Radiocarbon dating the Shroud of Turin

A critical review of the Nature report (authored by Damon et al) with a complete unbiased statistical analysis

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Collegamento pro Sindone Internet - October 2002

FOREWORD

The first and second edition of this small booklet, published about 15 years ago, shortly after the catastrophe, caused by the announcement of the mediaeval age of the Shroud, was for many of the doubting Shroudies of the first and second generation, the FIRST SCIENTIFIC refutation of the radiocarbon verdict.

Later this study has been used in many books on the Shroud, by famous authors like Dr. Baima Bollone, Prof. Emanuela Marinelli, Dr. M.Cl. van Oosterwyck, Frére Bruno Bonnet-Eymard and several others.

Many famous Shroud researchers of the first generation, like Secundo Pia, Prof. Tamburelli, Prof. Jerôme Lejeune, Dr. Alan Adler, Dr. Heller, Don Piero Coero-Borga, Rev. Rinaldi, Rev. Otterbein, Father Bulst, Mgr. Ricci do yet know the truth about the Shroud.

I am still grateful to have had the opportunity to came in touch with Don Coero Borga, the late Secretary of the Turin Shroud Guild. He guided my first steps in becoming a "Sindonologist".

Sindonologists like, Don Fossati, Father Dubarle, Rev. Dreisbach, Father Reuse, Rex Morgan, Paul Maloney and many of the second generation (including myself) are becoming old.

This reworked text of my first critical review of the Nature paper is written for the THIRTH and for all future generation of Shroudies to be.

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Introduction.

On October 13, 1988 Card. Ballestrero, Archbishop of Turin, Custodian of the Holy Shroud, announced during a press conference, the results of the radiocarbon dating of the Shroud of Turin.

He declared: "With a letter arrived at the hands of the Pontifical Custodian of the Shroud on September 20, 1988, signed by Dr. Tite of the British Museum as coordinator of the project, the laboratories of the University of Arizona, the University of Oxford and the Polytechnic of Zurich, which carried out the radiocarbon dating of the cloth of the Shroud of Turin, did finally communicate the result of their work.

The document states that the calibrated calendar age range assigned to the Shroud cloth with 95 % confidence level is from 1260 to 1390 AD.

The laboratories and Dr. Tite in a scientific journal will publish more precise and detailed information on the results, with a paper under elaboration. Prof. Bray of the institute of metrology *G. Colonnetti* confirmed the compatibility of the result."

One may wonder why the Church, did not wait for these "more precise and detailed information", to be examined in depth, by NEUTRAL scientists !

The reason was probably, that the Turin authorities, aware of the forthcoming press conference of Dr. Tite, were afraid to be accused of delaying the verdict of science.

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Indeed, on October 14, 1988, in London, Dr. Tite, assisted by Dr. Hedges (Oxford) and Prof. Hall (Oxford and a member of the board of the British Museum), sitting before a black board, on which was written 1260 – 1390 AD, announced in triumph, the same message in front of the world media.

For a short time, the "unmasking" of the Shroud was hot front-page news.

Prof. Hall, an Oxford experts in radiocarbon dating, said in a TV interview, to be 100 % sure about the radiocarbon dating results. He compared those, who still believe in the authenticity if the Shroud, to be believers in the flatness of the earth.

Dr. Tite, of the British Museum, in fact a radiocarbon apprentice, only claimed a 99 % confidences, because a 100 % confidence is unrealistic.

Another scientists said, ironically, "Radiocarbon dating is as unsinkable as the Titanic."

In reality, this was not a surprise for the insiders, because of the unavoidable communications leaks.

By co-incidence, Dr. Tite became the successor of Prof. Hall, Director of the Oxford Laboratory ….

The retiring Prof. Hall received from "45 friends" a gift of ONE million pounds ….. One of his cited "merits" was the unmasking of the Shroud. (Daily Telegraph, 25 March 1989)

Meanwhile, I started my own inquiry, by asking, the authorities in Turin, Dr. Tite (British Museum) Dr Damon & Dr. Donahue (Arizona) Dr. Hedges & Prof. Hall (Oxford) and Dr Wölfli (Zurich) for ample information.

The answer was that I had to wait, for the publication of a report, to be published in a scientific journal.

In 1989, shortly after the publication of the Nature report, I published the first edition of this paper, written in Dutch. My conclusion was then and still is:

"The claimed 95 % confidence for the mediaeval age of the Shroud is NOT supported by a statistical analysis, based on the data given in Table 1 of the Nature report."

Note that I did never doubt the correct dating procedures by the laboratories.

The famous writer and Shroud- author Ian Wilson, said in a TV interview: " I know some of the men, involved. They are integer scientists."

But the more I studied the matter, the more I became confused by the way, the sample taking and the statistical analysis have been conducted.

Of all the scientists, involved in the radiocarbon dating of the Shroud, only Dr. Tite, Dr. Hedges, Dr. Morven Leese and Dr. Wöffli replied to some of my many questions. Except for Dr. Hedges, all answers were evasive.

Prof. Hall replied by writing that he could not spent his precious time, to answer the questions, posed by scientists of little standard, blinded by faith …

Prof. Hall, former Director of the Oxford AMS Laboratory, declared: "I certainly did not believe that the Shroud was the burial cloth of Christ. I do not know whether the blood on the cloth was that of a man or a pig …" (The Tablet January 14, 1989)

The Turin authorities never replied to any of my questions.

Probably, because they were not at ease, with my severe criticism.

Finally I wrote to His Holiness Pope John-Paul II.

In spite of his authorization, (Letter Vatican 15-01-1990. Signed Mons. Sepe Assessor) Turin did not answer my requests …..

In view of the International Shroud Symposium, organised 7-8 September 1989, in Paris, by the French group C.I.E.L.T, I prepared a translation in English of my original Dutch paper, about the statistical analysis, as published in Nature.

The "Scientific Committee of C.I.E.L.T" REJECTED my paper.

