IN ANTICIPATION OF CARBON 14 DATING OF THE SHROUD OF TURIN

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At last the samples have been taken

The Shroud of Turin was removed from its reliquary on 21 April 1988 in order to take a cutting for radiocarbon dating. Three laboratories — Oxford, Zurich and Tucson — are therefore in possession of samples, and it is foreseen that the result could be known before the end of the year. A little more patience, then, and the long wait of more than 30 years, when dating by the carbon 14 method was first proposed, will end at last.

The news that this operation was imminent came in a press release published in London last January after a meeting of representatives of the three laboratories with Professor Luigi Gonella, to whom Cardinal Ballestrero had given the responsibility of supervising the scientific research on the Shroud, and Dr. Michael Tite, conservator at the British Museum, which is coordinating the carbon dating project. These laboratories were among the seven represented at the Turin meeting in the autumn of 1986.* At that time, it was agreed to propose a special protocol for the submission of the sample and the publication of the result. The final decision of the authorities responsible for the Shroud was to offer the analysis to only three of the seven, chosen primarily for their greater experience in the application of radiocarbon to archeological objects.

The waiting was well-justified

Until the end of the 1970s, it was obviously out of the question to proceed to this analysis, for several dozens of square centimeters of this precious cloth would had to have been cut away in order to produce about one gram of carbon, the amount needed to furnish the counters of C14 radioactivity and obtain a sufficiently accurate result. In 1970, it was announced that the same result could be obtained with a new technique having the advantage of using only a few milligrams. From then on the question of dating the Shroud was under serious consideration, but until 1985 it was necessary to curb the impatience of many people, especially the first physicists who had offered their services. In fact, this new method of radiocarbon

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*Dr. Evin was a member of that commission: see *Spectrum* #21, p. 21. He also participated in examining the Shroud on April 21 when threads were removed for the carbon 14 dating. ED.

analysis, called "accelerator method" or AMS process (Accelerator Mass Spectrometer), still had to prove itself and demonstrate that it could be routinely utilized with results equivalent to those obtained by the conventional counting method. There was nothing surprising about this waiting period, for in the methodology of analysis, it is common practice that a certain lapse of time should be allowed to pass between the first experimental results of a new method of analysis and putting it into routine operation; for bringing its technical details to perfect adjustment only progressively permits its use in routine work. Therefore one had to be certain that control of these particular accelerators was assured and that the laboratory personnel had published lists of their results obtained on divers types of samples measured also by the conventional method.

An analysis finally technically possible

This certainty was acquired at the International Radiocarbon Congress at Trondheim in August 1985. On that occasion, several laboratories reported on their performances of the accelerator technique in archeology and gave lists of dates which established that this control was at last achieved on very small samples. An account was even given of an intercomparison test on analyses of fabrics aged from 1000 to 2000 years, performed by six laboratories surely having in mind the prospect of a future dating of the Shroud. Thus the Trondheim meeting gave assurance that cloth from the Shroud would not be used as an experimentation or demonstration sample, and furthermore that its analysis by the AMS method would be *a priori* indisputable.

It must be pointed out that this long waiting period was beneficial, because it was thus possible, in the C14 technique, to avoid errors made in some other techniques in their application to the Shroud. In fact, in some cases conclusions had been drawn which afterwards were shown to be too hasty or partially erroneous, because the conditions of the use of the methods were poorly known or had not been properly respected. Lively polemics resulted, as well as a general impression of suspicion about some of the scientific studies made on the Shroud since 1973. One hopes that this prudence in the application of radiocarbon will stand as a good example of rational utilisation of a scientific method inspiring great confidence in its result.

The application of a well-known method

If there was such a long wait for the use of carbon 14, it is because both the method and this cloth are very well known, by scientists — especially archeologists — as well as by the general public. This common knowledge of the method is thanks to the simplicity of its principle and the dependability of its results. Almost all the chronology of the Prehistory of Modern Man, from the end of the Paleolithic to Protohistoric, is established on this method.

