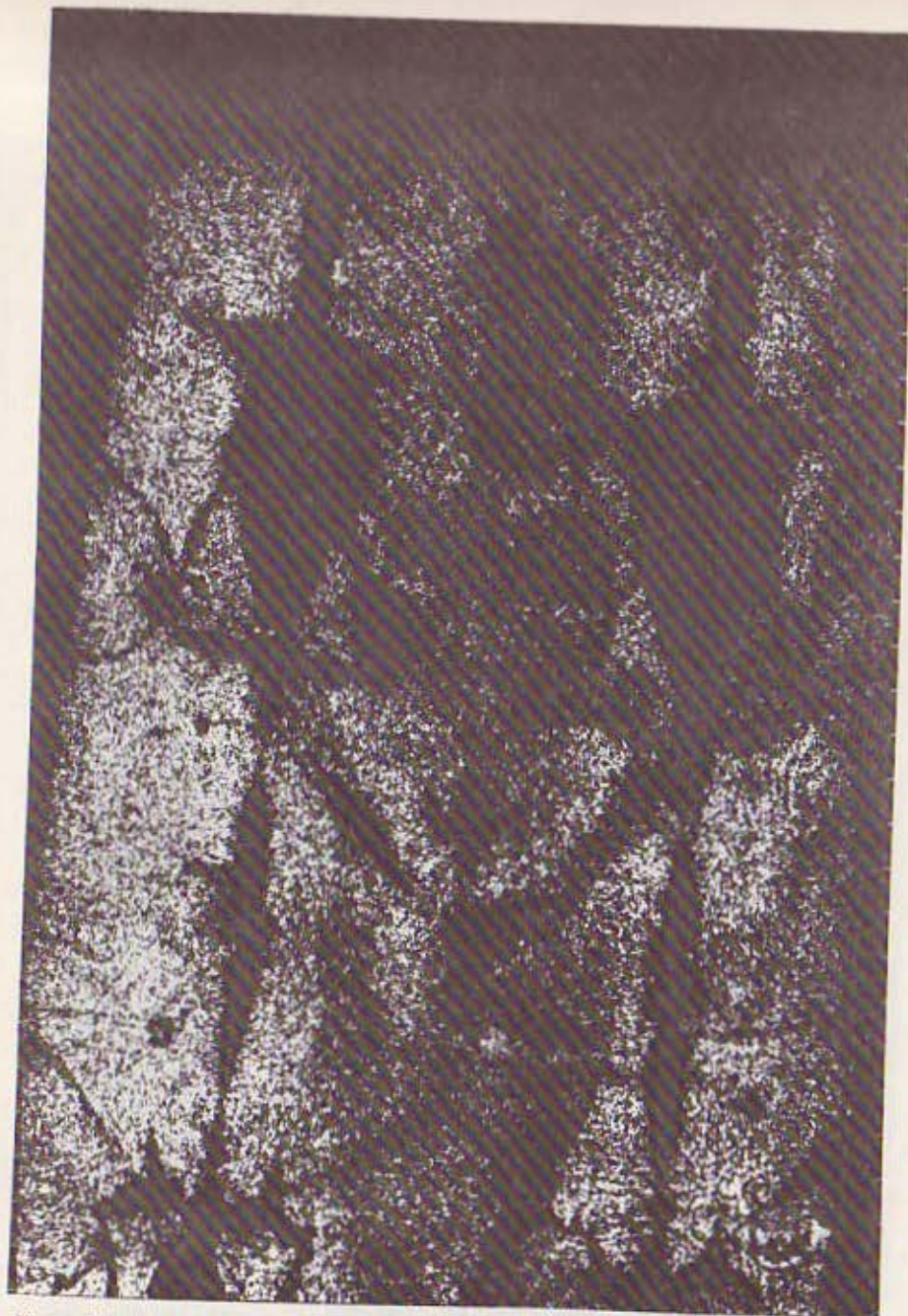


Figure 24. The same as figure 20, except the images from color transparency No. 2 were used. The results obtained from the facial region as shown in figure 20 appears to be consistent over the entire Shroud.

## V. Comments and Conclusions

1. The water marks and the numerous small intense features on the body have abrupt edges, whereas the large burn marks have smoothly decaying edges. This suggests a different mechanism of formation for the two types of features.

2. The short linear marks with small spots along them, which appear on the back of the figure, could be attributed to scourge marks.

3. The image of the facial region is composed of a wide range of spatial frequencies which are oriented in a random fashion. This indicates that the feature-generating mechanism was probably directionless (a characteristic which would not be consistent with hand application).

4. The information which causes the eye to recognize facial structure lies at very low spatial frequencies. Little physiological data is contained in small structure.

5. All impressions on the Shroud tend to be redder than the unmodified cloth itself.

6. The amount of information obtainable from these images is limited by the lack of quality photographic material and by the lack of a color and/or reflectance standard to relate color separations.

## VI. Recommendations

It appears that more could be learned about the nature of the image on the Shroud if more detailed and comprehensive data could be obtained. The following are some suggestions as to what additional photographic data would be useful, and what might be accomplished with such data.

1. The Shroud should be photographed with high resolution film of at least 4 by 5 inches format. Each photograph should contain within it the simultaneous exposure of a grey reflectance target containing at least a dozen patches of different, known reflectance.

2. Photographs should be taken through several different spectral filters; standard Wratten filters would be satisfactory. The filters and the films should be chosen to cover as broad a wavelength spectrum as possible. A standard set of color control patches should be included in each photograph. Color film produces pretty pictures, but it does not have the resolution or range of high quality black and white film.

3. Ultraviolet fluorescence photographs could be taken if it was determined that UV radiation would not damage the Shroud.

These measurements could help to separate the existence of foreign substances (and possibly the nature of them) from the base material.

4. Thermographs, or infrared imagery, might also be used to differentiate between the base material and material which had been modified by the adsorption or absorption of foreign substances.

5. Tests should be run to determine whether the spectral reflectance characteristics of the burned areas and water marks are difference from those of the figure impression. If they are, creation of the appropriate images would permit removal of all burn and water marks from the images.

6. Although it has nothing to do with imagery, some of the newer age dating techniques might be utilized to determine the age of the cloth.

Given any or all of the above data, the following computer analyses could be undertaken:

1. The first generation negatives recommended above would be scanned and digitized. Using the reflectivity charts, each image could then be related to a standard scale. This would permit quantitative comparison of the image reflectance in various spectral regions.

2. Using the various spectral images, multi-spectral classification could be performed to identify those areas on the Shroud which have common spectral reflectance characteristics. This could identify image areas which were formed by common physical processes.

3. Laboratory experiments could be conducted in an attempt to duplicate the chemical processes involved in the creation of the Shroud image. Similar cloth materials could be exposed to various compounds and processes and the resulting impressions photographed and analyzed in the same manner as the Shroud photographs.

## VII. Acknowledgements

We would like to thank Dr. John Jackson and Father Peter Rinaldi, S.D.B., for their support in supplying us with the film products which enabled us to perform this study. We would like to thank Tom Dolle for bringing us into this investigation and Michael Morrill of IPL for his aid in scanning the negatives.

## REFERENCES

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3. Dr. John Jackson, Dr. Eric Jumper, "Characterization of Image Intensity with Cloth Body Separation on the Holy Shroud by Computer Analysis."
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## Description of Image Processing Algorithms

A. High Pass Filter (figure 2)

The particular digital high pass filter used in these analyses is called a "DC-Notch Filter," (see reference 4) and is designed for computational speed. This type of filter basically consists of computing a low frequency component and subtracting it from the actual value, i.e., at each pixel, the mean of all pixels in a specified neighborhood around a pixel is subtracted from the DN value of that pixel. The resulting value is then added to some specified uniform bias. It can be shown that this process is equivalent to high pass filtering in the Fourier domain with a transfer function of the following form:

$$T(f_x, f_y) = 1 - \frac{\sin(\pi a_x f_x)}{\pi a f_x} \cdot \frac{\sin(\pi a_y f_y)}{\pi a f_y}$$

In the above expression  $f$  is a spatial frequency in units of cycles/pixel and  $a$  is the width of the "neighborhood" over which the mean was computed. The effect of this filter is to suppress features in the image which are larger than the dimension  $a$  but to pass smaller features. However, this algorithm often has the negative affect of creating an alternately dark/light border at the edges of large gradients in the image. This effect is termed ringing and is purely artifact; it should be ignored.

B. Derivative Filters (figures 3 and 4)

Derivative filters are computed by creating an image which at every point contains the difference between neighboring pixels. This procedure is equivalent to shifting an image with respect to itself a specified number of pixels and taking the difference between the two images. The orientation of the displacement governs the directionality of the derivative. This algorithm allows one to display local gradients in intensity as opposed to displaying intensity itself.

C. Fourier Transforms (figures 6 and 7)

Fourier transform images are displays of the amplitude of spatial frequency components. In figures 6 and 7 the lowest spatial frequencies are at the center and the highest are at the edges. The Fourier transform formula is of the form:

$$FT(f_x, f_y) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} P(x, y) e^{-2\pi i(f_x x + f_y y)} dx dy$$

where  $P(x, y)$  is the function whose transform is being computed.

In the suppression of the fabric weave, those complex values which lay along the path of the bright bases in figure 6 were reduced in amplitude until their contribution to the image was negligible. Because the fabric weave was aligned in a generally vertical or horizontal fashion only spatial frequencies in these orientations in the transform contained this information; thus a suppression of these frequency components was achieved. When the suppression step was performed, only a small percentage of the real signal was damaged as attested to by the absence of non-coherent information in the difference pictures.

D. Median Filter (figures 10-13)

The Median Filter is a nonlinear filter which is used to suppress local non-monotonic structure in an image. At each pixel the population of DN values is assembled (histogram) from a neighborhood symmetrically about it on the same picture line. The central pixel is replaced by that DN value which lies midway up the distribution. Features which are smaller than half the filter width and which are non-monotonic within this interval tend to be replaced by the local background. In figures 10 and 12, the Median Filter was run both horizontally and vertically.

# CONSIDERATIONS OF MOLECULAR DIFFUSION AND RADIATION AS AN IMAGE FORMATION PROCESS ON THE SHROUD

By Eric J. Jumper

## Introduction

For years I was convinced that Vignon's vaporgraph process was responsible for forming the image of the man on the Shroud of Turin.<sup>1</sup> The theory was rather a believable one based on Vignon's observation that body images on the Shroud appeared to be present even where the cloth could not possibly have been touching the body. This could lead to only one conclusion and that is that the image forming process was one which acted through space. So the idea of molecules being transported through space by a diffusion process and staining the cloth did at first seem to explain Vignon's observation. Vignon's suggested chemical constituents of blood, sweat, ammonia, and aloes also seemed believable since Vignon claimed to have formed a "good" image of a hand using various combinations of these constituents. This hand image, I must admit is now rather infamous since neither I nor anyone I have contacted has ever seen a picture of it. Be that as it may, it is important to note two points. (1) A prerequisite for image formation was a damp cloth<sup>2</sup> and (2) Vignon reported that his hand image was clearly visible on the back of his test cloth as well as on the front.

Doubts about the validity of a vapor transport mechanism being responsible for the image began to nag at me after examining some of the results of our three-dimensional studies<sup>3</sup>. The first hint of doubt came with the discovery of images over the eyes which appear to be coins. It is hard to imagine an organic stain mechanism acting to form not only images of the body but also of inert objects such as coins. Another question is "why did the hair images follow the exact same law of intensity versus distance as did the body image?" Still another interesting characteristic of the image began to plague me

and that was the fact that nowhere on the body image was the image saturated (that is to say nowhere did the image intensity reach a plateau and remain at that intensity). This last characteristic can be plainly seen in the three-dimensional pictures in reference 3. The final problem, which sets my doubts running wild was the important discovery of the 1969 Scientific Commission that the image was only a surface phenomenon.<sup>4</sup>

In the remainder of this paper I will present some of the passages from the Commission report and the results of our three-dimensional work which caused me to try to explore the problem further; describe a rather crude experiment I performed; present my attempt to quantify a diffusion process for molecules being transported through space from a body to a cloth; draw some conclusions based upon my analysis and the results of this paper; and finally mention briefly some observations on radiation as a possible cause of the image on the Shroud.

## Character of the Stain on the Shroud

As I implied from the above, I was always under the impression that the image on the Shroud was present on the back of the cloth as well as on the front. This impression was caused by the often quoted account of the Sisters of Poor Clare.<sup>5</sup> The following passages quoted here from the commission report clearly contradict not only this impression but further state that the image does not even penetrate the surface fibers on the front side of the Shroud:

"In the past the fabric was strengthened by sewing it at the edges and in several other points all over the back surface against another cloth; during our recent examination a small area of the more recent piece of cloth was unstitched and it was found that the image appears only on the top side of the original cloth, i.e. it does not go through the fabric. Recent laboratory tests of samples of the fabric taken from several spots where the colour is deeper prove with sufficient certainty the absence of any substance which might have been absorbed by the threads . . . . Therefore, in all likelihood, the image is completely superficial." (Page 65)

"At the moment of (the thread) snapping with a relatively slight amount of fraying, it could be observed that the reddish tint of the thread was limited to the surface, while the inside appeared to be perfectly white." (Page 24)

"This coloring is found only on the surface fibers, so much so that the above-mentioned coloring(sic) was only observed on the reverse of the thread at the level of the underlying fibers by transparency." (Page 50)

So we can say with some certainty that the image is a surface phenomenon.

Results of our three-dimensional work show that the Shroud image has at least two further characteristics which leave doubts in my mind about the image being the result of molecular transport.<sup>3</sup> The first, was the possible discovery of images of coins over the eyes. If these images are images of coins, it is hard to imagine the image of the coins forming in exactly the same way as that of the body. The second bothersome characteristic is rather more subtle. Nowhere on the Shroud is the image saturated. The significance of this observation cannot be explained in such simple terms as those of the coins, and will be withheld until later in this paper.

### Experiment

It was not clear to me how linen would react to staining, so a simple experiment was performed. It consisted of making a solution of water and green food coloring and then placing one end of a linen fiber into the solution. Two types of fibers were used, one dry and one damp. This of course did not simulate some sort of dry transfer stain but it did simulate in my mind the kind of conditions Vignon seemed to suggest in his vaporgraph theory. The results of these tests were rather surprising. In the case of the dry linen thread the stain progressed at about 1 cm. in 4 seconds against gravity. It should be added that the stain spread "without limit" as long as there was fluid and thread available, that is to say the stain front seemed to progress at a constant velocity rather than at a continually slowing rate as is characteristic of a diffusion process. The dry spread velocity,  $V_{DRY}$ , was:

$$V_{DRY} = d/t = 1/4 = .25 \text{ cm/s} \quad (1)$$

When the experiment was repeated with a damp linen thread (the condition suggested by Vignon) the stain spread about half the distance in the same time and slowed as it spread. This rate was more in keeping with what would be expected by a diffusion process. The diffusion coefficient could then be crudely determined assuming Fich's law of diffusion as:<sup>6</sup>

$$D_{DAMP} \cong d^2/4t = (.5)^2/(4)(4) = .016 \text{ cm}^2/\text{s} \quad (2)$$

Crude as the experiment was it provided me with a measure of how a stain acts on a linen cloth. I think that the reader will find in the conclusions, as I did, that even errors to factors of 10 in these numbers will seem insignificant when times required for molecules leaving the body to arrive at the cloth are determined. It is impor-

tant to note that the above experiment yielded numbers for the reaction of the stain in the cloth. It is now necessary to examine the behavior of the molecules being transported from the body to the cloth through the intervening space.