By co-incidence a member of CIELT, Bourcier de Carbon, a professional demographic statistician, spotted the importance of my statistical analysis.

Following his analysis, based on the Nature report, there are only 44 chances in 1000, that the results of the radiocarbon laboratories are homogeneous.

At the last minute, I was allowed to distribute my lecture among the participants of the Symposium.

During the Paris Symposium I had the opportunity to debate with Dr. Tite, Prof. Evin and Prof. Gonella. I presented them all, my statistical analysis.

Prof. Gonella became furious. He blamed Dr. Tite about some violations of the protocol of the testing an some promises never kept. I will not repeat the words used ….

Some statements taken from Italian journals

***La Republica* (29-09-1988) ; "The laboratories acted in a *mafia* way …"**

***Iota Unum* (05-02-1989): "The Turin authorities were warned about an anti-Shroud intrigue, organised by the *Palazzo Giustiani* and some members of *Opus Dei*. (Based on an anonymous letter)**

Prof. Gonella, technical advisor of Mgr. Ballestrero, declared in May 1989:

"The Church was blackmailed by a number of persons, who did everything to make us say NO, in order to say that the Church was afraid of the verdict of science. In any case, the laboratories acted very badly. I still protest their absolute lack of scientific professionalism and the way they conducted the experiments. I have told them in their faces, that they are *mafiosi*."

After his retirement, Cardinal Ballestrero declared: "In my opinion the Turin Shroud is authentic. The radiocarbon measurements dating the Shroud in the Middle Ages would appear to have been performed without due care. (Interview with the German paper *Die Welt* (5 September 1997).

This severe statements are a blame for Dr. Tite and the British Museum.

None of the parties involved did react against these severe accusations..

When I saw this declarations, I wondered why Mgr. Ballestrero and Prof. Gonella did not support my quest for the truth, by giving me and other, certainly better qualified scientists, access to his files, marked "TOP SECRET".

A scientific hand calculator at hand, I invited Dr. Tite and Prof. Evin to perform their own statistical analysis. This is not difficult, one only have to bring in the dates of Nature ….. The computer program does the rest.

Dr. Tite being a perfect English gentleman, declared that he was neither a statistician nor a radiocarbon expert. He promised to ask the advice of Dr. Morven Leese of the British Museum, the author of the statistical analysis, as published in Nature.

Prof. Evin, a French radiocarbon expert did not take the calculator at hand, but declared: "Even if your calculations are correct, they will not explain an error of 1300 years !"

Which is correct, but Prof. Evin did not answer the simple question: "Why were the dates biased, in order to support a non existent 95 % confidence ?"

In fact, Dr. Tite handed over my work to Dr. Morven Leese.

She replied: "Your calculations are correct. The difference between your and my work, are due to the use of different weighting systems …."

I reworked my calculations, strictly following the advice given by the authors of the method, Dr.s Ward & Wilson. The result confirmed my earlier work.

In vain, I asked Dr. Morven Leese to send me her calculations.

I know well that it is not customarily, to publish calculations in full in scientific papers, like I will do in this paper, but to avoid any misunderstanding, it would have been much easier, if Dr. Leese, the three laboratories and the British Museum had given me their calculations and reports in full.

In fact, the relationship between the error and the number of measurements is of the uppermost importance, for it determinants the ERROR range.

Example: For the Shroud, the mean result 691+-31 is the result of THREE independent measurements provided by Oxford, Zurich and Arizona.

These INDEPENDENT measurements are the results of an unknown number of DEPENDENT measurements, each with a specific UNKNOWN error.

Error range, for x numbers of measurements, assuming equal weights and ONE extreme value. (10 targets per run)

X	Confidence level = 68%		95 %	Number of runs & targets	
1	691 +- 31	660 - 722	630 - 752		
3	691 +- 54	637 – 745	585 - 799		
12	691 +- 179	512 - 870	340 – 1042	1	120
24	691 +- 515	175 - 1206	- 1700	2	240
36	691 +- 778	1469	- 2216	3	360
48	691 +- 1041	1732	- 2731	4	460

Note:

The possibility to obtain such an extreme result not by chance alone, is very small, but not impossible. In practice, such extreme results are "outliers", which are removed, but in any case, they should be noted in the report.

(See the Burleigh report.)

Example:

The radiocarbon laboratory of Toronto only takes in account, measurements with a least a 50 % probability.

Prof. Bene (University of Geneva) evaluated the statistical analysis in this paper. He wrote: "Your excellent work confirms the meaning of other scientists. The radiocarbon data indicate that the samples were not homogeneous. Such samples cannot be representative for the Shroud."

Following Father Rinaldi, (Holy Shroud Guild. USA) the calculations in this study are evidence that the conclusion published in Nature: "With a 95 % confidence, the Shroud is medieval" is scientifically not tenable. (Press Conference New-York 08-12-1989)

Following Prof. Jouvenroux (University Aix-Marseille. France) this paper was the first scientifically refutation of the radiocarbon dating of the Shroud.

The redactions of Radiocarbon and Nature refused to publish this study.

Even for a simple "Letter to the Editor" there was no place ……

Following Radiocarbon, I almost twisted the figures, unaware of the real meaning of standard deviations and standard errors.

Following Nature, the only remark made by the neutral referees, concerned the dimensions of the strip of which the samples were cut.

They were changed from ~7 x 1 cm into ~70 x 10 mm.

I asked Dr. Laura Garwin, Physical Science Editor of Nature, to review the statistical analysis, given in this paper and to point out were I was wrong.

She replied on 19 June 1989, by the following unacceptable evasion: "You are now asking me (a Doctor ex science!) questions that are beyond my ability to answer.."

On 7 August 1990, Mr. C. B. Morris, Secretary of the British Museum, finished the "co-operation" of the British Museum, telling me, that he has seen my correspondence with Dr. Tite, the former Keeper of the Research Laboratory and Dr. Morven Leese. He himself was not competent to comment on the issues raised. But for the British Museum, the matter was closed.