Radiocarbon is considered so reliable that it is used to appraise archeological objects of recent date, as is now the case of the Shroud. Furthermore, the principle and the application of the method are easy to explain. To calculate the age of a carbonized material, only two fundamentals need be stated:

1. One simply measures the sample's radiocarbon content;
2. The material must have been previously purified in order that only the carbon that it had in its original composition will be extracted.

These two statements are developed in the two following sections; they are essential for understanding the application of the radiocarbon method to the dating of the Shroud of Turin — an ordinary carbonized vegetable material, but charged with a long history.

The Origin of Carbon

The carbon 14 method was discovered by the American W.F. Libby near the end of the 1940s. He demonstrated the fact that all the molecules carbonized in exchange with atmospheric carbonic gas, contain not two kinds of carbon (carbon 12 and carbon 13), but a very minute proportion of a third kind: carbon 14. This carbon isotope has two peculiarities: first, it forms continuously in the carbonic gas [carbon dioxide] that we breathe and from which plants (thus, flax) form their cells; and second, it is radioactive, that is, at the end of a certain time after its formation each atom of carbon 14 decays spontaneously, emitting a little ray. The principle of the method is thus conceived: as long as an organism is living, it renews its molecules thereby maintaining a constant amount of carbon 14, but as soon as it dies, this amount decreases progressively. Physicists have calculated that dead carbonized materials lose half of their C14 population every 5,570 years. Consequently, one simply has to measure how much of this decrease has taken place to calculate the length of time which separates us from the death of the organism and thereby date, for example this or that archeological layer by the charcoal it contains or this Shroud by the flax of which the fabric was made.

But in their different strata, these organic materials, fossils, could have undergone many vicissitudes. The worst to be feared outside of course of the total loss of carbon, which would render dating impossible — is the secondary deposit of carbon. There are many ways that this can happen, for carbon is present in various chemical forms which, in solution or as fine dust, can impregnate archeological objects. The task of the laboratory before measuring the residual quantity of carbon 14, is to subject the samples to be dated to chemical treatments which eliminate these secondary deposits by different dissolvent processes. However, the influence of contaminants should not be exaggerated for the cleansing methods are very efficient and it is very well known how to clean vegetable materials, for example by extracting their cellulose. Besides — and this is often forgotten — , the greater the difference in age between the contaminant and the material contaminated, the weaker is the influence of the contaminant. Imagine then a cloth about two thousand years old; if it is contaminated by contact with an oily liquid some two or three centuries after its formation, the modification in the age will be slight, and even so much the weaker because, after many centuries, the weight of the remainder of the contaminating liquid will be very weak in comparison with that of the vegetable fibre itself. Thinking then of the Shroud of Turin, one supposes that it has been sheltered from significant contaminations over the centuries. Dust and pollens and even perspiration could certainly have come upon it whenever it was displayed in the open air, but these types of contaminants contain very little or no carbon. Besides, we know that since the middle of the XIVth century, the Shroud has been enclosed in a chest almost all the time, as the remarkable state of conservation of the ensemble of the fabric attests. If some carbon particles had been added by the fire of 1532 in the areas reached by carbonization, all the rest of the cloth is intact, and threads were removed precisely from an unaffected area. Thus, one cannot pose the question of contamination of the object without quantifying its influence. Fortunately, on the multiple samples which have been dated by the radiocarbon method, experience shows that the influence of contaminants is rarely perceptible provided that the laboratories have carried out the normal pretreatments. It goes without saying that this will be done in the case of the Shroud which, although from the physical or chemical point of view can be considered an ordinary sample, yet it should more properly be regarded as exceptionally well-preserved in comparison with many other objects found in excavations and for which the C14 date is entirely satisfactory.

This is also the moment to dispose of all kinds of hypotheses about possible outside influences; of magnetism, of perturbation by the radiation of different instruments used in the examination of the fabric, the isotopic fractionation of various origins that some people have imagined.... All these suspected physical actions can have no influence whatever on the structure of the material and are quite incapable of transforming the nuclei of the carbon atoms of the flax.