### Analysis of the Molecular Transport of Ammonia Through Air

Although it is rather presumptuous to assume that if the image was formed by molecular transport the responsible molecule was ammonia, it is, however, in keeping with Vignon's hypothesis. The use of ammonia serves as at least a model and will yield results not too different than would be expected for many molecules that could be postulated as will be pointed out in the equations.

The diffusion coefficient for ammonia through air was calculated according to the equation suggested by Hirschfelder.<sup>7</sup>

$$D(\text{NH}_3, \text{Air}) = \frac{.001853 \sqrt{T^3 (1/M_{\text{Air}} + 1/M_{\text{NH}_3})}}{P \sigma_{ij}^2 \Omega_D} \quad (3)$$

Where T is the temperature in °K, M is the molecular weight in gm/g-mole, P the pressure in atmospheres,  $\sigma_{ij}$  the collision cross-section in Å, and  $\Omega_D$  the reduced collision integral. Since M for air is about 17 gm it can be seen that any molecule responsible for the stain with a larger M than that of ammonia ( $M_{\text{NH}_3} \cong 29 \text{ gm}$ ) will have only a minute effect on D. Using the values given in table 1 the diffusion coefficient turned out to be:

$$D(\text{NH}_3, \text{Air}) \cong .5 \text{ cm}^2/\text{s}$$

TABLE I  
Values of terms in Equ. 3.

T	300 °K
P	1 Atm
$M_{\text{AIR}}$	17.03 gm
$M_{\text{NH}_3}$	28.97 gm
$\sigma_{ij}$	2.9 Å
$\Omega_D^*$	2.3

### Conclusions based on the figures arrived at for a Molecular Stain

Under the assumptions that: (1) the stain was not a dry transfer process, (2) the molecule responsible for the stain either was ammonia or acted similar to it in its transport and (3) 2.5 cm is a reasonable distance to use as an average cloth body distance, (This seems to be justified by our three-dimensional work) let's take a look

\* $\Omega_D$  is a function of  $kT/\epsilon$  the value used for  $\epsilon/k$  was 558.3° K

at some of the ramifications of the preceding analysis. In order to get an idea of the times involved in a diffusion process, first consider the supposition that the process took hours — say as many as 30 as has been suggested by Vignon<sup>1</sup>. What would this mean to the clarity of the image on the cloth? If the stain acted as it did in my experimental samples, this would mean that no clear image would even be present, for to move 100 cm would have taken only 400 seconds or 6.7 minutes in the case of a damp stain on an otherwise dry cloth (100 cm/.25 cm/sec).

In the case of a damp cloth the time to move 100 cm would be approximately 43 hours. Calculated by:

$$D \cong \frac{d^2}{4t} \quad \text{OR} \quad d \cong \sqrt{4Dt} \quad (4)$$

$$\text{AND} \quad t \cong \frac{d^2}{4D}$$

but after only one minute the spread would be approximately 2 cm., and in say 5 seconds the spread would still be 0.5 cm. Of course all these spread distances are totally incompatible with what is seen in the case of the very fine resolution image of the Shroud.

The answer seems to lie in a very short molecular "burst." However, how short is a reasonably short time? To help answer this question I examined the time it would take for the first evidence of a sudden presence of ammonia particles to be felt 2.5 cm from their location. This again can be calculated using equation 4 (but now using the diffusion coefficient for transport through air). The time is around 3 sec! We could continue cutting the time back but as we do the Fick's law diffusion model begins to break down. As the molecular burst becomes shorter and shorter the tendency for the gas to homogenize begins to predominate which would cause no definition in the image whatsoever.

So then from time considerations alone — Vignon's proposed formation process seems doubtful. What about the surface phenomena characteristic of the Shroud image? In my experiment on threads there was no question that the stain had penetrated the entire thread. Again I had more doubt since the Shroud image is only a surface phenomenon. Also apparent in my experiments was a tendency for the stain to saturate, that is, come to a certain stain intensity and not get any darker. Nowhere on the Shroud did we find this phenomenon. See, for example, the three-dimensional pictures. In no case does the image reach a plateau, which would occur if saturation had taken place. It is also apparent that the image

was not pressure sensitive, that is, the image on the back appears to possess the same fall-off characteristics as the front image even though the pressure differed greatly the front associated with only the weight of the cloth on the top (front image) and on the back (back image) associated with the weight of the body. (These are of course assumptions which seem fully justified by the Shroud itself). This also has a profound influence in and of itself on the assumption of a molecular stain, since one would expect that the responsible chemical would be more abundantly present when the cloth was in contact with the body and even more so under pressure. Saturation would certainly be apparent in either of these conditions.

These facts significantly influence my doubts about a molecular stain even if the stain was a dry transfer. In fact, one would expect at a minimum that the points where the cloth contacted the body would have shown saturation (as was the case when we three-dimensionally analyzed images formed by contact experiments).<sup>3</sup>

### Observations on Radiation

Some very simple radiation experiments were performed by John Jackson and myself prior to this conference and the following was found:

1. Images could be formed of varying intensities up to at least the intensity of those found on the Shroud without saturation.
2. Unless actual ignition took place only slight spreading of the image occurred.
3. It appeared that if the image was formed by a radiation process the intensity of the radiation would have to have been very high. This conclusion was based on the fact that while the actual laser flux used was not quantified in every case, in the short time of cloth exposure to the laser there was an image on the reverse side of the cloth almost as dark as the one which appeared on the front.

Post Conference Note: Dr. Rogers showed me a piece of cloth which he exposed to a rapidly moving torch which clearly exhibited an image which was present only on the front of the cloth.\*

\* This point also cleared up some doubt about one way I thought a forger may have made the Shroud. If he heated a Bronze Statue say until it was glowing hot I thought he might be able to throw the linen over it for a short time and remove it, leaving a scorched image. These temperatures (lower than melt temperature) would give off radiation with too low an intensity to form only a surface image. Our experience shows that the image would also be present on the back. This work then proves that it could not be a forged image of this type.



### Closing Remarks and Summary

While it does indeed seem possible that a molecular transport process over reasonably long periods of time (a minute or longer) would set up a molecular concentration gradient which could form some sort of intensity pattern interpretable as an image, it seems very unlikely in my mind that molecular transport could have formed the image we find on the Shroud. This opinion is based on the observations of stain spreading I made in the simple experiment, the fact that the stain on the Shroud does not penetrate even the surface fibers of the cloth and the fact that the Shroud image is nowhere saturated. While it cannot be concluded that radiation caused the Shroud image, in the specific areas of stain spreading and saturation, radiation cannot be ruled out.

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COLOR ANALYSIS OF THE TURIN SHROUD:  
A PRELIMINARY STUDY

By John P. Jackson

Color photographs of the Shroud were taken for the first time in 1973 by a Scientific Commission appointed to study the Shroud and by some who viewed the relic during an Exposition that year. One participant of the Exposition, Father Otterbein, was kind enough to loan me an original color transparency he took of the facial image of the Shroud. Since this transparency was not taken for scientific reasons, information regarding illumination, exposure time, etc. was not available; but it seemed to me that a study of relative color variations could nevertheless be performed. In particular, it seemed possible to study relative colors of the body and hair images, possible objects atop the eyes, beard and blood images, and 1532 scorch patterns.<sup>1</sup> In this paper, the results of my study will be presented.

The approach was to scan selected regions of the image with a microdensitometer probe beam as shown in Figure 1, four passes for each scan path. During three of these passes, Wratten Filters (No. 92-red, No. 93-green, No. 94-blue) were consecutively inserted into the probe beam so that only red, green, and blue colors of the image would be detected. On the fourth pass, no filter was inserted in order to standardize the color measurements. Tracings of image density\* in each color band were automatically recorded onto graph paper by the microdensitometer.

\* "Density" is used in this paper and figures to refer to the degree of image darkening as sensed by the microdensitometer operating on a linear scale of 0-100. Though related to photographic density and transmittance, this quantity is not equal to either. The microdensitometer scale, however, was identical for all scan passes.

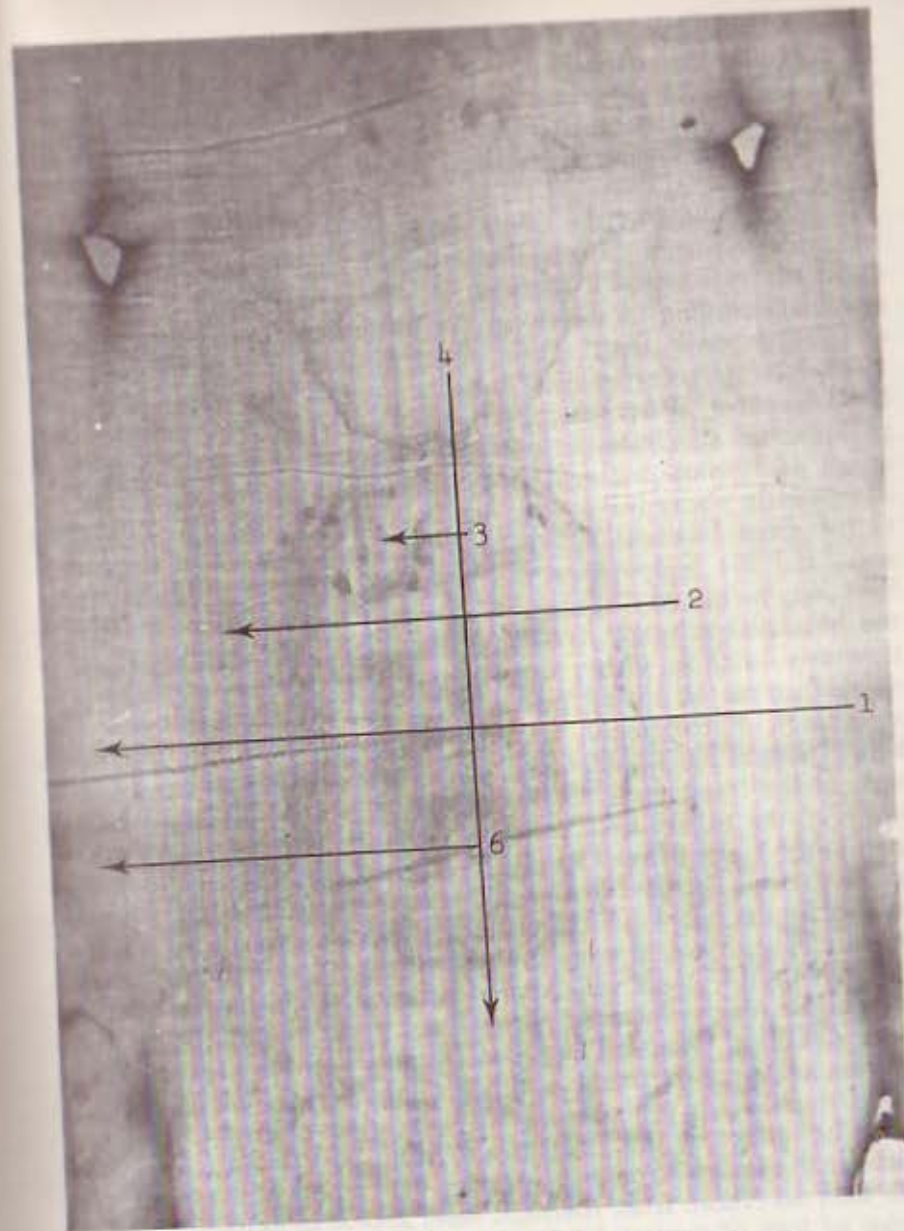


Figure 1. Black and White Reproduction of Color Slide scanned. Each line indicates scan paths. Scan 5 through the right side blood image is not shown. Over each scan path, four separate passes were made with green, blue, red filters and finally with no filter.

The collected data were plotted and then interpreted according to the following assumption: that generally different kinds of image stains show different mixes of red, green, and blue at the same value of overall (neutral) density and that the continuous variation of this mix with neutral density would be different for different image types.

87 samplings of the image, each with four color measurements, were selected from the microdensitometer scan plots. These data are displayed in Figures 2 through 4. Each data point is plotted in symbol according to where on the image it refers. Figure 2-Green and 3-blue show that, within slight data scatter, all of the aforementioned image types tend to fall along the same curve. Figure 4-Red, however, does not display such uniformity. Notably, data points from the burn patterns fall significantly below the Shroud image data points for neutral densities less than 60 while they fall significantly above for neutral densities greater than 60. According to the given assumption, this behavior would signal that the scorch areas and the body image are probably different kinds of stains. However, before such a conclusion is drawn, it should be noted that the burn points below neutral density 60 do not extrapolate continuously to those higher than neutral density 60 as might be anticipated since all these points refer to the same process (i.e. scorching). Furthermore, it should be noted that all the data points below neutral density 60 were taken from the scorched area to the right of the facial image (i.e. at the start of scan path 1- see Figure 1) while all the others were collected from the left (i.e. at the end of scan paths 1 and 6- see Figure 1). A visual inspection of the entire image shows a gradient in overall density from right to left, probably caused by uneven illumination during exposure (made by a simple flash). Thus, it would seem probable that a combination of uneven shading on the image and microdensitometer detector response is responsible for the apparent discontinuous shift in burn pattern (red) color densities. Had the burn pattern data points all fallen along a continuous line, as in the blue and green plots, the effect of the right-left gradient would probably be fairly judged insignificant.

This effect of the gradient also seems to have affected other parts of the image. For instance, hair data points of neutral density less than 40 (taken from the right side) appear to extrapolate below those of hair of neutral density 70.3 and 72.2 (taken from the left side). Other hair data points refer to the top of the head, are therefore midway between the right and left sides, and lie somewhat below the left hair data points (where the darkening due to the right-left gradient is noticeably greater).

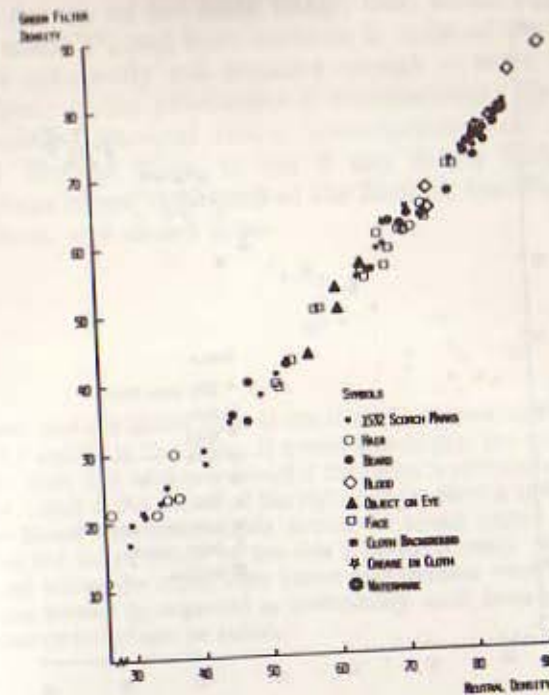


Figure 2. Green Filter Density versus Neutral Density. All image types fall on same line.