For many radiocarbon experts and other scientists, this paper is the work of one of the small group of "scientists of little standing" blinded by their faith and their vested interest in the Shroud of Turin.

But, if made in blind, strictly following the proposed Ward & Wilson procedure, using solely the dates given in Table 1 of the Damon et al. paper, any statistician must find the same results and come to the same conclusion.

Every neutral scientist, reviewing this paper will come to the ASTONISHING conclusion that all calculations and statements presented here, are CORRECT.

This study, based on the Nature dates, identifies clearly a systematic bias and unexplained variability.

Such a failure leads to a loss of resolution and reduced radiocarbon dating users confidence.

This should be, following the conclusions of the "International Collaborative Programme" (Scott et al. Glasgow 1990) a matter of great concern …

But not for the radiocarbon expert, when dealing with the radiocarbon dating of the Shroud.

In New York, I invited Dr. Marion Scott, present at a Shroud Symposium, to evaluate the radiocarbon data for the Shroud, as presented in Nature.

Even if this should be only a matter of seconds for such an expert, she avoided to answer my written question, telling the moderator, that she would reply by letter.

Following my own calculations, made strictly following the procedures proposed by Dr. Scott, the laboratory of Arizona failed the "Intra Laboratory test" (Internal Error Multiplier < 1) and only Zurich passed the "Inter Laboratory " test (External Error multiplier < 1).

Needless to say, that I still wait for her letter.

The International Collaborative Program.

Probably to safeguard the reputation of the participating laboratories, the whole survey was held incognito.

Out of 58 laboratories, only 15 laboratories passed the THREE series of testing in a "program of dating samples of wood, peat and carbonate, in TOTAL BLIND" conducted by Dr. Scott et al.

From the FIVE AMS laboratories, only ONE passed the THREE tests.

Following Andy Goghan (New Scientist. September 1989) only SEVEN laboratories produced results that the organizers of the trial considered to be satisfactory.

To pass this test, BOTH the IEM (Intra Error Multiplier) and EEM (External Error Multiplier), the quotient of overall age range of a laboratory, divided by the square root of the sum of the squared errors on the dates and the mean, should be < 1. About the same method is used in earlier "outlier" tests.

(See "Inter-comparison program by Burleigh et al. Page.)

Following Dr. Baxter (Director Scottish University Research. Glasgow), Accelerator Mass Spectrometry (AMS) used last year by a laboratory at the University of Oxford to date the Turin shroud, allegedly the burial cloth of Jesus Christ, came out of the survey badly."

I asked Dr. Baxter, one of the directors of the program, to evaluate the result of my calculations, based on the Scott et al report, of the radiocarbon dating of the Shroud. He did not reply.

Dr. Hedges (Oxford) did not answer my questions, probably because Oxford did not participate in this survey.

Instead, as by co-incidence, Dr. Hedges contacted Dr. Baxter, who suddenly tempered his criticism on the AMS method .

IEM & EEM for the Shroud radiocarbon dates.
Formula: $(X - M)/ (Ex^2 + Em^2)^{0.5}$
Only NEGATIVE results > 1 are given
Arizona: IEM Mean: 646 +- 17 Mean: 646 +- 31
$(701 - 646)/(17^2 + 33^2)^{0.5} = 1.49$ $(701 - 646)/(31^2 + 33^2)^{0.5} = 1.21$
$(690 - 646)/(17^2 + 35^2)^{0.5} = 1.13$ $(690 - 646)/(31^2 + 35^2)^{0.5} = 0.94$ ←
$(646 - 591)/(17^2 + 30^2)^{0.5} = 1.59$ $(646 - 591)/(31^2 + 30^2)^{0.5} = 1.27$
Arizona EEM W. Mean 672 +- 13 Mean A = 646 + 31 Un. Mean 691 +- 31
$(672 - 646)/(17^2 + 13^2)^{0.5} = 1.21$ $(691 - 646)/(31^2 + 31^2)^{0.5} = 1.03$
Oxford EEM W. Mean 672 +- 13 Mean O: 750 +- 30 Un. Mean 691 +- 31
$(749 - 672)/(13^2 + 31^2)^{0.5} = 2.29$ $(750 - 691)/(31^2 + 30^2) = 1.37$
Comment:

Based on this test, it is clear that Arizona fails both IEM & EEM, while Oxford fails EEM. There is little difference between the computer and Nature dates.

The results of this tests show that is unlikely that the errors quoted by the laboratories for sample 1, fully reflect the overall scatter.

Even the arbitrarily enlarged errors for Arizona and the mean, do not reflect fully the overall scatter.

These results show clearly, why Dr. Scott did not answer, in front of the New York Symposium.

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Please, read the following note very carefully!

A NOTE ABOUT THE ABSOLUTILITY OF EXPERIMENTAL RESEARCH.

In 1881 Michelson & Morley made some research about the velocity of light.

In 1905 Einstein's thesis "Zur Elektrodynamic bewegter Korper" was based on the absolute velocity of light: 299.792.458 m/sec. (See note)

In 1916 Einstein (1879-1955) release a paper "Die Grundlagen der Algemeine Relativitatstheorie". (Law of Relativity) with the famous formula $E = mc^2$

About 1935, experiments made by Einstein, Podolsky & Rosen, indicated the possibility of larger velocities. But no conclusive evidence was found.

Recently, during research at the University of Berkeley, one measured velocities about 4.7 times the velocity of light, when a photon passes through a mirror … (Tunnel effect).

Today one knows that his "Tunnel effect" plays an important part in the collisions between molecules. In space, every second millions molecules of ammonia or hydrogen pass THROUGH molecules of nitrogen, showing some acceleration.

The result of such experiments, shows that one must be careful, to consider any measurement to be "absolute".

Note: Scientifically, it is not allowed to write 299.792.458 m/sec. for the velocity of light. Because the determination of the velocity of light is function of two main factors: The accurateness of distance measurement and time determination.