The analysis procedure

Radiocarbon dating of the Shroud is therefore possible by the application of this simple method to that sample which, all things considered, is ordinary datable material. One might ask why this operation was not adopted sooner. The only reason, already briefly mentioned, was because of the quantity of carbonized material necessary for the analysis. Certainly, there could be relatively quite a lot of carbon 14 in the organic tissues of materials dating from one or two millennia, but this radiocarbon content, even at its maximum value, is extremely low; there is only about one C14 atom for 10^{12}

atoms of C12, that is, less than one in a trillion. One can understand how difficult it is to detect the C14 and, even more, its variants. To mitigate the inconvenience of such a feeble content of this isotope, physicists had to develop extremely sensitive apparatuses.

Since the 1950s, there have been counters capable of detecting the decay of the C14 atoms one by one, and this technique is still used for 90% of the samples analysed at present. The very scant quantity of carbon 14 decaying in a few hours and the minimum energy of each decay required that the equipment should be extremely sensitive and particularly stable. These are the proportional counters (a kind of Geiger counter) or scintillation counters. But even with these delicate instruments, one comes up against another difficulty: the random character of the radioactive phenomenon. In fact, according to the laws of statistics, in order for a radiocarbon analysis to be sufficiently precise, it is necessary that a relatively large number of decays be detected, and therefore one must start with a rather important quantity of carbon. In practice, several grams of carbon are used and the counting runs from two to three days. But if, instead of several grams, one has at his disposal only a few milligrams to treat, the time of counting must be considerably lengthened. Some laboratories were able to miniaturize the sample to only ten milligrams, but the measuring took more than a month. These analyses are so difficult that they cannot be considered for routine procedures. They could not be applied to the Shroud unless the burned parts of the fabric were used, entailing excessive risks and delays in the analysis. In fact, it is impossible to use the radioactive detection method as a practicable way to date samples of a few milligrams, the maximum amount allowed to be removed from the Shroud. These technological obstacles were surmounted by the discovery of another procedure.

The method proposed in 1978 and standardized in regard to routine counting a few years later, involves the use of machines which do not detect the atoms by their radioactivity but which separate them by their difference in mass: these are in fact powerful separators of isotopes. These instruments (which have to be coupled to a small accelerator) have the possibility, starting from a very minute mass of sample, to create a stream of carbon ions and to accelerate it so powerfully that a passage in a magnetic field separates it into three distinct streams, according to the mass of each of the three carbon isotopes, C12, C13 and C14. Receiving them on sensitive plaques, one can determine the ratio of C13/C12 and C14/C12 of the carbonized material that had been put into the machine. This is not the place nor is it the specialty of the author to describe the difficulties inherent in this method, difficulties that justified the years devoted to bringing the method to perfection. It is now well established that the radiocarbon contents measured this way are rigorously identical to those obtained by the radioactivity detectors on the same material.

It is thus possible to date samples of a few milligrams, but one might imagine that such a minute quantity of carbon renders them more easily contaminated by recent carbon.

Indeed there are certain additional risks involved in the preparation of the sample but its miniaturization allows it to be purified by more sophisticated chemical procedures for extracting the original carbon. One can thus utilize the separation method which isolates several milligrams of each organic molecule and separates them from others which are thought to have a secondary origin. This last observation explains why, since it was affirmed that only five milligrams of fabric would suffice to permit, theoretically, several measurements, the laboratories were given 5 to 10 times more, so that they could push to the maximum the chemical purifications. So now three laboratories are conducting treatments on a small quantity of fabric from the Shroud of Turin: despite the ordinary character of an operation which has been done routinely on other samples for several years, we are nevertheless going to witness a dating operation that is altogether extraordinary.