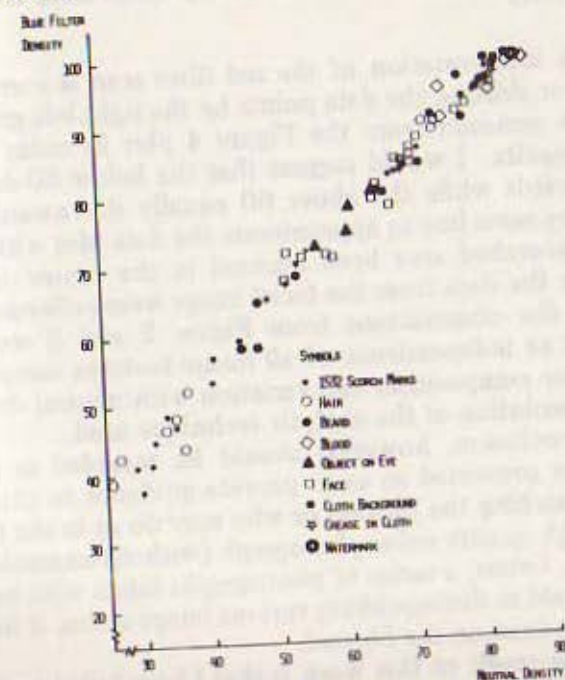


Figure 3. Blue Filter Density versus Neutral Density. All image types fall on same line.

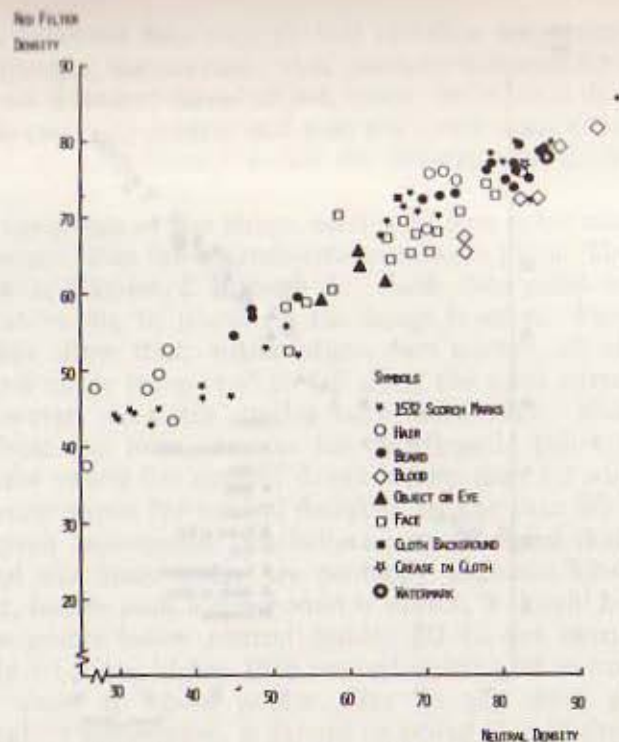


Figure 4. Red Filter Density versus Neutral Density. All image types fall on same line if scorch data samplings (solid stars) are corrected (see text).

If this interpretation of the red filter scan is correct, then the tendency for shifting the data points by the right-left gradient would have to be removed from the Figure 4 plot in order to correctly assess the results. I would suggest that the below 60 data points be shifted upwards while the above 60 equally downwards until they fall along the same line to approximate the data plot which would result had a scorched area been scanned in the center of the photograph where the data from the facial image were collected. With this correction, the observations from Figure 2 and 3 would follow, namely that an independence of all image features sampled with respect to color composition and variation with neutral density exists within the resolution of the analytic technique used.

This conclusion, however, should be regarded as preliminary and has been presented so as to provide guidance to those who are actively researching the Shroud or who may do so in the future. Obviously, a high quality color photograph (without anomalous density gradients) or, better, a series of photographs taken with narrow band filters would aid in distinguishing various image stains, if indeed more than one type exist on the Shroud.

Thus, the result of this work is that I have failed to detect with certainty any difference between the color composition and variation

with neutral density of the body image, hair, blood image (on forehead-"three mark")\*, and burn patterns in spite of the fact that the method used apparently was sensitive enough to sense the right-left density gradient on the photographic transparency. Because of this result, I would recommend future investigations into the composition of the Shroud image to see if any subtle differences exist between various image structures of the Shroud, specifically those of the body, blood, and scorch areas.

\* I sampled also the blood stain at the side which produced the neutral density values 87.5 and 92 in the plots. It would appear that the side stain might be slightly redder than that of the forehead if the latter is extrapolated to the lower density values. And if the effect of the right-left gradient is taken into account, the right side blood data presumably should be raised higher than as plotted suggesting that the blood image on the side is fundamentally "redder" than that of the forehead where the other four blood data samples were taken. However, this observation should be regarded as preliminary until more precise and comprehensive measurements can be taken.

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## COMPUTER RELATED INVESTIGATIONS OF THE HOLY SHROUD

By Eric Jumper, John Jackson, and Don Devan

### Introduction

Ever since Secunda Pia captured the image of the Holy Shroud with his camera, photographs of the Shroud have been used almost exclusively as the basis for scientific research into the mysteries of this precious relic. Much has been learned from these Shroud photographs by scholars who tirelessly studied them using the unaided eye. Undoubtedly there is still much which can be learned through investigations of this type. What we intend to discuss here is an altogether different approach to studying photographs of Holy Shroud, this approach involves the use of computers.

Before entering into our discussions of computer techniques for investigation of the Holy Shroud, it is well to address the topic of expectations. To many people, the very mention of computer techniques for such a study suggests aesthetic enhancement. In reality, this is only a small portion of what can be done using computers. In fact, the work we have done to present does not even address the question of aesthetic enhancement.

In what follows, we discuss our initial investigations into the use of computer techniques to study the Holy Shroud. We will first address our effort in scientifically enhancing Shroud photographs and comment on some of our findings. We will then discuss some of the work we have done in examining the density patterns of the Shroud image and how this might relate to the cloth-body positioning and understanding of how the image was formed on the Shroud at the time of Jesus' burial.

Finally, we will discuss some of the things we believe are possible using computer techniques. It is not until this last section that we will even address the question of aesthetic enhancement.

## I. Scientific Enhancement of the Shroud Photographs

By scientific enhancement of the Shroud photographs, we mean the enhancement of images for the purpose of extracting scientific information. To conduct our scientific enhancement study, a commercially available filmstrip of the 1931 photographs of Enrie<sup>1</sup> was used. The Shroud photographs on the filmstrip served as source transparencies for a computer process which involved the transformation of the visual information contained in the grey shades of the image on each photograph into a set of numerical values. Once a numerical representation of each image was obtained, it was computer processed and a new computer enhanced image was recreated on a viewing screen. The enhanced images presented here are photographs of these recreated images. Figure 1 gives a schematic representation of the enhancement process, a detailed explanation of which is contained in our article published in *Sindon*.

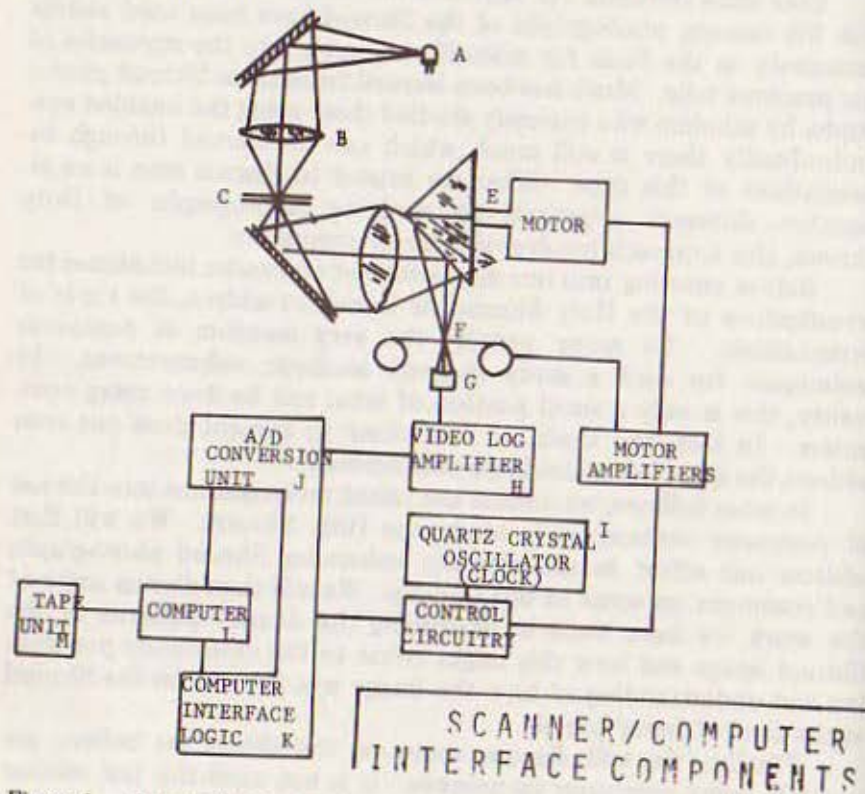


Figure 1. Schematic of optical scanning device. Light originates at point A, reflects off rotating prism B, intersects film at C, and the amount of light unattenuated by the film is detected by photomultiplier at G. System components H through L convert the photomultiplier signal to a numerical value which is recorded on magnetic tape at M.

Some of the results of this effort are presented in Figures 2 through 7 and 12 through 15, the even numbered figures being the originals scanned and the odd being the enhanced version of the previous figures.

Examination of Figures 2 and 3 shows how some of the fainter portions of the image have been exaggerated so that the outline of the hair and shoulders are more noticeable. It should be noted that the edges of the image are not distinct but somewhat hazy. This is in contrast to what can be noticed from Figures 4 and 5 of the face. Here, even under enhancement, the edges of the face are quite distinct. It is our opinion that this indicates an obstruction of some sort which hindered the normal process by which the image was formed, perhaps a chin bandage as proposed by Barbet<sup>2</sup> or a fold as proposed by Ricci<sup>3</sup>.

Figures 6 and 7 reveal a feature not previously noticed by investigators of the Shroud<sup>4</sup>, the possible existence of a thumb positioned as indicated in Figure 7a.

This observation would tend to discount Barbet's speculation that the thumb remained drawn into the palm of the hand at the time of burial. In as much as the absence of the thumb on the Shroud has generated significant medical discussion in the past, we thought that an independent experiment ought to be performed to see if the thumblike feature appearing on the computer picture could properly be identified as a thumb. We constructed a full-sized unbleached muslin model of the Shroud upon which we drew to exact scale the actual image of the body. Using the model, we enshrouded volunteer subjects of heights varying from 5 feet 10 inches to 5 feet 11-7/8 inches so that the appropriate features on their bodies coincided as much as possible with those indicated on the cloth. With the subject's thumbs placed first under the palms then along their right arm as indicated in Figure 7a, measurements were made to locate the point of contact of the Shroud with the right arm. In every case, the placement of the thumb under the palm caused the knuckles of the left hand to raise, shifting the contact point of the naturally draped Shroud further up the right arm than the actual contact point indicated by the onset of blood stains on the Shroud (again see Figure 7a). Photographs demonstrating this result are shown in Figures 8 through 11.

Additional work (detailed in Section II) indicates that the density of the thumblike image is consistent with that density which would be produced by an object about 3 cm beneath the cloth, the distance a thumb would be from the naturally draped cloth if it were as shown in Figure 7a. It is, therefore, our opinion that the new image is a thumb.

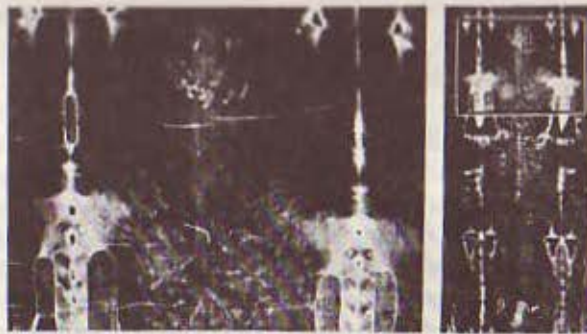


Figure 2. Unenhanced picture of back of head.



Figure 3. Computer enhanced version of back of head.



Figure 4. Unenhanced picture of face.



Figure 5. Computer enhanced version of face.



Figure 6. Unenhanced picture of hands.



Figure 7. Computer enhanced version of hands. Arrow points to thumblike feature.

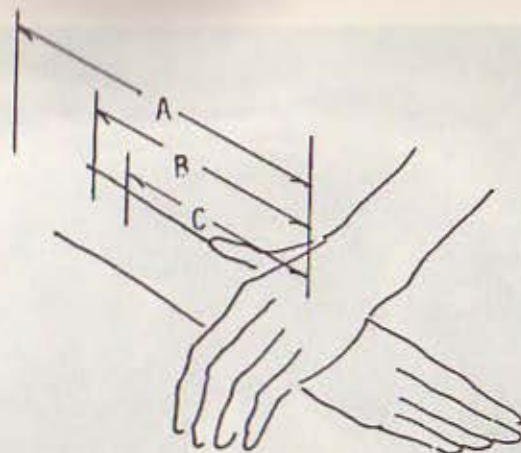


Figure 7a. Position of the thumb as it appears in Figure 7. Also indicated are experimental points of contact of our cloth model with lower forearm (as discussed in text) with thumb under the palm (point A) and to the side of the forearm (point B). The true contact point is determined by the onset of blood flow (point C). The thumb on the side and not under the palm best explains the position of the onset of blood flow on the forearm according to the Shroud.



Figure 8. Enshrouded subject with thumb under palm. Pointed out is the initial contact point of shroud model with forearm.



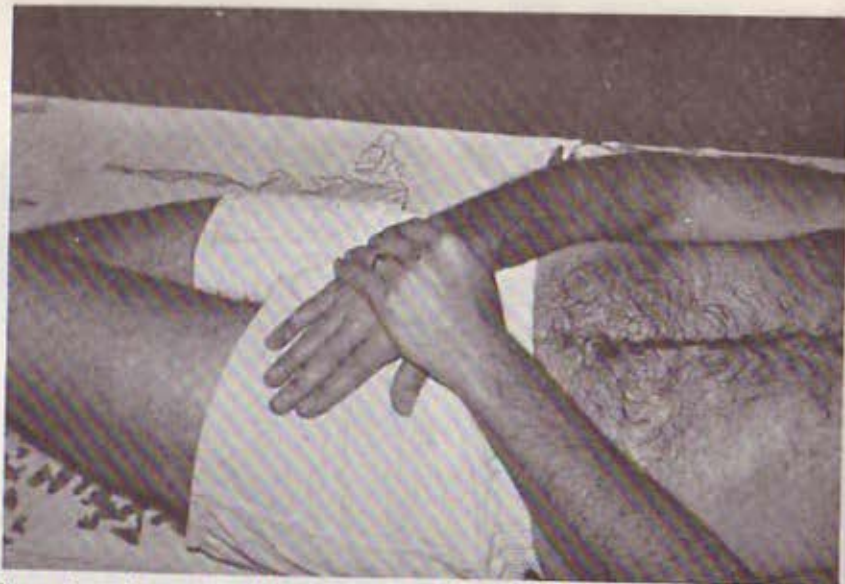


Figure 9. Undraped subject indicating thumb location for experiment of figure 8.