Even with an electronic time devise, with an error of 1/10.000 sec, and assuming an absolute correct distance measurement, all measurements should be given with +- 3-km/sec errors. Therefore one should NOT use numbers like 299.792.458 m/sec. but rather ~300.000 km/sec.

Nevertheless, radiocarbon experts use values as low as 1.15 x 10^-12 for the ratio $^{12}C/^{14}C$. This is like dividing the mass of an insect with the mass of an elephant.

In fact radiocarbon dating reports only probabilities, not exact dates.

Following experts like Taylor (1987) and Scott (Glasgow 1992), radiocarbon is NOT a DIRECT, bur rather an INDIRECT way to determine the age of an object.

In reality, radiocarbon dating is based on the ASSUMPTION, that one knows the exact isotopic composition at origin of the object to be dated. And of course, that the object did not exchange ^{14}C with the environment.

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SHORT INTRODUCTION INTO RADIOCARBON DATING.

One of the by-results of atomic research, was the discovery of the possibility to date artifacts, by measuring the small amount of the natural radioactivity, caused by the presence of ^{14}C isotopes.

For this discovery Dr. Willard F. Libby (+1980) was awarded, in 1960, with a Nobel Prize in Chemistry.

The method is based on THREE postulates:

A: In the atmosphere, the production and the disintegration rate of ^{14}C are relatively CONSTANT. (This level is assumed to be near constant at least over the last 40.000 years.)

B: ^{14}C is uniformly redistributed in space, water and all living organisms.

The disintegration of ^{14}C is assumed to be constant under all conditions.

Contamination by other sources is excluded.

The half-life of ^{14}C is 5560 years.

Following Wigley & Muller (Radiocarbon 23 N° 2 pages 173-190): "Since living materials constantly recycle carbon with the environment, they contain an amount of ^{14}C which is in equilibrium with, but not necessarily equal to that contained in atmospheric CO_2."

C: The ratio ^{14}Co (at origin)/^{14}Cm (measured) represent the time of death of any living organism.

Basic formulae = Half-Life x ln ($^{14}Co/^{14}Cm$)

Today, the half-life of ^{14}C has been enlarged from 5560 to 5730+-40 yr.

This means that all "conventional Libby dates" are to be enlarged by a factor 1.029, to obtain a "corrected radiocarbon age".

In practice things are not so simple.

A number of "empirical" corrections for the Suess-effect, background, and -d^{13}C natural and laboratory fractionation have been applied.

Based on a large number of -d^{13}C measurements one decided to use only 0.95 of the ^{14}C/^{12}C ratio in international oxalate ^{14}C standard.

(This will lower any RAW RC. date by about 400 years)

The exact equation for the "calibrated radiocarbon age" is:

$$\text{RC age bp} = [\text{H.L.} / \ln 2] \times \ln [0.95 \times {}^{14}\text{Co}\}/{}^{14}\text{Cm}]$$

When the measured value for -d^{13}C differs from the standard value – 25 o/oo these dates have to be corrected for difference in –d^{14}C.

Simplified: The difference in d^{13}C indicates a DOUBLE change in ^{14}C.

For a sample of Fm 0.5000 (rc. age 5740) and –d^{13}C= 15 o/oo the rc. age will be corrected age will be:

d^{13}C = 0.015 → +0.025 – 0.015 = 0.010 and -d^{14}C = 2 x 0.010 = 0.02

Corrected fraction ^{14}C = 0.52 Corrected Rc. age = 5407

An apparently difference of 333 years, due to an ENRICHMENT of 2 o/oo in ^{14}C.

In reality, 1 o/oo of ^{13}C is NOT equal to 1 o/oo of ^{14}C.

For each ^{14}C particle, there are ~96.521.730.000 ^{13}C particles.

Example:

Composition of a sample of 0.8968 mg pure MODERN carbon (Standard AMS sample):

1 mol of pure carbon weights 12 gr. and contains ~6.03 x 10 ^23 C-atoms.

Thus 0.8968 mg, contains [(6.03 x 10^23) x 0.0008968]/12 = 45.064 x 10^15

Total carbon isotopes = 45.064.000.000.000.000.000

^{12}C = 42.590.543.249.951.020.876

^{13}C = 473.706.749.980.000.000

^{14}C = 48.979.124

Thus a loss of 1 o/oo ^{13}C means a NATURAL transfer of 473.706.749.980.000 parts ^{13}C against only 2 x 48.979 parts of ^{14}C.

If the reaction ^{13}C → ^{14}C → Nitrogen, is activated by the presence of silver powder (catalysator), superheated steam, (heat source) and CO (a promoter) than one needs only a shift of 7.836.679 parts ^{13}C → ^{14}C to explain a shift of ~1300 years for the Shroud.

Note that 7.836.679 parts ^{13}C are only a very, very small fraction of ~0,000.000.000.165 of the total ^{13}C on the loose !

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Wigley & Muller (Radiocarbon 23 N° 2 1981) give a complicated series of not less than 31 steps to compensate for variation in the isotopic compositions of samples before and during pre-treatment, chemical conversion, and measurement.

Following the abstract of the Wigley paper: "Recent work has suggested that the relative fractionation of ^{13}C to ^{14}C may differ from the accepted value of b = 2."

A generalized dating equation is

$$\text{Activity} = \text{Beta} \times [\{{}^{13}\text{C}°/{}^{13}\text{Cst}\}\text{^b}] \times 0.95\ \text{A}\ \exp(-8068/8267)$$

Here Beta is a parameter which reflects changes in atmospheric ^{13}C and ^{14}C content, where the exponent b may vary between 1.8 ~ 2.6.

It is clear, that the variation of b, (even from 1.5 to 3) cannot cause large errors.

On the other hand variations in Beta can cause very large errors.

In practice Beta is not directly measurable. It is probably the main reason for erroneous radiocarbon dating results. A fact often "forgotten" by radiocarbon experts.

To simplify, the value [2 x d(^{13}Cst – ^{13}Cm)] = ^{14}C) is added / subtracted to the ASSUMED concentration in ^{14}C measured in the sample .