An Exceptional Procedure

The fibre of the linen of the Shroud therefore constitutes a material that can be qualified as ordinary for carbon 14 dating; it is, of course, the Shroud itself that is extraordinary. Here is an object which is not only charged with a long history, but is renowned because of the very precise date that one believes can be attributed to it: the death of Christ, today dated within some five years. Certainly, a number of other very well known archeological objects are also subjected to the radiocarbon test, but not for a single one of them can a date be proposed that is so ancient and so precise and at the same time dated by other methods of investigation which converge in a most impressive way. Of course, that cannot in the least influence the normal dating process now underway, and even less the result, which will be independent of every datum outside of its radiocarbon content, but it does justify the adoption of a special procedure for the manner of removal of the sample, for its submission to the laboratories, and for the publication of the result. Because of the celebrity of this cloth and the rapidity with which the media will inform a very wide public of the result, the means chosen must, from the very beginning, respond to the principle doubts and objections that non-specialists could spontaneously raise. Also, to better explain the exceptional character of what has finally been decided, it is well to explain the customary course leading to the determination and the publication of a date.

When an archaeologist desires to have something dated, he chooses a laboratory, proposes the material, giving an accurate description of it and the archeological reasons for the analysis; he submits the necessary quantity and thus makes an implicit act of confidence in the scientific probity of the laboratory. He expects, on the other hand, that the responsible person of the laboratory will not accept to do the analysis unless he knows that his apparatus is correctly regulated. The measurement is performed one time only, unless later on some doubt should arise about the sampling or a better treatment process is discovered. Therefore it is normal that the person requesting an analysis accepts this unique result, for in choosing this laboratory he intends to give it his full confidence. Perhaps his choice was motivated by his knowledge of the publications and intercalibration operations published by the laboratory. For this reason, the personnel of dating centers find it unjustified that the same sample would be dated concurrently by several laboratories. Such is the custom of mutual confidence that has been established over the past 30 years.

However, for the Shroud, the three laboratories have by mutual agreement not only accepted but have even proposed a special procedure which runs counter to the principles stated above. In fact, it seemed to them as well as to those responsible for the scientific studies on the Shroud, that it would be too complicated to explain these principles to a non-specialist public and that it would be simpler to show by some supplementary — and a bit spectacular analyses, that indeed one could, without qualms, have perfect confidence in them.

And so they proposed a sort of intercalibration of this sample by having it measured by more than one laboratory, in this way averting the objection often posed of the irregularity, temporary or continuous, of a single laboratory. Certainly, it is highly improbable that an accident should happen just at the moment of measuring this very sample, but again, granted the importance of this particular analysis, the fact of having it done by three different laboratories eliminates every imponderable, since it is quite impossible that an accidental deviation should occur at the same time in the three laboratories.

They also accepted to receive three other linen samples of known age, along with the linen from the Shroud. Each laboratory therefore received three small pieces of fabric dating respectively from the Roman period, from the High Middle Ages and of a few dozen years around 1300. This is a quite pedagogic means to demonstrate the good calibration of the three laboratories to the general public.

Thus, instead of having, as is customary, a single analysis on a single small fragment, we have come to the point of awaiting the results on 12 measurements in order to obtain this famous dating. It was suggested that two further advantages could be added to this multiplication of measurements: reduce the statistical margin of error of the final result; and guarantee a sort of anonymity to the Shroud sample in regard to the three other linen samples. It is important not to be too optimistic about that. Certainly, the combination of the results of three laboratories will permit us to reach a little better accuracy than if a single one did the measurement, but one should not over-estimate this possibility, thinking that by multiplying the analyses one would progressively reduce uncertainty. In fact, in the carbon 14 method as in every analysis technique, there are incompressible imprecisions at different steps of the procedure. To neglect this aspect of affairs would lead to giving a false precision, to attribute a so-called "exact" age that in reality would be false. We will see, in the following section, what one can expect from now on as a margin of uncertainty in the final result, almost independent of the number of laboratories.