Figure 11. Undraped subject indicating thumb location for experiment of figure 10.



Figure 10. Enshrouded subject with thumb along arm. Pointed out is the initial contact point of shroud model with forearm.

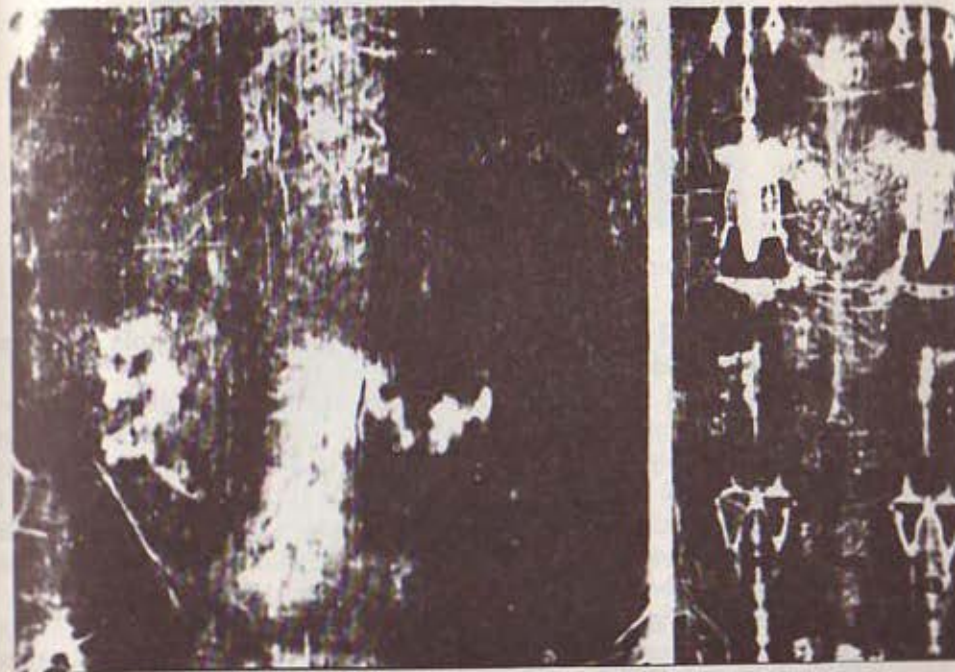


Figure 12. Unenhanced calf and ankle area.



Figure 13. Computer enhanced calf and ankle area.

Figures 12 and 13 show how the computer was able to fill in the calf and ankle areas of the legs.

Figures 14 and 15 show the most interesting result, the appearance of faint images along lower portions of both legs. These images had not been noticed previously as attested to by Bulst<sup>5</sup>. As explained in more detail in *Sindon*, we feel that these images are in fact side images of the legs of Jesus. The existence of these side images is significant because it suggests that the image forming process on the Shroud had to be a horizontal as well as vertical one.

Finally, Figure 16 shows the result of a computer technique called gamma enhancement which presents on the viewing system only the highest density portions of the original image. In the case of the Shroud, this became a map of the blood stains, and thus contact points of the Shroud on the body.

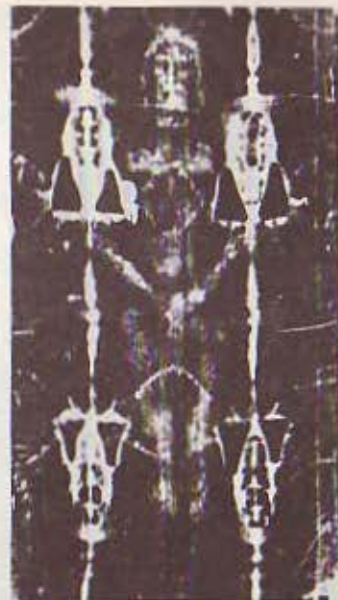


Figure 14. Unenhanced full front image.



Figure 15. Computer enhanced full front image. Arrows indicate faint side images.



Figure 16. Gamma enhancement of full front image.

## II. Image Density vs. Cloth-Body Separation

Vignon was among many who have noticed how the image on the Shroud varied with separation of the cloth from the body of Jesus. Even a casual inspection of the Shroud reveals that the strength of the image decreases with cloth-body distance. But to make precise how this variation occurs, more than just unaided eye techniques are required; such analysis requires a careful characterization of the intensity of the Shroud image as well as some applicable measurement of cloth-body separation. Having access to instruments capable of performing the density measurement, we performed a study to determine how image intensity on the Shroud depended on cloth-body separation as depicted on the Shroud.

We began our study by determining the cloth-body separation distances. To do this, we constructed a cloth model of the Shroud to actual size by projecting a photographic image of the Shroud on cloth and the body, blood, water, and burn marks, were each drawn in its own distinctive color. This model, shown in Figure 17, was draped over reclining subjects (Figure 18) in such a way that all image features were aligned over the corresponding body parts (Figure 19). Under the assumption that all blood marks indicated a



Figure 17. Model of Shroud.

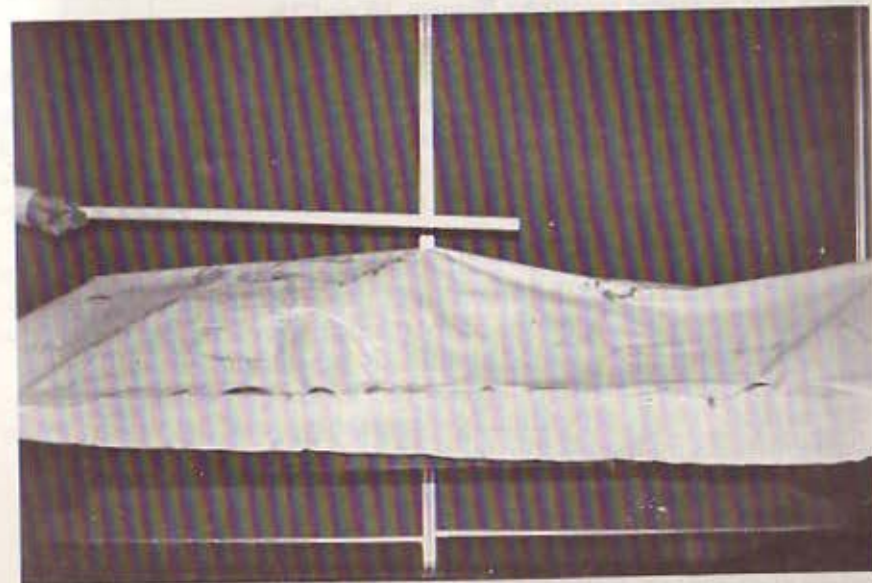


Figure 18. Draped reclining subject.

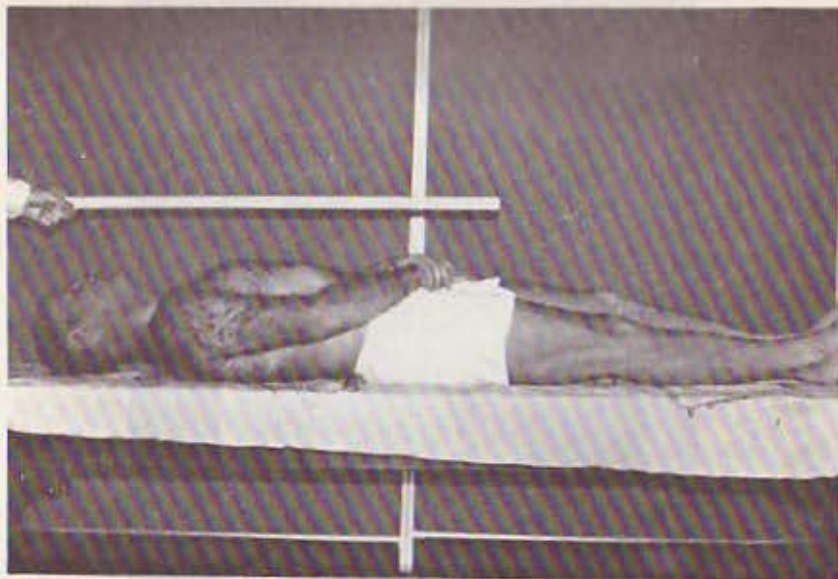


Figure 19. Undraped reclining subject.

direct body contact point, we required that all such marks touch the subject. Care was also taken to assure that all body images were over the appropriate body features though not necessarily in contact.

We then photographed the enshrouded subject with the cloth in place and removed to obtain Figures 18 and 19.

From these photographs, we constructed a drawing similar to Figure 20 which indicated relative positions of the ridge of the cloth and the body profile below it. This drawing permitted the accurate measurement of body-cloth separation distances along this ridge line which we assumed would give an estimation of the actual distances which must have been present in the case of Jesus' burial configuration.

After completing the body-cloth distance measurements, we proceeded to determine the intensity of the body image along the projection of the ridgeline on the Shroud image shown in Figure 21, (the line from which we measured cloth-body separation).

An original lantern slide given to Father Peter Rinaldi by Enrie, the official 1931 exposition photographer, was graciously made available to us by Father Rinaldi for these measurements.

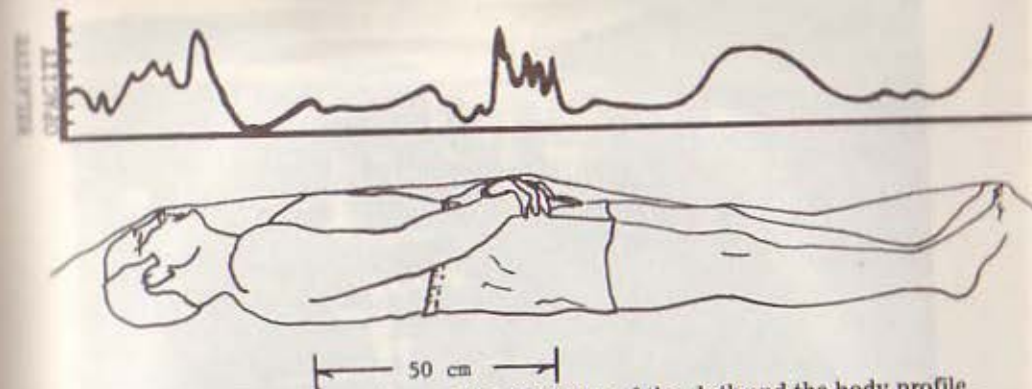


Figure 20. Relative positions of the ridge line of the cloth and the body profile below. Image intensity scan shown above figure.

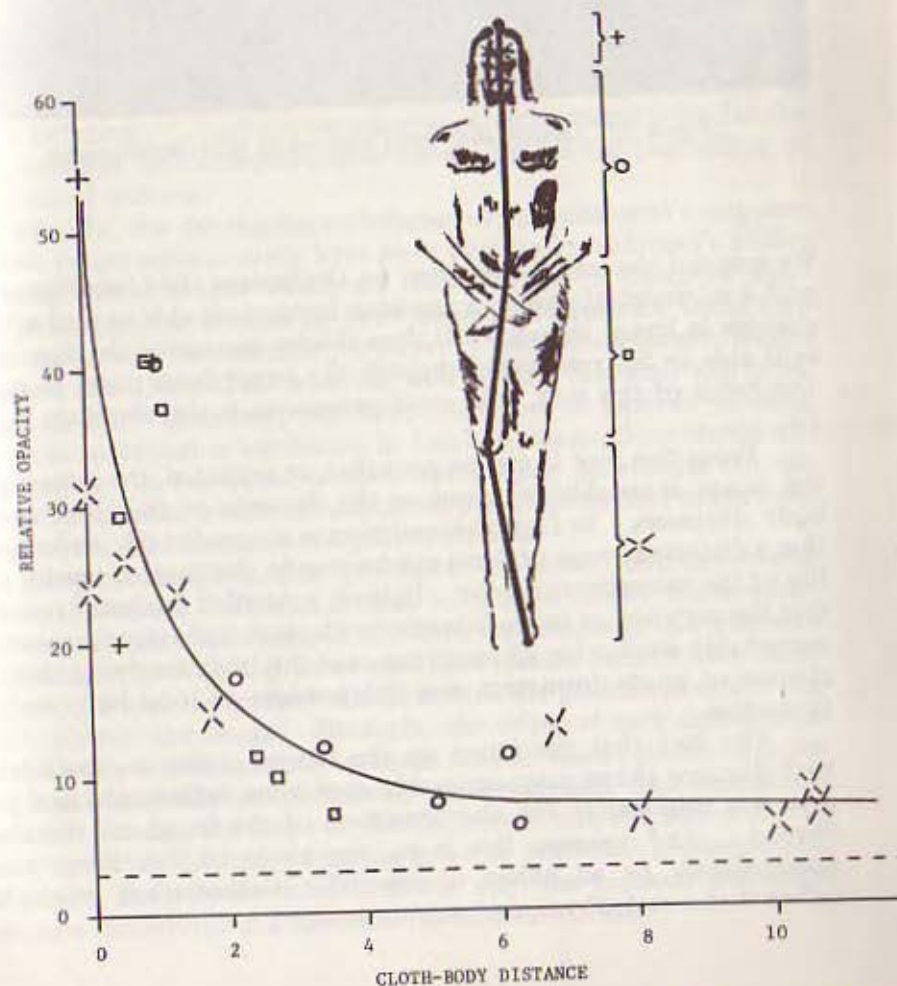


Figure 21. Ridge line intensity scan and correlation to cloth-body separation.



Figure 22. Lantern slide being scanned by microdensitometer.

We scanned the image contained on the lantern slide (see Figure 22) with a microdensitometer, a precision instrument able to read minute changes in image intensity. It does this by measuring the amount of light able to be transmitted through the image from point to point. The result of this scan, after some processing, is also shown in Figure 20.

From this plot it can be seen that, as expected, the intensity of the image invariably increases as the distance of the cloth to the body decreases. In fact, this variation is so predictable and regular that a distorted image of Jesus can be seen in the image intensity profile of the microdensitometer. Indeed, a detailed analysis<sup>6</sup> revealed that the variation of image intensity with cloth-body distance seemed remarkably similar for all locations over the body implying that the process of image formation was independent of local body surface properties.

The fact that the image on the Shroud varies so predictably with distance shows unquestionably that some definite physical process was responsible for the formation of the image on the Holy Shroud. And because this is so, the study of this image must appropriately be an object of scientific, mathematical principles, rather than a metaphysical phenomenon.