Errors due to differences in d^{13}C from the reference value –25 o/oo
(Here the –d^{13}C correction is introduced in the ^{14}C at origin.)

o/oo -d^{13}Cm	10	20	25	30	35	
% d^{14}C	+ 2	+1	0	-1	-2	
% RCo	97	96	95	94	93	
% RCm 90	619	534	447	360	271	Radiocarbon age years bp.
80	1593	1507	1421	1333	1243	
70	2697	2611	2525	2437	2349	

In theory, a –d^{13}C value LOWER than –25 o/oo, (which means in fact MORE ^{13}C present) will lower the raw rc. age.

Note that –d^{13}C is based on replicates of the PDB reference, where d^{13}C pdb = 0. (Carbon from the marine carbonate fossil Belemnitella Americana, found on the Peedee formation in South Carolina. H. Graig. 1953.)

In the atmosphere the –d^{13}C for CO_2 = ~ -7 o/oo.

This means that during the reaction C + O_2 → CO_2 there is a loss of 7 o/oo in ^{13}C and consequently of about 14 o/oo in ^{14}C.

In plants, one finds for CO_2, -d^{13}C values of about –23 - 25 o/oo.

A loss of about ~ 18 o/oo due to photosynthesis.

Today we know, that this is not true for all types of living matter.

C4 plants (maize and sugarcane -d^{13}C = -14 o/oo) are much richer in ^{13}C than C3 plants (Pea -d^{13}C = -26 o/oo. Sugar beet -d^{13}C = -30 o/oo)

The influence of the environment is clearly illustrated by research by Vogel (1978) and Medina & Minchin (1980). They measured -d^{13}C values in leaves from the SAME tree in the Amazon and Bavaria forests.

Height	Amazon	Bavaria.
0	-35.2	-31.6
30	-29.8	-25.1

This means that the ^{13}C and ^{14}C content of leaves from the SAME tree may differ about 1 % in ^{14}C and about 2 % from the ambient atmosphere.

Some metabolism processes may even cause local changes in ^{13}C and ^{14}C.

The larger the differences in temperature, the larger the changes in ^{13}C and ^{14}C may become.

This means that, during natural reactions in the atmosphere, photosynthesis in plants and by other processes, an unknown amount of the ^{13}C present in pure carbon, at origin, will be transformed into ^{14}C and further into ^{14}N (nitrogen).

Example:

The –d^{13}C = 27 o/oo for the Oxford (Table 1 Nature) indicates that the rc age 750+-30 (Table 2 of Nature) corresponds to a RAW rc. age of 788+-30

Simplified calculation:

Raw date 8268 x ln(0.95/0.8636) = 788

Corrected date 8268 x ln[(0.95/ (0.8636 + 0.004)] = 750

From this, it is clear, that like any other scientific method, radiocarbon dating has his limitations and the results cannot be interpreted uncritically.

In fact, because of the "probabilistic nature" of radiocarbon dating, the calibration from radiocarbon to calendar ages leads sometimes to more than one calendar age ! The

tables and calibration graphs from Stuiver & Pearson, may give up to FOUR calendar ages for one single radiocarbon age.

Some examples:

Table 1A – B (Stuiver & Pearson. High Precision calibration. Radiocarbon)
AD 1260 = BP 690 = RC age =779+-10 $D^{14}C$ = -13.4+-1.2
AD 1390 = BP 560 = RC age = 579+-12 $D^{14}C$ = -6.5+-1.5
Table 3
RC age bp = 720 Calibrated = 680 Calendar AD = 675
For error = 100 AD 1225-1306 & 1359-1379
For error = 200 AD 1047-1092 & 1118-1143 & 1150-1410
RC age bp = 760 Calibrated = 685 Calendar = 685
For error = 160 AD = 1047-1092 & 1118-1143 & 1150-1320 & 1347-1388

The difference between calendar and radiocarbon ages is caused by the irregular calibration curve, based on dendrochronical data.

The first results, the dating of some Dead Sea scrolls, by Libby, were a success.

All dating resulted in an error range 150 – 450 years.

A number of dating on very old "Redwood" (Sequoia Gigantean) trees, were conform on the number of year-rings.

Then Libby started to date a number of objects found in Egyptian tombs.

Some results were clearly in contradiction with the historical order of succession of the Pharaohs!

Two examples, among a large numbers of uncertain measurements:

The tomb of Zoser (2700 BC) was dated about 2030 BC.

The tomb of Snefrou (+ 2590 BC) was dated about 2900 BC

Every time Dr. Libby provided eloquently some explanation, but he could never persuade the archaeologists and historians to change the chronology of the Pharaohs ….

Of course, Dr. Libby became aware of the fact that none of his postulates was correct. The near equilibrium of ^{14}C production and loss of ^{14}C by disintegration and also the equal distribution of ^{14}C in all matter, were only an utopia.

Example:

In radiotherapy, radioactive material concentrates in human tumour-tissue.

Almost systematically radiocarbon ages were about 400 years to old. Therefore the -$d^{13}C$ normalisation of – 25 o/oo was introduced. (Found by Calvin)

One of the problems was the question: "May one assume that measurements on long living wood, are representative for short living materials like plants?"

Following experiments, conducted by the Russians Dr. Kouznetsov et al, the concentrations in ^{14}C and ^{13}C are NOT uniformly distributed in the different parts of flax.

Flax		Central Russia			Middle Asia		
		$-d^{13}C$	$-d^{14}C$	Ratio	$-d^{13}C$	$-d^{14}C$	Ratio
Lipids	20 %	40	72	1.80	35	68	1.94
DNA	2 %	30	59	1.97	33	62	1.88
RNA	3 %	30	57	1.90	31	60	1.94
Prot.	15 %	22	52	2.36	26	52	2.00
Polsc.	60 %	19	41	2.16	15	28	1.87
Average =		24	53	2.22	28	54	1.93

This means that the different components of the same flax will show a different apparent radiocarbon age.