Besides all this, it was resolved to conduct the analysis as a "blind sample" procedure; the four fragments of cloth were given in boxes labeled only with numbers, of which the identity is known only by the coordinators of the operation. It is incontestable that this way of submitting the sample assures that no laboratory could officially publish its result, but it does not prevent each laboratory from knowing which of the four boxes contains the cutting from the Shroud. Everyone knows that this is a very special fabric of which no other example exists and greatly enlarged photographs of it have been widely published. One must therefore attribute to this so-called "anonymous" operation no motive other than the desire to avoid indiscretions and certainly not to avert any sort of suspicion from those who will make the measurement since, even in the face of this exceptional procedure, one must respect the confidence that one posed in these scientists in choosing them to perform this analysis.

The presentation of the result

Many people expect the carbon 14 dating of the Shroud to be very precise. One must immediately undeceive them and make it clear that in the best of conditions and after averaging the three results given by the laboratories, there can be nothing closer than a span of 200 years. It will not be possible to pinpoint where the exact age of the Shroud can be situated within the span, but — and this is of primary importance — as to the outside limits of the span there can be absolutely no mistake. This affirmation requires an explanation about the different ways of expressing a date and why, in the case of radiocarbon, one cannot really hope for an accuracy closer than two centuries.

In current language, there are several ways to express the age of an object or the date of an event, depending on how precisely it is known. One can give an exact date without any margin of uncertainty: for example, some people affirm, on the basis of certain studies, that Christ died on 3 April 33 (but others maintain another date, equally "absolute" — 7 April 30). Sometimes one thinks he is giving a precise date by saying that Christ died at age 33 (which in any case is not proven), but the date is only relative because it depends on the date one ascribes to His birth. If one is content to say that He died while Pontius Pilate was procurator of Judea, the date again is vague, falling around a period between about A.D. 29 to A.D. 36. Finally, if one takes the reign of the Emperor Tiberius as point of departure, one situates this event even less precisely, but within very exact limits: from A.D. 14 to A.D. 37. These last two modes of expression, addressing the notion of time-intervals, best illustrate the result of a carbon 14 dating operation; first one determines a certain time-span within which the date is bound to be located (one century, 150 years, 300 years); then one sets the precise limits of that interval.

To understand the first step, one must go back to the principle of the carbon 14 method: we have seen that to date a carbonized material, one had to determine the C14 content. The value obtained is expressed as "percent of the C14 international standard" or as "radiocarbon age". But we have seen that every analysis implies a certain margin of uncertainty inherent to the limits of the means of measurement. To indicate this margin, a number with the plus-or-minus sign, ±, is joined to the given value; or, the value is not given, but only the outside limits of the interval of possible variation. For example, the result of the dating of an Egyptian fabric preserved at the Museum of Lyon, and reputed to be of the last period of the Ptolemies, could be expressed this way: C14 content: "78 ± 2%", or "76@80%" of C14; and radiocarbon age "2000 ± 200 BP" or "from 2200 to 1800 BP" (BP signifies "Before Present" [1950] and characterises the calendar ages of C14).

Anticipating what will be published as the final result of the analysis of the Shroud, it is possible that one might read, for instance, "The carbon 14 date of the Shroud is 1990 BP, that is, 40 B.C. so it is older than was foreseen". This reading of the result would be erroneous for it lacks the statistical margin.

But the determination of this interval of time in C14 content or C14 age constitutes only half of the dating operation, for it is quite evident that it is more important to have the date in normal chronology, that is, in real age. This entails the "correction" or the "calibration" of the dates. Why must all C14 dates be corrected? Because one of the basic hypotheses of the method is not altogether exact. To calculate ages by radiocarbon, one presupposes that the C14 content of the atmosphere has always remained the same. However, in measuring the growth rings of very old trees, it has been seen that this content has fluctuated several percents in the course of the centuries. Based on these measures, every C14 date can be corrected almost year by year, and in this way to pass from the radiocarbon calendar (in BP) to the calendar of the real year, Before Christ (B.C.) or Anno Domini (A.D.). The result will surely be published in BP and in real years, and this could be misinterpreted. One could read, for instance, an assertion like this: "The dates obtained on the three control samples had to be corrected to adjust them to their real age. This proves that the equipment was incorrectly regulated or that the carbon 14 method does not give good results." Instead, these corrections are completely normal, they are made on all results bearing on the last two millennia and the only inconvenience is that they widen the interval of uncertainty.