We believe that the ability to characterize a fall-off relation of image intensity provides students of the Shroud with a technique to help answer some critical questions regarding the mysterious Shroud image. For example, the problem as to how the cloth lay over the body of Christ can be addressed by using the applicable cloth-body distances indicated by each theory of how the body was draped. Thus, questions such as whether or not the sides of the cloth were held away from the body by the walls of a possible burial enclosure<sup>7</sup> or if the body was wrapped by a series of tucks and folds proposed by Ricci<sup>8</sup> can be addressed.

### III. The Potential of Computer Processing

Over the past several years, a rather remarkable fusion of scientific disciplines has been occurring. Physicists, mathematicians, engineers, computer experts, doctors and psychologists have combined their skills and techniques to create the "new" field of visual image enhancement and pattern recognition. Although a new field, it is a rich one . . . perhaps necessarily so, since vision is by far the most complex and comprehensive human means for perception of the physical universe.

Already, the developing techniques of the science of computer-assisted image enhancement have been used to extend man's ability to clarify visual images which are often unclear or distorted when first photographed or seen by eye. Such techniques are being used more and more, for example, to improve medical diagnostic images obtained with X-rays, or with the new nuclear medicine and ultrasound devices. Similarly, the recent advances in analysis of earth resources information contained in Satellite observations would not be possible but for visual pattern recognition techniques (to distinguish cultivated land from unplanted land, and healthy crops from diseased, etc.) developed in the past few years.

As a visual object, the "problems" of the Shroud are several-fold: the visual "contrast," that is, the dark/light relationships between recognizable features and their surroundings are distorted (with respect to the image of an undraped human form) by the drape of the cloth and the process which created the gradations of staining which convey the image. Similarly, the edges of such features are blurred; this simultaneously reduces overall visual clarity and impact, and disguises or obliterates small physical and anatomical features. Finally, the drape of the cloth itself, and the interaction of this drape with the image-forming process, introduce geometric size and shape distortions which combine with the contrast and edge-sharpness distortions in a somewhat symbiotic manner.

All of these "problems" of the image on the Shroud have at least potential solutions, or approaches toward solutions, in this "library" of image enhancement techniques. While, in general, there are no absolute prescriptions, "do this and that and the image will certainly improve," it is well established that the chances for successful enhancement are directly related to the quality of the initial photographic image and to the care and knowledge which went into the preparation for obtaining that image.

Ideally, a photographic "experiment" should be designed from a definite plan as to the image enhancement techniques whose application is anticipated. In this light, the film should be exposed under carefully controlled conditions which permit the opacity (the so-called photographic density) of each point on the film image to be associated with the amount of light energy which was actually reflected from the real object. Similarly, the intensity of light shining onto the Shroud should be measured so that the Shroud's reflectance properties can be determined. Large format cameras should be used to permit "scanning" devices which convert the film image into a form suitable for computer processing to retain the highest possible degree of geometric resolution — to "see" the details of the weave of the cloth so that, if desired, this weave can be eliminated, filtered out, of the enhanced image.

Further, if new photographs of the Shroud could be made under scientific conditions such that the image intensity could be calibrated in terms of the spectral reflectivity of the image, then this quantity could be determined as a function of cloth-body distance as described in Section II. The implications of this could be far reaching, for then, the spectral reflectivity variation on the Shroud could be tested against those predicted by various theories ranging from Vignon's vaporograph to Ashe's scorch<sup>9</sup> hypothesis and in so doing, inconsistent theories can be eliminated. This would involve nondestructive testing of the Shroud since all that would be required of it is a special photograph. Perhaps one day this can be done and we will be one step closer in understanding the origin of the fascinating image on the Shroud, an image which might even be a key in understanding the phenomenal aspects of Resurrection.

Finally, and perhaps most importantly, comparison experiments similar to those discussed in Section II should be performed to permit point by point distances to be measured between a cloth (of similar fabric to the Shroud) and a human form over which the cloth is draped or closely wrapped according to hypothesis being tested as to the true manner in which the Shroud lay on Christ's body. These experiments, coupled with a known light-intensity/film-opacity

correspondence, would permit a most important relationship to be formed — the relationship between the intensity of staining of the Shroud (as manifested by the amount of light reflected) and the distance between the surface of the Shroud and the physiological features beneath that surface.

Having established this relationship — which embodies spatial light value distortions from the corresponding pattern of light reflection from an undraped human form, it would be possible, to some extent, to compensate the Shroud image for these "grey-shade" distortions and thus create a more natural "photograph-like" representation of the form which lay beneath the Shroud. Similarly, those geometric "profile" distortions brought about by the drape of the Shroud can be corrected by a process similar to one used to eliminate wide-angle lens distortions from satellite mapping camera images. In this process, a known object (the photograph of an undraped human form) is imaged through the distorting system (the photograph of the draped form) and then the changes needed to produce the true image from the distorted image are measured over many small regions which comprise the total image. These connections are then applied to the experimental images (the actual Shroud image) to produce the true image (the "reconstructed" undraped form).

Given the dark/light gray-shade pattern of the Shroud image or of a reconstructed "true human form" image, other patterns can be emphasized by image enhancement techniques. These patterns may yield new insights into the process which formed the image on the Shroud, or to provide evidence in support of hypotheses concerning the image. For example, it is possible to create contour patterns showing clearly all regions of equal light reflection intensity, a process which we have already tried (see Figure 23). Or, it is possible to isolate one range of reflected light intensity values and to highlight this range.

On a smaller-scale level, it is possible to "zoom in" on selected regions of the image and to greatly expand the light/dark gray-shade contrast of such regions to permit the eye to perceive otherwise invisible subtle gray level distinctions. Very often such subtle low contrast regions are additionally degraded by edge blurring, perhaps caused by the inherent edge-blurring properties of the process which formed the Shroud image. If the distorted "softened" edge of a region on the image which is known a-priori to actually have a sharp edge can be measured with good resolution, it is possible to recreate an image with the edge blurring distortion removed or reduced.

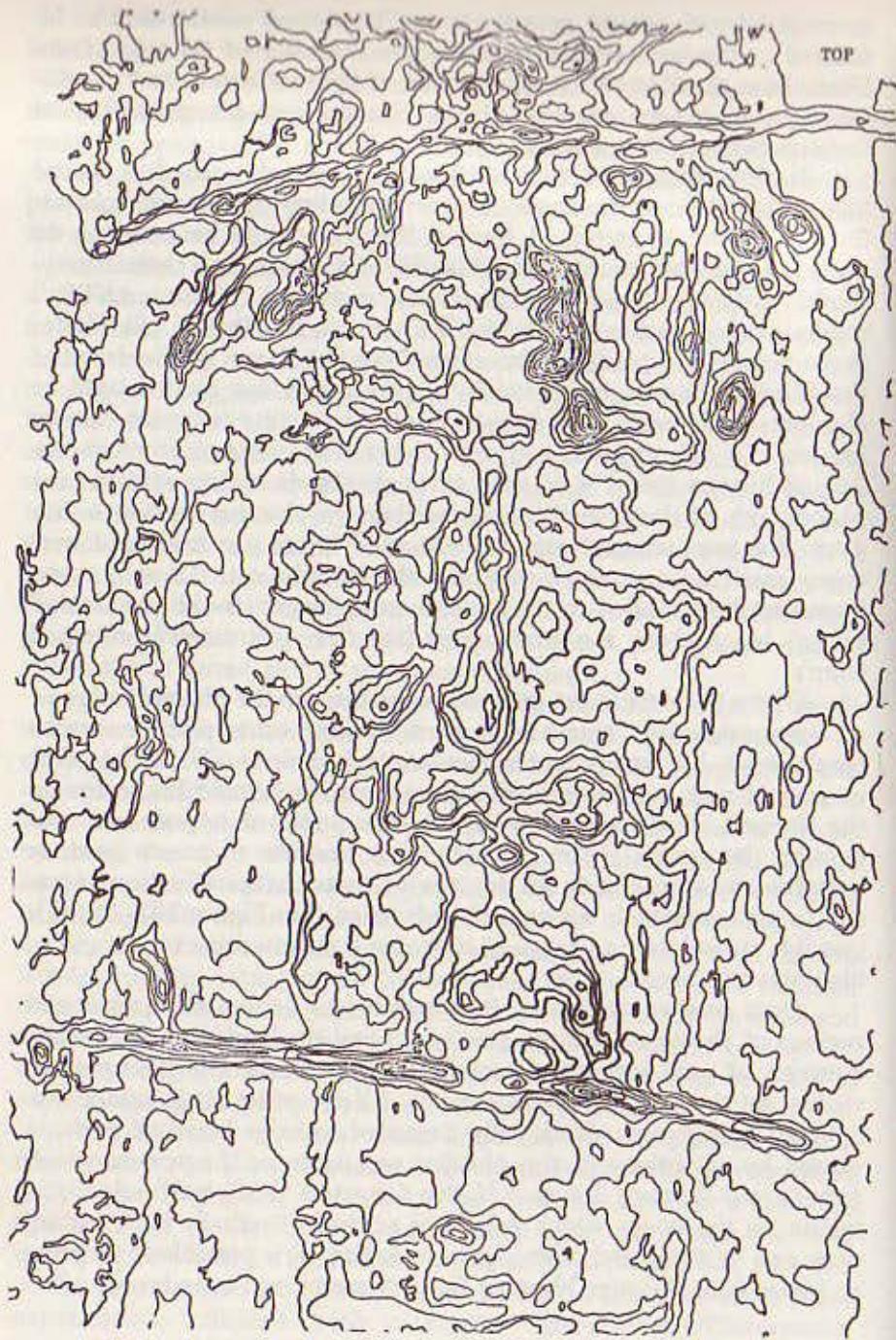


Figure 23. Density contour map of face.

Still another group of image enhancement techniques are available which involve the concept of "spatial frequency" manipulation. These techniques make use of the mathematical fact that any image pattern of dark and light film areas can be created by the super-position of a series of overlapping regular "weavelike" patterns ("reference to weave is in a general sense and not specifically the thread weave of the cloth which of course has a characteristic pattern contributing to the total image.") Each such "weave" consists of a repetitive sequence of dark peaks merging into light troughs which in turn build back to dark peaks. Different weaves have different "frequencies," that is, different distances between adjacent peaks — as well as different "amplitudes," that is, different peak film opacity or density.

It is mathematically possible, in the computer, to determine the weavelike structure which represents the Shroud image and to then modify this structure so as to produce certain results in the visual Shroud image which would be recreated from the modified weave pattern. By this means, for example, it would be possible to eliminate the perhaps distracting texture introduced, in enlarged images of Shroud features, by the weave of the cloth. Since the weave itself is very close to a weave pattern (with a quite small distance between adjacent peaks), the degree of elimination could be quite high. Similarly, the visual impact of large-area blemishes due to water or fire staining could be reduced since such features act like weave pattern with a relatively large distance between peaks.

The above are but a very few of the techniques which could be brought to bear on the enhancement of the Shroud images for both aesthetic and "technical" purposes. They are presented primarily to indicate the potential of this new area of the technology in augmenting the body of detailed knowledge as well as enhancing the visual presence of this most fascinating and awesome relic.

- <sup>1</sup>Produced by Don Bosco Filmstrips — F 13 La Santa Sindone. The authors are grateful to the Holy Shroud Guild for permission to print photos from this copyrighted series.
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- <sup>3</sup>Ricci, Giulio, private communication.
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By Robert D. LaRue, Jr.

Giuseppe Enrie's photographs of the Turin Shroud taken in 1931 have long been standard references for shroud related research. Enrie's photographs, however, are inadequate for today's advanced research techniques. This paper will present the errors that exist in the reproduction of tones in his photos, why they exist, and implications to current research.

In March of 1977, I first saw color transparencies of the Shroud. Having previously seen only reproductions of black and white prints, I was surprised at how faint the image on the cloth appeared. Initially, I thought that the slides may have been overexposed or poorly duplicated. Closer examination revealed detail in the cloth weave that would have been lost by overexposure or washed out by repeated duplication. Why then did the black and white prints show the image in such bold contrast to the cloth? If this effect was due to a tonal distortion of the image by the photosensitive materials employed, how would current shroud research projects be affected?

Since the image appeared to be a reddish-brown color, it seemed possible that Giuseppe Enrie had used orthochromatically sensitive emulsions for the black and white photographs taken in 1931. Orthochromatic emulsions are not sensitive to the color red, so areas of the emulsion exposed to red light will record no exposure. The rust-colored image on the light colored cloth would record on an orthochromatic negative as an almost transparent image against a black background. Prints from this negative would show the image as black against a nearly white cloth background: exactly the appearance of Enrie's photographs.

Enrie's own writings confirmed my deduction that orthochromatic emulsions were used for his 1931 photosession.<sup>1</sup> Enrie



was familiar with its handling and photographic response characteristics. In addition, Panchromatic emulsions — sensitive to all visible colors — were not yet readily available in 1931, and perhaps unobtainable by Enrie. To further enhance the contrast between the off-white cloth and the image, Enrie used a yellow filter for some of his exposures. Such a filter would increase the contrast between the stain and the cloth while eliminating yellows and some browns.

In the official report of the 1969 Turin Commission on the Holy Shroud, the photographer Gian Battista Judica Cordiglia reports that he was surprised to see that his photographs were quite different from Enrie's; "We were astonished to find that the developed picture did not look as if it had been 'engraved' as with Enrie's pictures, but fainter and more diaphanous."<sup>2</sup> Cordiglia's photos did not have the inherent contrast of Enrie's plates because the 1969 photos were taken with panchromatic emulsions, which much more accurately reproduced the full range of tones of the image. Only by contact printing his black and white panchromatic negative on to high contrast photomechanical film was he able to approximate Enrie's results. Cordiglia's original negatives contain far more valuable information for analysis than his enhanced contrast reproductions.

Enrie's use of orthochromatic emulsions produced boldly detailed photos which, for general use and analysis, were extremely valuable. However, the emulsions' inability to accurately reproduce the image's relative tones of red introduced tonal distortions in his negatives. The orthochromatic emulsions recorded the varying tones and densities of the image as essentially only one density on the negative — any red areas would be clear and indicate no density on the negative. Subtle variations of tone apparent in the 1969 color slides are therefore absent in the 1931 black and white photos.

As the analysis methods applied to the shroud become increasingly sophisticated, the tonal errors of Enrie's photos become increasingly significant. In the computer-generated three dimensional reconstructions of John Jackson and Eric Jumper, these errors are particularly important. Using Vignon's hypothesis<sup>3</sup> that the intensity of the image varies inversely with cloth-body distance, and microdensitometer intensity scans of Enrie's photos, Jackson and Jumper were able to quantify the cloth-body distance relationship and as a result construct a surface relief computer image of the body once contained by the cloth. Errors in that relationship may well be present due to the tonal errors in Enrie's photographs. The presence of these errors could greatly change any hypothesis one might make about the process which formed the image.

The use of photographs obtained with panchromatic emulsions would provide a finer, more accurate graduation of tones containing significantly more detailed information for future intensity/cloth-body distance relationship correlations.