Example:

The lipids fraction of the Russian and Asian flax will be apparently about 250 years older than the polysaccharide fractions.

(Acts Shroud Symposium CIELT. Rome 1993)

Following Kouznetsov, most of the non-polysaccharides, low in ^{13}C and ^{14}C, will be removed from the flax, during retting and spinning processes. Consequently the final flax product will be richer in ^{13}C and ^{14}C. Radiocarbon dating of this flax will result in apparently YOUNGER dates.

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THE CONTROVERSY ARIZONA VERSUS KOUZNETSOV.

In Rome (1993) Kouznetsov made sensation, because he claimed to have proven, that the Chambéry fire caused an enrichment in ^{14}C, large enough to explain the medieval radiocarbon date of the Shroud.

Note that Kouznetsov performed in fact the experiments from Dr. M. Cl. Van Oosterwyck. Several laboratories had refused to co-operate.

Finally the French scientist Guy Berthault made the experiments possible.

The "Big fire" experiment gave the following results:

Incubation time 1 hour at 140 °C, in an artificial atmosphere (0.03 % w/w CO_2, 20 g/m³ water 60 g/m³CO)

After about 30 minutes, a kind of equilibrium was reached.

The ^{14}C shifted from the gas-faze to the linen, causing an enrichment from –54 o/oo to –36 o/oo, while in the gas faze, the content in ^{14}C decreased from –36 o/oo to -48 o/oo.

The ^{13}C shifted from the linen to the gas faze, causing a decrease from –12 o/oo to –20 o/oo, while in the linen, the content in ^{13}C increased from –28 o/oo to –22 o/oo.

The changes observed are rather small, but they indicate that some enrichment in ^{14}C is NOT excluded. Important is the fact, that changes in ^{13}C and ^{14}C do not always follow the rule of thumb, 2 x $-d^{13}C = -d^{14}C$.

Nevertheless, Kouznetsov claimed to have obtained the following results:

A Boukara linen, historical age 760-840 AD, dated by radiocarbon about 960-1070 AD, dated after the fire experiment 1210-1290 AD.

In terms of fractions of modern carbon we have a enrichment from 0.8397 to 0.8739, (About 104 %, were one needs an enrichment of 116 %, to explain the medieval age of the Shroud.)

After a quick examination of the paper, I told Kouznetsov in private, that because of the $^{14}C/^{13}C$ ratios in ALL the different parts of the crude flax were about 2, the error in the age corrected for $-d^{13}C = 25$ o/oo will be rather small.

Correcting to a value of $-d^{13}C = 19$ o/oo would only cause a shift of about 120 years.

Kouznetsov was not impressed by my remarks.

In a paper, published later, "Effects of fires and bio-fractionation of carbon isotopes on results of radiocarbon dating of old textiles: the Shroud of Turin," (Journal of Archaeological Science 23. 1996) Kouznetsov et al, presented again the "heat theory" of Dr. M. Cl. Van Oosterwyck.

Finally Kouznetsov rejected the results of the radiocarbon dating of the Shroud.

Following this paper, under hydrothermal conditions, heat and the presence of silver ions acting like a catalyst, may start textile cellulose carboxylation, which leads to an enrichment in ^{14}C.

In an artificial atmosphere of 0.03 % w/w CO_2, 60µg/m-³CO and 20 g/m-³ water ionised with silver ions, a funeral linen of known age BC 100- AD 100, found in En-Gedi, was heated during 4 hours, at a temperature of 200 °C.

These experiments were conducted, following the advise of Dr. M. Cl. Van Oosterwyck, in order to reconstruct the Chambéry fire of 1532, in which the Shroud was heavily damaged.

Results (Activity = dps scale adapted by the author to recalculated En-Gedi activity)

Temperature °C	25	50	100	150	200	250	300	350	400
-d^{14}C dps g-1	24	26	30	32	37	37	36	35	
Activity			17		18		19		20
RC age			2175				800		
-d^{13}C o/oo	24	22	20	18	17	16	15	14	

Time min. 200°C	30	60	90	120	150	180	210	240
-d^{14}C dps g-1	22	24	31	34	38	37	36	35	33	32
RC age	2175				800			
Activity	17	18	19	20				
-d^{13}C	25	24	23	22	21	20	19	18	17	16	15

Note:

The results stated in the captions of figures 9 & 10 are indeed not in agreement with the graphs 6 – 7 – 8. (Kouznetsov paper)

From these graphs, one may assume that, after about 2 hours at 200 °C an equilibrium was reached. From that time on, the ^{14}C content starts to lower.

Based on the Arizona experiments, after about 15 hours at 200 °C, the effect of heat becomes about zero.

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In the same issue of the "Journal of Archaeological Science"", the scientists of Arizona, replied by claiming that they did not notice any rejuvenation of the same En-Gedi sample, during their own "fire" experiments..

Dr. Hedges (Oxford) after experiments on very old carbon, made the same remark. Dr. Hedges assumed that using very old "almost dead" carbon would make the experiment very sensitive for any eventual enrichment in ^{14}C.

Moroni et al, reported that their fire experiments resulted in an ageing 1295 BP to 1405 BP (^{14}C Analysis made by Arizona)

Comparison Kouznetsov – Arizona

Arizona	Time	°C	CO_2	CO	H_2O	Silver	Age	d^{13}C	Change
Start	15.30	200	-	-	-	2195	-25.3	-43 yrs	
End						2152	-25.9	-0.6 ^{13}C	
Kouznetsov									
Start	2	200	0.03	20 g/m³	60 g/m²	2175	-25.3	-1375 yrs	
End					800	-22.0	+3.9 ^{13}C		

Arizona made the following SIX remarks:

1: Following Kouznetsov et al, the ^{14}C activity of the En-Gedi linen was 0.22 dps. which is in fact about the activity of modern linen.