So, finally, what will the time-interval be in the case of the C14 dating of the Shroud of Turin? It is not possible to give an exact response to this question for two reasons: first, because one cannot forecast the precision each laboratory will give to its result and therefore what will be the average of the three. One can visualize that the C14 age will have a margin of ±80 or 100 years, that is, an interval before correction of 160 to 200 years on the radiocarbon calendar. Afterwards the correction will set a limit in real time of 200 to 250 years, that is to say, between two centuries and two and a half centuries. But remember, this interval signifies above all that the exact date of the Shroud could not fall outside the two precise dates which limit the interval.

To conclude these remarks, the publication of the result of the C14 dating of the Shroud ought to be presented under this form:

> "The flax used to make the fabric of the Shroud grew, with near certainty, between the year X and the year Y (200 to 250 years separating X and Y)."

For example, the result could be: "Between 160 B.C. and 50 A.D."; or, "Between 190 and 410 A.D."; or, "Between 1070 and 1290 A.D." This is the only presentation that would be scientifically exact. Every ulterior transformation of the result by another form of expression would introduce additional imprecision and would lead to serious errors, particularly if it were to designate the middle of the interval, even with a ± margin. This point is extremely important: the C14 date of the Shroud must always remain an interval of time delimited by two exact dates between which there is no justification whatsoever for giving preference to this or that precise year and, again, above all, not to a date in the middle. The respect, by everyone, of this imperative rule will preclude abusive interpretations which otherwise will not fail to appear, for, to be quite plain, statistically there is very little chance that the middle of this time-interval would be situated at 30 or 33 A.D.!

Conclusion

After 30 years of waiting, the Shroud of Turin is going to undergo the test of the best known dating method. Wise precautions have been taken to stress the confidence that one can have in the three laboratories. In submitting the sample to them, a procedure was chosen which allies scientific rigor with careful attention to the pedagogical imperatives for those who, all over the world, will receive this important information. Essential cautions have been given before the publication of the result. It is to be hoped that when the date is announced, there will be no misunderstandings, no confusion of terms, no arbitrary criticisms about the sampling or the method or those who will have made the measurement. This hope stands, whatever the result. If the calculated interval comfortably covers the date of Christ's death, very little controversy should arise, so weighty are the convergent conclusions brought forward by other methods of scientific research. If the interval is so far from the years 30 or 33 as to exclude these dates, then the radiocarbon method will be the first scientific method to bear with all its weight (and it is not of the least) against the authenticity of the Turin Shroud as that of Christ, and the mystery of this fabric and the formation of these images will remain complete. But if, finally, this interval misses only slightly the known date of the death of Christ, then, taking into account the other evidence, one would in all honesty have to pose precise questions about the accuracy of the measurement and the mode of the correction calculation. A healthy controversy would then be possible and it would be imperative to review in detail every step of the operation.

For now, one must expect to wait awhile longer, and in the meantime prepare oneself to accept sincerely the result of this analysis. Its artisans, in the course of many long years, have devoted all their patience and their knowledge to render it completely worthy of confidence. Let us hope that all those who are interrogated by the Shroud will rightly know how to receive this new message of Science which has already answered so many of their questions.

ACKNOWLEDGEMENT

I am very grateful to Dr. Kenneth B. Tankersley of the Department of Anthropology, Indiana University, for his intensely conscientious assistance in guiding me past the technical mysteries which blocked the progress of translation of this paper from the French. But responsibility for the English version, with whatever its defects, is mine alone. Dorothy Crispino