Enrie's photos were produced with the latest technology and materials available to him, and have served for nearly forty years as prime research objects for shroud investigators. Photographs from the Turin Commission and those yet to be taken, will provide new sources of information for further research.

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## A PROBLEM OF RESOLUTION POSED BY THE EXISTENCE OF A THREE DIMENSIONAL IMAGE ON THE SHROUD

By John P. Jackson

### Introduction

If the image on the Turin Cloth was not three dimensional, the sharp detail which characterizes the image would present no difficulties.<sup>1</sup> For then, such high resolution could be easily explained as the result of a simple point by point contact transfer between the cloth and body. But, as established in Reference 1, the image is three dimensional and therefore such a "direct contact" mechanism could not have been responsible for generating the Shroud image since (it would seem) the production of the image must have occurred through the space between the cloth and body. This being the case, it now becomes a problem to explain the sharpness of the image. As I will show in this paper, many physical processes which could have discolored the Shroud from a distance (i.e. diffusion, thermal radiation, etc.) degrade resolution of the projected image much too severely to account for the sharpness of the image on the Shroud.

I do not offer any specific theory as to how the Shroud image might have been formed. Rather, my purpose is to evaluate how various "three dimensional" image forming mechanisms affect image resolution. My approach is to examine a class of plausible image formation mechanisms (i.e. those which act through space) by a single, simple model characterized by parameters which can be adjusted to values corresponding to specific image formation mechanisms. I then derive restrictions upon these parameters which must be met in order to explain the observed degree of resolution of the Shroud image. In so doing, those image formation mechanisms corresponding to combinations of parameters which do not meet the calculated criteria I discard from among the possible candidates of three dimensional image formation processes.

### General Model for Image Formation

The class of image generation mechanisms considered in this paper will be that in which particles are emitted in various directions from a Point A on Surface 1, as shown in Figure 1, and then absorbed on Surface 2 at various locations. Surface 1 obviously corresponds to the body surface beneath the Shroud and Surface 2 to the Shroud cloth itself. Depending on the details of the transference of particles between the two surfaces, the distribution of particles on Surface 2 will vary, but the number density on Surface 2 will govern the resolution of Point A on Surface 2.

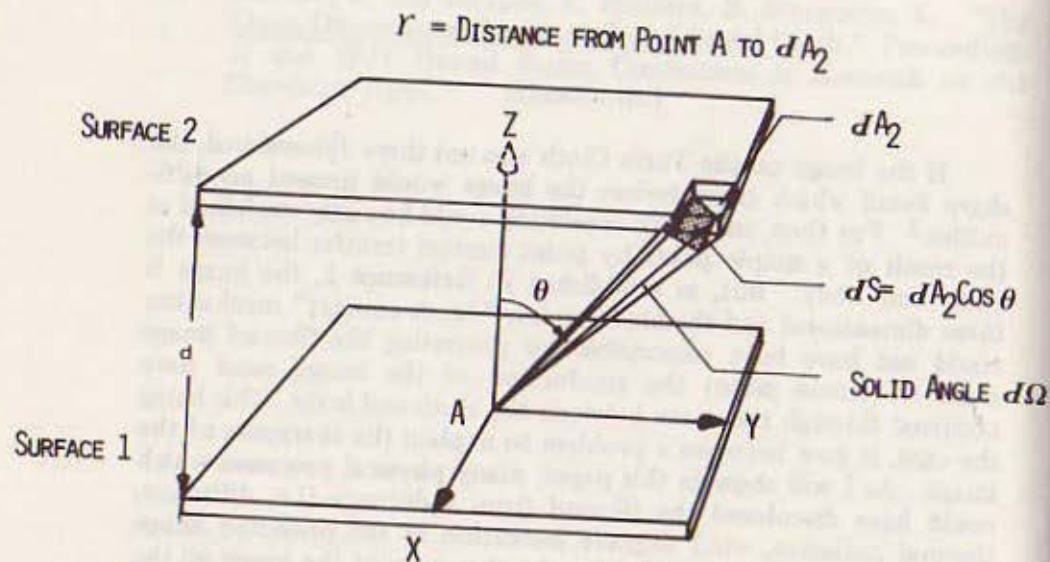


Figure 1. Schematic illustrating the geometric relationships which in the text describe the transfer of particles from point A on Surface 1 to an area  $dA_2$  on Surface 2.

As a generality, the particles emitted from Point A are allowed to be anisotropic, that is, that the degree of emission varies with direction. If a total of  $N_A$  particles are released in a time interval  $\Delta t$ , the number of particles,  $dN_1$ , that go into solid angle  $d\Omega$  are taken to be

$$dN_1 = \left( \frac{m+1}{2\pi} \right) (\cos^m \theta) N_A d\Omega \quad (1)$$

where  $m$  is the index which adjusts the degree of anisotropy\* and  $\theta$  is the angle measured from the vertical of Surface 1 (see Figure 1). Large  $m$  corresponds to most of the particles being emitted upwards.  $m$  equal to zero, on the other hand, corresponds to the dispersion of particles evenly in all directions.\*\* If equation (1) is integrated over the entire solid angle available for emission, a hemisphere of angle  $2\pi$  steradians, then an integration over all solid angles,  $\int_{\Omega} \left( \frac{dN_1}{d\Omega} \right) d\Omega$ , will equal  $N_A$ .

As the particles travel to Surface 2, it might be possible that some are absorbed. To allow for this possibility, a parameter,  $k$ , which governs the degree of absorption (in units of inverse distance) is used. Then, the number of particles passing through the area  $dS$  of Figure 1 is

$$dN_s = dN_1 e^{-kr} \quad (2)$$

where  $r$  is the direct distance between point A and position  $x, y$  on Surface 2.\*\*\* If  $d$  is the separation distance between Surfaces 1 and 2, then

$$r = \sqrt{x^2 + y^2 + d^2} \quad (3)$$

As particles are absorbed on Surface 2, it might be that the absorption coefficient  $\alpha$  (i.e. fraction of particles absorbed) is anisotropic and depends also on  $\theta$ . This possibility is accounted for by assuming

$$\alpha = \alpha_2 \cos^n \theta \quad (4)$$

where  $n$  is the index of absorption anisotropy and  $\alpha_2$  a constant which is less than or equal to unity. Note that high values of  $n$  tend to sharpen the image (even though the emission from Surface 1 may have been totally isotropic,  $m=0$ .)

Thus, the number of particles  $dN_2$  which pass through area  $dS$  and are absorbed on Surface 2 is

$$dN_2 = \alpha dN_s \quad (5)$$

\* The  $\cos^m \theta$  factor is used to express anisotropy since it is a form often found in physical problems. For instance, the limb darkening of the Sun being the result of anisotropic emission of radiation is expressed via a  $\cos^2 \theta$  term.

\*\* In a sense, molecular diffusion corresponds to the case  $m=0$  since, even though particles do not travel in straight line paths, diffusion of  $N_A$  particles from a point source produces an isotropic distribution of particles at all later times.

\*\*\* This equation is used to express particle absorption since it is used very often in physics, for example in attenuation of radiation.

Now, if  $n_2(x,y)$  is the number of absorbed particles per unit area on Surface 2, then by definition

$$n_2 = dN_2/dA_2 \quad (6)$$

where  $dA_2$  is the projection of area  $dS$  onto Surface 2 given by

$$dA_2 = dS/\cos \theta \quad (7)$$

Combining Equations (2), (4), (5), (6), (7) and the definition of a solid angle,

$$d\Omega = dS/r^2 \quad (8)$$

the following relation for  $n_2(x,y)$  results,

$$n_2(x,y) = \left( \frac{m+1}{2\pi} \right) \alpha_2 (\cos^m \theta)^{n+1} N_A e^{-kr/r^2} \quad (9)$$

But from geometry,

$$\cos \theta = d/r \quad (10)$$

so,

$$n_2(x,y) = \left[ \frac{(m+1) \alpha_2 N_A d^{m+n+1}}{2\pi} \right] \frac{e^{-kr}}{r^{m+n+3}} \quad (11)$$

and the total number of particles,  $N_2$ , found on Surface 2 must be

$$N_2 = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} n_2(x,y) dx dy \quad (12)$$

Thus, the probability of a particle absorbed on Surface 2 being found in the region  $x$  to  $x+dx$  and  $y$  to  $y+dy$  is

$$f(x,y) dx dy = n_2(x,y) dx dy / N_2 \quad (13)$$

Thus,

$$f(x,y) = C e^{-kr/r^{m+n+3}} \quad (14)$$

where

$$C = (m+1) \alpha_2 N_A d^{m+n+1} / 2\pi N_2 \quad (15)$$

is a normalization constant.  $f(x,y)$ , then, may be considered to be a sort of "probability image" of Point A of Surface 2.

### The Condition For Resolution

Consider now two identically emitting points on Surface 1, Points A and B, which are separated by a distance  $D$  along the  $x$ -axis with their midpoint at  $x=0, y=0$ . The combined "probability image,"  $f_{AB}(x,y)$ , of these two points on Surface 2 would be given as a superposition of two individual point probability functions  $f(x,y)$  each like that of Equation (14),

$$f_{AB}(x,y) = 1/2 [f_A(x,y) + f_B(x,y)] \quad (16)$$

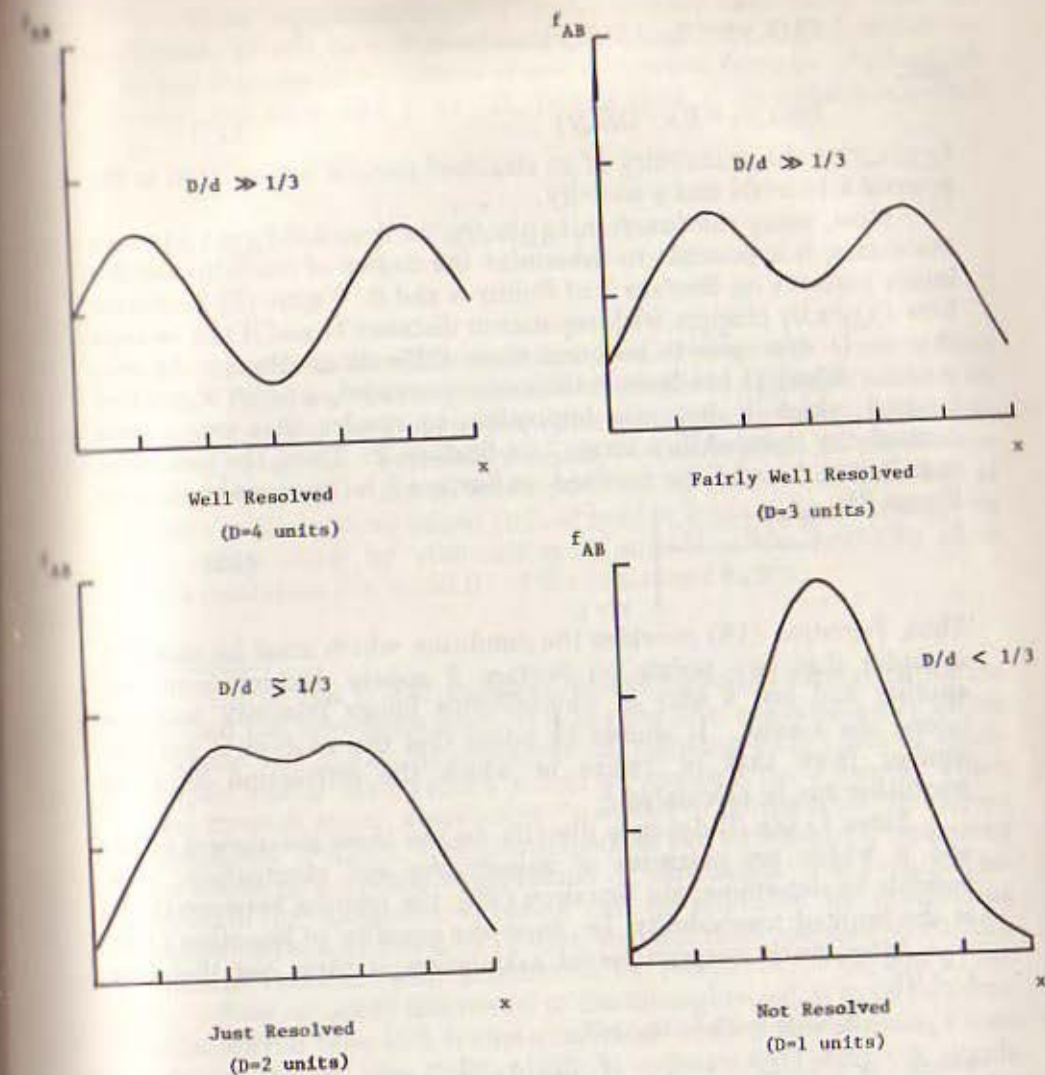


Figure 2. Diagram to show how the probability image  $f_{AB}(x,0)$  on Surface 2 varies with separation distance  $D$  between points A and B on Surface 1. Limit of resolution of points A and B on Surface 2 occurs when  $D = 3d$  (see text). At  $D/d = 1/3$ , the second derivative of  $f_{AB}$  at  $x=0$  is equal to zero.

where:

$$f_A(x,y) = f(x + D/2,y)$$

and:

$$f_B(x,y) = f(x - D/2,y) \quad (17)$$

$f_{AB}(x,y)$  is the probability of an absorbed particle being found in the interval  $x$  to  $x+dx$  and  $y$  to  $y+dy$ .

Now, using the function  $f_{AB}(x,0)$ , the function  $f_{AB}(x,y)$  along the  $x$ -axis, it is possible to determine the degree of resolution of the image patterns on Surface 2 of Points A and B. Figure (2) illustrates how  $f_{AB}(x,0)$  changes with separation distance  $D$  and it can be seen that as  $D$  decreases it becomes more difficult to discern the two points. When  $D$  has been sufficiently decreased, a point is reached beyond which it becomes impossible to resolve that two points formed the "probability image" on Surface 2. Thus, the condition that Points A and B be resolved on Surface 2 is (by consideration of Figure 2):

$$\left. \frac{d^2 f_{AB}(x,0)}{dx^2} \right|_{x=0} \geq 0 \quad (18)$$

Thus, Equation (18) provides the condition which must be satisfied in order that two points on Surface 2 appear distinct from one another and not a blur of unintelligible image intensity patterns (along the  $x$ -axis). It should be noted that this analysis is not dissimilar from that of optics in which the diffraction limit of resolution can be calculated.<sup>2</sup>

Since  $f_{AB}(x,0)$  depends directly on the three parameters  $n$ ,  $m$ , and  $k$  which are measures of anisotropy and attenuation, it is possible to determine, via Equation (18), the relation between them at the limit of resolvability, i.e. from the equality of Equation (18).