Note: Indeed Kouznetsov used in Figure 6, on the ^{14}C Activity scale the value of 0.22 dps (disintegrations per second) for modern linen, instead of ~0.17 dps for the En-Gedi linen of 2175 years old.

Probably a wrong scale was used, when preparing the paper for printing.

On the other hand, one find the correct ages on figures 9 & 10.

2: The samples, which had been heated, gave ^{14}C activities of up to 0.34 dps, equivalent to 150 % of the pro-bomb modern carbon.

(If indeed a correct scale was used.)

It is impossible to derive an age of 700 – 800 years BP from the data, using any accepted calculation of ^{14}C ages, or even equation 4 presented by Kouznetsov.

This level cannot be achieved even by complete exchange with contemporary air, which has a ^{14}C level of 110 % modern ^{14}C.

(Following Dr. Hedges, the ^{14}C level of contemporary air is ~150 %.)

Kouznetsov indicated clearly that he used the correction factor K.

Equation 4: (T/ln 2) x ln[(A° x K)/Am]

3: The results quoted in the captions of Figures. 9 & 10 are not consistent.

Here again, one does not take in account that Kouznetsov used the K factor.

4: The section of calibration curve shown in figure 10 does not bear any relation to the curve published by Stuiver & Pearson (1986).

The "smoothed off" curve is indeed deformed, were the radiocarbon scale seems to be compressed or the calendar scale to be stretched out.

Anyway, the specific "dents" for the era 1100 & 1300 are easily identifiable.

To evaluate this critic, one should compare the original Stuiver & Pearson graphs 1B & 2B. (Radiocarbon)

On the "smoothed off" graph 2B, there is no trace of the sharp dents.

The laboratory of Groningen uses also hardly recognisable "smoothed off" graphs.

5: Kouznetsov exaggerate the small fractionation effects on stable carbon.

Again one takes not in account the factor K.

6: In reference to the comment of Kouznetsov on the dating of the Turin Shroud, we point out that if the Shroud sample were heated to 300 °C, it would have charred significantly.

This is correct.

The quoted values for $d^{13}C$, by Damon et al (1989) within the usual range for cellulose textiles of about –23 to – 25 o/oo.

But Arizona did not comment on the $d^{13}C$ value of Oxford, were – 27 o/oo is OUTSIDE the usual range !

One seems to forget that 1 o/oo of ^{13}C is about 10.000.000 o/oo of ^{14}C. If only a trace of ^{13}C reacts to ^{14}C, than the whole radiocarbon theory becomes very unstable.

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Comment of Jull et al, on Kouznetsov et als Chemistry.

Assuming a recent 20 % contamination by 2-carboxy-Beta-D-glucose one can make up the following balance:

For the En-Gedi linen, dated 2195, Fm = 0.761 of modern carbon and Fc = 110

Fm heated treated: 0.2 x 1/7 x 1.1 = 0.0314
0.2 x 6/7 x 0.761 = 0.1305
0.8 x 0.761 = 0.6088
Total = 0.7707

Radiocarbon age = 8030 x ln 1/07707 = 2091.

A change of only ~100 years.

Note a:

Even when the temporary air contains 150 % of modern ^{14}C, the final result will be only 0.7816, and the change will be ~ 200 RC. years.

Note b:

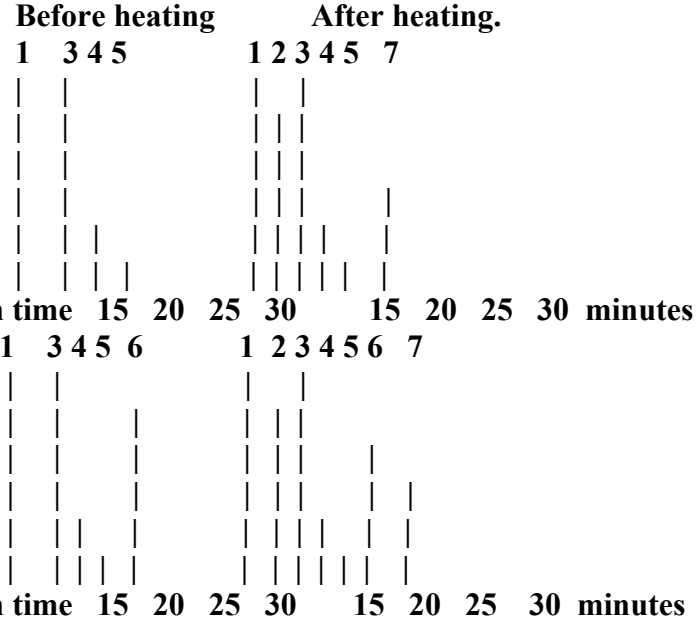
The chemist who inspired the Arizona remarks did not take in account the many other reactions possible (isotopic ion-exchange, hydrolysis, addition, substitution, oxidation, reduction, de-polymerisation, biological degradation).

In nature, the isotopic composition of plants changes without any problem ….

In fact, in nature, any ^{12}C atom can be "activated" in many ways and become ^{13}C or ^{14}C.

Kouznetsov gives a number of spectral analysis of the composition of the linen before and after his heat experiments.

Figure 3 shows 4 graphs.



Peak 1: Buffer
Peak 2: 2-acetyl-6-methyl-beta-D-glucose
Peak 3: Beta-D-glucose
Peak 4: Cellobiose
Peak 5: Unidentified impurities
Peak 6: 2-carboxy-Beta-D-glucose
Peak 7: 6-methyl-Beta-D-glucose.

Where Arizona only focuses on the quantitatively value of the peak 3, they seams to have NOT noted that the COMPOSITION of the linen did change by heating. During the experiment, TWO new products were formed.

This confirms the findings of the late Dr. Adler, who said: "Before any new radiocarbon dating of the Shroud, one should examine carefully the chemical composition of the linen. I found evidence of the presence of burn shards all over the Shroud, not reported by any of the radiocarbon labs".

Similar findings were reported by:

The Swiss Dr. Max Frei, who noticed the presence of many fungus spores and pollens on the Shroud. Following Paul Maloney, who examined the taped samples of Max Frei, there exist millions of pollens on the Shroud.