After much straightforward calculation, it turns out that (for  $k > 0$ ),

$$k = -b + \sqrt{b^2 - 4a} \quad c/2a \quad (19)$$

$$\text{where } a = \left(\frac{D}{2r_0}\right)^2 \quad r_0 b = \left[ \frac{2(m+n)+7}{4} \right] \left(\frac{D}{r_0}\right)^2 - 1 \quad (20)$$

$$c = \left(\frac{m+n+3}{r_0^2}\right) \left[ \frac{(m+n+5)}{4} \left(\frac{D}{r_0}\right)^2 - 1 \right] \quad r_0 = \sqrt{\left(\frac{D}{2}\right)^2 + d^2} \quad (22)$$

$$(23)$$

These equations simplify under certain conditions. On the Shroud, as will be explained and quantified later, I find certain resolved features of separation  $D$  and distance  $d$  from the cloth which satisfy the inequality  $d \gg D$ . In that limit, these equations reduce to

$$k \approx \frac{r_0}{D^2} \left[ 4 - \left(\frac{D}{r_0}\right)^2 (\ell + 4) \right] \quad (24)$$

with the additional restriction that  $\ell \ll 4 \left(\frac{r_0}{D}\right)^4 - \frac{11}{4}$ , a very large value.\* Equation (24) expresses the fact that  $k$  decreases as  $\ell$  increases because, as  $k$  decreases, there would be no need to attenuate the edges of the "probability image" of each point as much since with large  $\ell$  not as many particles are emitted or absorbed at angles to form those edges; and, of course, it is necessary to suppress the edges either by attenuation or anisotropy (or both) to allow high resolution (i.e. small  $D$ ) of the two image points.

### Discussion

Up to this point, a general model for image formation on the Shroud has been presented. It is not the only one which may be envisioned but it has the advantage of assessing what kinds of anisotropies and/or attenuations would be required for a process which acts through space, distributing "particles of information" in various directions. Further, various mechanisms can be selectively examined by choosing a specific combination of parameters. For example, resolution by molecular diffusion can be estimated by considering values of  $(m,k,n)$  equal to  $(0,0,0)$ , thermal radiation also by  $(0,0,0)$ , thermal radiation with attenuation by  $(0,k,0)$  ( $k > 0$ ), and so on.

Now, to apply this model to the Shroud image, it must be determined what ratio  $D/d$  is characteristic of it. For this purpose, I have chosen the lip area from which to estimate this ratio. A simple measurement of the distance between the two lips (which are easily resolved on the Shroud) gives a value of  $D_{lips} \approx .4$  cm. The fact that the lips lie well below other features on the Shroud's three dimensional facial image, for example the nose, implies that the lips could not have been touching the Shroud (reference 1). This fact was also confirmed by the placing of a cloth model of the Shroud over a

\*  $\ell = m + n$

volunteer subject, as described in Reference 1, and then measuring the resulting value of  $d_{lips}$  to be 1.1 cm. Thus the ratio  $D/d_{lips} = 1/3$ .\*

### Conclusions

Given this value for  $D/d$ , it is possible to determine the required values of  $m, n$ , and  $k$ . These are plotted in Figure (3) via Equation (24).

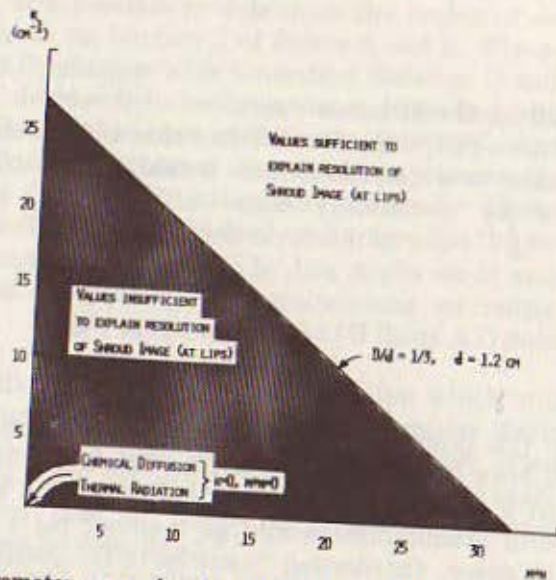


Figure 3. Parameter space showing what values of  $k$  and  $m + n$  are required to explain resolution of Shroud image.

For most of the curve, the attenuation  $k$  is greater than  $10 \text{ cm}^{-1}$  even as high as  $25 \text{ cm}^{-1}$  for small values of the anisotropy parameters  $m$  and  $n$ . Such values must therefore be considered in order to explain the degree of resolution of the Shroud image within the context of the model presented in this paper. But it would seem, from the work that my colleague, Eric Jumper, and I did in characterizing image in-

\* This value is probably an upper limit.  $D_{lips}$  should really be evaluated at the limit of resolution, which is definitely not the case for the images of the two distinct lips. Thus,  $D_{lips}$  must actually be smaller than the .4 cm given above. Also,  $d_{lips}$  is probably even greater than the measured 1.1 cm since the volunteer subject had no beard which would have elevated the cloth higher.

tensity versus cloth-body distance (Reference 1), that  $k$  should not exceed 1 or  $2 \text{ cm}^{-1}$ . Thus, I must conclude that models with little or no anisotropy, such as molecular diffusion or unattenuated thermal radiation, cannot be responsible for the image on the Shroud. In the small domain where  $k$  is acceptable, i.e. on the order of 1 or  $2 \text{ cm}^{-1}$ , the anisotropy parameter  $m+n$  would have to be on the order of 25 or greater. That is, the combined effects of both emission and absorption anisotropies would have to explain an extremely high anisotropy by a term  $\cos^{25} \theta$  which appears in Equation (9). Further, if the anisotropy of emission was too great, then other problems arise, for instance in the nasal region, since it would be then impossible to account for the production of an image directly above the "sides" of the nose which slant at relatively large angles from the horizontal. It would seem that the image of the nose would then appear much too wide and deformed on the Shroud image.

In view of the fact that actual required attenuations or anisotropies are probably even greater than those discussed above (because  $D/d_{lips}$  is probably smaller than  $1/3$ ),\* I am forced to conclude that

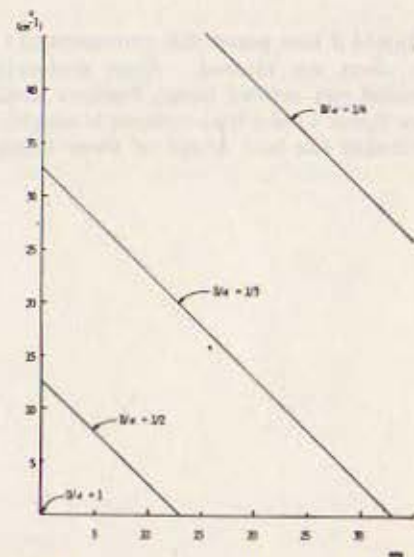


Figure 4. Sensitivity to the ratio  $D/d$  of line separating those values of  $k$  and  $m + n$  which are required to explain resolution of Shroud image from those which do not.

\* Figure (4) shows graphs of  $k$  versus  $m+n$  for various values of  $D/d$ . It is apparent that a given curve can be shifted upwards quite significantly for only modest decreases in the ratio  $D/d$ .

any reasonable physical mechanism which can be approximately treated by a combination of parameters (m,k,n) of my model classification scheme cannot simultaneously produce a three dimensional image and an image of high clarity as is the Shroud image.† This, I believe, eliminates simple molecular diffusion and thermal radiation (as proposed by Ashe)<sup>3</sup>, as possibilities of Shroud image formation.\*

I am not prepared to offer any alternative hypothesis at this writing, but it would seem that one significantly different than the category of those investigated here needs to be considered. But, to be successful in understanding how the Shroud image was formed, more research must first be conducted. Until then, its origin will probably remain a scientific puzzle.

\* However, Ashe's view that the image is the result of a scorch is not necessarily incompatible with this result because mechanisms other than isotropic thermal radiation could scorch cloth.

† Using Janney's figure 3 (see paper this proceedings) I have calculated that features smaller than .6cm are blurred. Since molecular diffusion/thermal radiation processes should not resolve image features smaller than cloth-body distance separation (see figure 4) and that distance is roughly 1cm, then Janney's blurred image approximates the best image of these image forming processes.

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# AN ELECTRONIC TECHNIQUE FOR CONSTRUCTING AN ACCURATE THREE-DIMENSIONAL SHROUD IMAGE

By John D. German, Jr.

In their paper entitled, "The Three-Dimensional Image on Jesus' Burial Cloth," which was presented at the Albuquerque conference and is included in these proceedings, Drs. Jackson, Jumper, Mottern and Stevenson discuss two interesting aspects of analyzing the shroud image. The first is a technique for generating a three-dimensional television image of the man of the shroud by using a Model VP-8 Image Analyzer manufactured by Interpretation Systems Incorporated. The second, which resulted from analysis of that three-dimensional image, is the empirical relationship between the image intensity and the cloth-body distance. The curve describing that relationship is reproduced here as Figure 1.

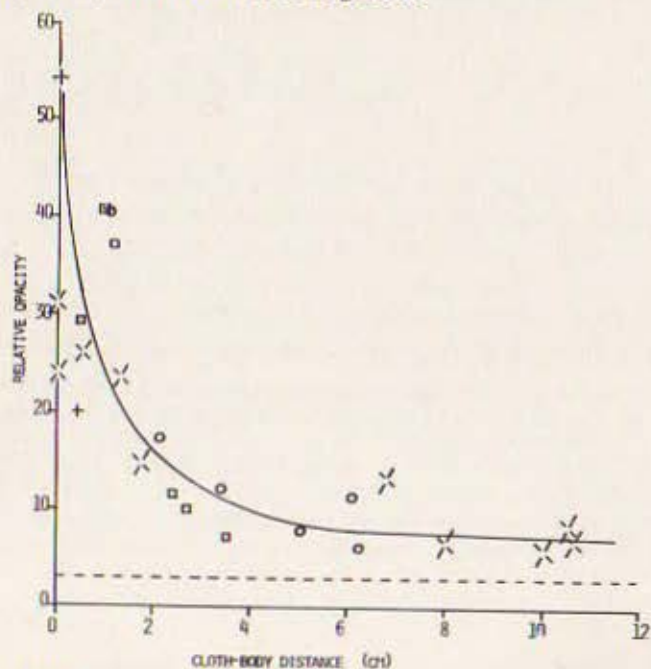


Figure 1. Relative opacity of the photographic negative of the shroud versus cloth-body distance.

The nature of this relationship revealed an important source of error inherent in the construction of the three-dimensional image of the shroud. The image on the cloth was formed by a process that resulted in a non-linear relationship between the image intensity and the cloth-body distance. The image analyzer system, however, creates a three-dimensional image for which the relief (analogous to cloth-body distance) varies linearly with the intensity. The practical result of this linear relationship is that the image is distorted. If the gain (amount of relief) is reduced to produce an image with a realistic nose and forehead, the fainter portions of the image corresponding to large cloth-body distances have little or no relief. On the other hand, if the gain is increased to bring out these fainter portions of the image, the nose and forehead grow way out of proportion.

The purpose of this paper is to discuss a technique for eliminating this distortion and thereby producing a more accurate three-dimensional image. The technique involves a system that electronically transforms the linear image intensity versus relief characteristic of the image analyzer to a non-linear characteristic that corresponds to the actual image intensity versus cloth-body distance relationship. This system is called the transfer function generator.

A diagram of the transfer function generator is shown in Figure 2. It consists of two video-frequency operational amplifiers connected to a number of resistors, diodes and external bias voltages. The first amplifier, labeled op amp A, inverts the video signal coming directly from the television camera control system and multiplies it by a factor of ten to put it within the range of the adjustable diode bias voltages at the input of the second amplifier. The gain characteristics of the second amplifier, called op amp B, can be adjusted to produce any desired transfer function by a technique called piecewise linearization: approximating a curve by a series of straight lines. Before describing the details of circuit operation, let me discuss the transfer function that is necessary in this case.

The equation that best describes the image intensity versus cloth-body distance curve is

$$\text{Relative Opacity} = 9 + 46 e^{-1.03d} \quad \text{Equation 1}$$

where  $d$  is the cloth-body distance in centimeters. Since the television camera produces maximum signal for maximum transmittance of the photographic negative, the equation of interest must relate transmittance,  $T$ , to cloth-body distance,  $d$ . This equation is

$$T = .91 - .46 e^{-d} \quad \text{Equation 2}$$



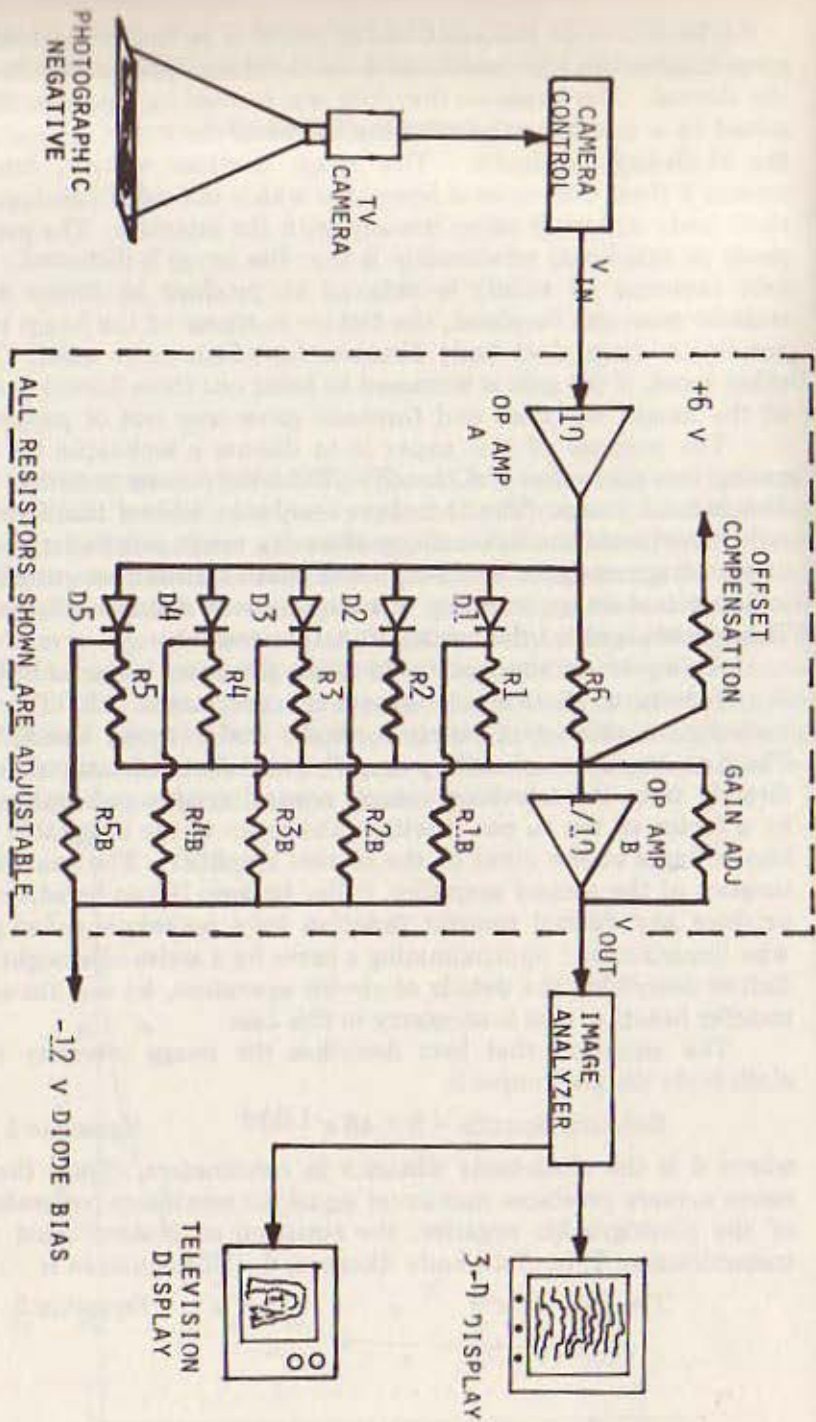


Figure 2. Diagram of the image analyzer system with the transfer function generator installed. The transfer function generator is enclosed by the dashed line.

When this is combined with the linear intensity versus transmittance characteristics of the television camera, the required relationship between the input voltage,  $V_{in}$ , and the output voltage,  $V_{out}$ , becomes

$$V_{out} = 0.64 (1 - e^{-23.2V_{in}}) \quad \text{Equation 3}$$

This relationship shown as the solid line in Figure 3 is the transfer function that must be approximated by the piecewise linearization technique. Intuitively, this curve seems to be of the correct shape. For small values of input voltage, which represent low image intensity levels, comparatively large values of output voltage occur. For larger values of input voltage, the resulting gain is much lower. The effect of this transfer function will be to greatly increase the relief of the points with a low image intensity relative to the points having a high image intensity, i.e. increase the relief of the eyes and cheeks while suppressing the relief of the nose and forehead. This is exactly what is needed.

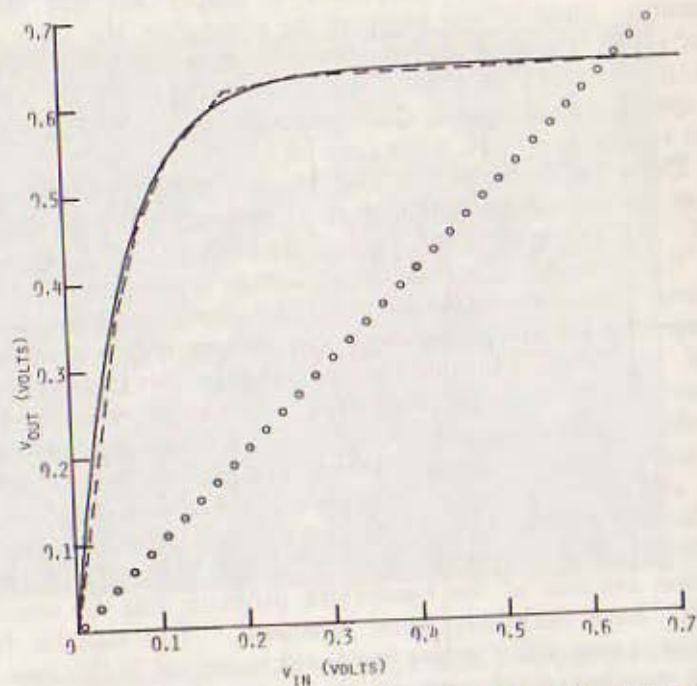


Figure 3. Transfer functions for a video signal of 0-0.7 volts. The straight dotted line is the original transfer function between the TV camera control unit and the image analyzer. The solid line is the transfer function necessary to produce a correct 3-D shroud image as specified by Equation 3. The dashed line is the actual transfer function produced by the transfer function generator.

The generation of a transfer function by piecewise linearization with an operational amplifier is accomplished by causing the gain of the amplifier to change at certain selected values of input voltage. These values are called break points and can be seen in Figure 3 as noticeable bends in the dashed line. The gain of an operational amplifier is simply the ratio of the feedback resistance to the input resistance. If the input resistance can be increased as the input voltage increases, the gain will decrease. This is the function of the diodes shown in Figure 2. Each diode is forward-biased by a negative voltage applied through resistors R1B through R5B. With the input voltage to op amp B between 0 and -0.62 volts, all the diodes are forward biased, the effective input resistance is the parallel combination of R1 through R6, and the gain is a maximum. When the input voltage to op amp B is between -0.62 and -0.80 volts, diode D1 becomes reverse-biased, R1 is removed from the parallel combination making up the input resistance, and the gain decreases slightly. This process continues until, for op amp B input voltages greater than -2.76 volts, the input resistance is simply R6 and the gain is minimum. Since all the resistors are adjustable, the gains and break point voltages can be set to any desired value. The "gain adjust" control is used to produce a maximum output voltage of 0.7 volts and the "offset compensation" control is used to remove a slight dc offset voltage produced by the diodes.

The preliminary results of correcting the image intensity distribution with the transfer function generator are shown in Figures 4 and 5. Although there is a noticeable degradation in picture quality with the transfer function generator in operation due to some problems with the bandwidth of the operational amplifiers, the photographs definitely show that the generator is performing as designed. In Figure 4, notice that with the transfer function generator in operation, the relative height of the nose, brow and cheekbones are reduced while the hair, hollows of the cheeks and bridge of the nose are brought out more. Shown in Figure 5 are photographs of black and white television pictures of the photographic negative of the shroud with and without the transfer function generator in operation. There is some loss of detail with the generator in operation because of the bandwidth problem, but the areas of low intensity have definitely been increased. The transfer function generator is essentially analog image enhancement in this case.

In conclusion, the use of the transfer function generator to compensate for cloth-body distance has enabled us to construct a much more accurate and realistic three-dimensional image of the man of the shroud. The reduction in image quality caused by the bandwidth problem should be easily corrected; we are currently working on solving this problem.

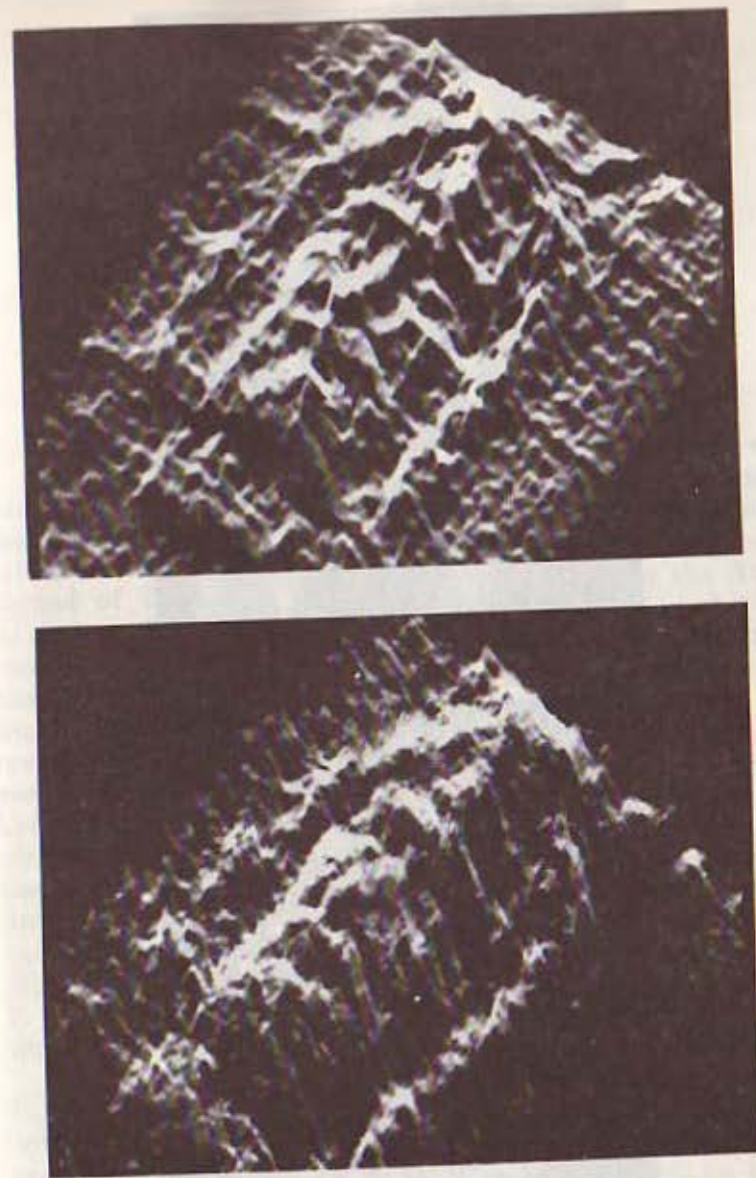


Figure 4. Three-dimensional image of the face. The top photograph is the best image obtainable without the transfer function generator. The bottom photograph represents the preliminary results of image correction with the transfer function generator.

By Kenneth E. Stevenson

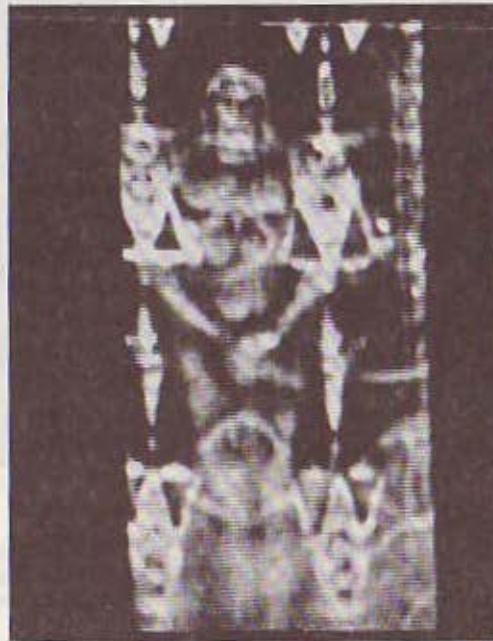
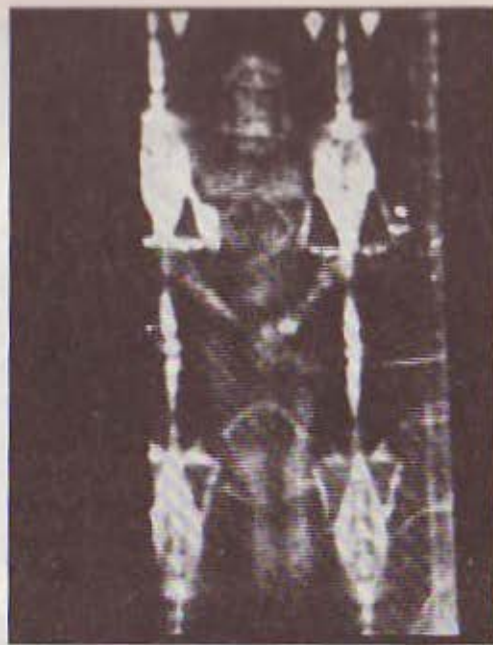


Figure 5. Television picture of the front shroud image. The top photograph was taken without the transfer function generator in operation. The bottom photograph is the preliminary result of analog image enhancement with the transfer function generator.

Normally every editor makes his glowing comments about a written work at the beginning of that work; however, considering the very sensitive nature of these proceedings, I have purposefully held off until the end. About ten years ago, I was introduced to the Shroud of Turin at a Catholic Discussion group at the Air Force Academy. Since I did not really know the Lord at that time, I mentally filed the interesting new information away for future reference. Some three years later when I met the Lord, I immediately began looking for information on what was by then only a dimly remembered lecture. I was appalled to find that almost no one had ever heard of the Shroud other than as some vague relic of the Catholic Church. It Is The Lord, by Peter Rinaldi, filled in the gaps somewhat and proved a useful vehicle for introducing the Shroud to the uninitiated, but it was all that I could find. At no time did I ever dream that I would have the opportunity to study in detail the exciting research in these proceedings, let alone to help to compile them! Indeed I am forever indebted to Drs. Eric J. Jumper and John P. Jackson for the privilege of editing these proceedings. It is a singular honor that I'll dearly cherish. But there is more.

In the past six months I have without a doubt witnessed the Hand of the Lord at work in a very real way. In fact, just the way in which so many different papers from various authors complement each other is unusual to say the least. Men from several denominations, myriad backgrounds and two different continents have combined their efforts in an attempt to bring the Shroud out of obscurity and into the public eye. Time, money, equipment and expertise have been volunteered in an unprecedented way. All along the way, people have responded with enthusiasm to the entire project as if it were their own.

In fact, the project has broken down many barriers. Non-believers have trod enthusiastically in the footsteps of Delage seeking the truth of the Shroud. Protestants and Catholics have put aside their differences and stood together in awe before this Holy Relic. And as more people are blessed or troubled by the mysteries of Christ's passion, death and resurrection as displayed on a linen cloth, the words of the apostle Paul before King Agrippa become strikingly appropriate.

"None of these things are hidden from him; for this thing [Christ's Passion, death and resurrection] was not done in a corner." (Acts 26:26) Indeed the Gospel is not hidden in a corner, for the Shroud bears evidence which demands reflection for believer and non-believer alike!

All has not been roses however, and I would be remiss if I didn't include both sides of the story. In the unfolding of the history of this relic, men have been overly pious or zealous, arbitrary, dogmatic, selfish, secretive and unfair. As a result, the Shroud and its supporters have been maligned and ridiculed.

Between the covers of this book authors have taken varying viewpoints but hopefully for the first time in its history none of these will become the be all and end all for the Shroud. We must not allow that to happen. But there is a dilemma here. How can we sanction all viewpoints and yet arrive at the one truth?

God's word gives us an answer:

". . . If this counsel or this work be of men, it will come to nought: But if it be of God, ye cannot overthrow it; lest haply ye be found even to fight against God." (Acts 5:38-39)

In our study if we allow all the right to their opinions and theories — with an eye for the protection of the Shroud — and if we in prayerful faith allow those theories to be objectively, scientifically and faithfully carried out in non-destructive experimentation, God will take care of the rest.

What then is my purpose? — To show that all of these papers have a common goal — To overcome the handicaps imposed by 2000 years of obscurity and controversy — To bring the Shroud and with it the Gospel to the world! We already have seen the impact the Shroud has on all who are exposed to its mysteries. Authentic passion relic or exquisite forgery, the Shroud demonstrates to all ". . . what is the breadth and length, and depth, and height; . . . [of] the love of Christ, which passeth knowledge." (Eph. 3:18)

Therefore, since the Gospel is not a belief in a cloth, but in the person of Jesus Christ and His vicarious sacrifice, anything that lends evidence to or just sheds light on that sacrifice is powerful indeed.

St. Paul also said, "I am not ashamed of the Gospel of Christ; for it is the power of God unto salvation to every one that believeth." (Romans 1:16) We, like Paul, must be bold; we must hold up for the world to see, the evidence of the God-man, Jesus Christ!

Even if the outcome of our research leaves unanswered questions, or gives unwanted answers, the world, "[seeing our] boldness and perceiv[ing] that [we are] unlearned and ignorant men, [will] marvel; and . . . [take] knowledge of [us] that [we] have been with Jesus." (Acts 4:13) Maranatha.