On the Frei tape 2A/a, (and on 7 others) taken close to the place where taken the samples to radiocarbon date the Shroud, one found evidence of burn shards.

Prof. G. Riggi (1981), who reported his discovery of mineral coated pollen grains, located exclusively on the non-image side of the cloth. Also a number of insects and strange plants particles. (Lecture P. Maloney. Rome 1993.)

Dr. Heller, who discovered the presence of pseudo-morphs, (In this case, carbon atoms replaced by iron particles, present in blood.)

Dr. Garza-Valdes, who found coated fibres. (Micro-biological coatings)

Prof. H. Gove and Dr. Donahue (Arizona), both radiocarbon experts, looking through the same microscope, confirmed the findings of Dr. Garza-Valdes. Both agreed that such a contamination could indeed influence a radiocarbon dating.

****

In the thermal gas treatment described by Kouznetsov, the En-Gedi sample is exposed to an "artificial atmosphere" containing 0.03 % w/w CO_2, 60µg CO m^{-3} and 20g. M^{-3} water. This gives ~ 15 mg pure modern carbon.

Following Arizona the small amount of CO present is without much importance.

Without verification, they assume the concentration in CO_2 to be given in VOLUME %, where Kouznetsov used weight/weight.

Note:

Traces of CO play an important part as promoter or inhibitor, in many chemical reactions.

Arizona does not even take in consideration the influence of water (in the form of superheated steam) and silver ions.

The importance of silver is illustrated, by the use of silver powder to reduce the background effect from 3 % to 0.4 %, when preparing very old samples for radiocarbon dating in the Zurich laboratory.

****

Jull et al finally concluded: "We believe the ^{14}C method described (by Kouznetsov) had not had appropriate control experiments performed. Additionally, the AMS ^{14}C measurements were done on an apparently untested piece of equipment with no reference to normal procedures of reproducibility, standards control and blank samples."

Note:

In Arizona and Oxford, the experiments were conducted in glass. Here no contact with the atmosphere is possible.

Were one should try, to reconstruct the Chambéry fire, were the combination of a closed shrine, melting silver-tin solder, a warmed up Shroud, smouldering wood and linen, evaporating quenching water provided an ideal atmosphere to contaminate the Shroud in many ways.

****

Back to ^{14}C theory.

The background effect was introduce to compensate for a 3 % activity measured in DEAD carbon.

Due to industrial activities, (Suess-effect) the content of ^{14}C in space was decreasing, by the combustion of coal and fuel. Because of nuclear testing and other activities the ^{14}C in the atmosphere tends to increase. The half-life of ^{14}C was set from 5560 to 5730 years. Some expect it will be raised to 7200 years ….

Nevertheless, today some laboratories prefer to give their results as "Libby dates", while other prefer to express their results % of radioactivity.

Example: Measured activity 0.5 of modern carbon.
Libby age (5560/ ln 2) x ln (1/0.5) = 5560 (ln 2 = 0.693)
Age corrected for background 3 %,
8020 x ln [(1-0.03)/(0.5-0.03) = 5811
Age corrected for $d^{13}C$ –0.025 ➔ 0.05 ^{14}C
8020 x ln [(0.95-0.03)/(0.50-0.03)] = 4232
Age corrected for Half Life 14C = 5730
8268 x ln[(0.95-0.03)/(0.50-0.03)] = 5553

This application of correcting factors shows how different errors may compensate one another. But in extreme cases, they may all point in the same direction and cause extreme large errors.

Note:

Following Dr. N. van der Merwe (Universities of Harvard & Cape Town) in "American Scientists". Vol. 70: "It is probably fair to say that these calibrations were done on a purely empirical basis, without regard to the systematics which lay behind deviations in $d^{13}C$. Correction factors should NOT be used to adjust radiocarbon dating results toward the archaeological and historical ages, or to justify systematically aberrant dates."

Some examples

A: The Antwerp Roman boats.

During the enlargement of the harbour of Antwerp, were found two boats.

Base on historical evidence and stratification, one believed these boats to be of Roman origin.

Following experimental radiocarbon dating, the boats were IX-X Th. Century.

B: The mammoth of Garon.

The laboratory of Lyon (France) dated the bones of a mammoth 3150 +- 240 years BP. (1200 BC) (Sample Ly 492. Date 1976)

The explication, given by Dr. Evin: "The bones have been in contaminated by minerals, which have been polluted by water, probably rich in ^{14}C."

C: The Lindow man and woman.

In the marshes of Lindow (Cheshire England) were discovered the corpses of a man and sometimes later of a woman.

Following the archaeologists, the man was from Celtic origin, dated before the Roman era. The corpse, knick named "Pete Marsh" is still present in Room 35 of the British Museum, marked "IRON AGE 600 - 300 BC".

The Lindow man was radiocarbon dated by THREE laboratories, using THREE different systems.

	Peat	Wrist	Vertebra		Hair	Bones
British Museum (Scintillation)	2399	-	-		-	-
Oxford (AMS	2455				1920	1850
Harwell (Mini Beta counter)	2290	2420*	1480	1810	1530	1825

***= Outlier.**

The over-all difference of about 400 years between Hartwell and Oxford was never solved.

Dr. Gowlett (Harwell) agreed to remove the 2420 date (Wrist), but finally the British Museum did not change the archaeological date, 600 – 300 BC, based on the stratification of the peat, in which the corpse was found.

The difference between the samples of the wrist, vertebra and hair was probably caused by some exchange with the peat.

The THREE laboratories confirmed the dating of the peat.

Strangely no information was given any dating of the rope, used to strangle Pete Marsh.

Some time later, one found, in the same area, the corpse of woman, believed to be very old.

At the request of Prof. Hall, the corpse was send to the British Museum. Before any examination result was published, the police identified the woman, a person reported lost in 1960.

(BTST. N° 47 1998.)

D: The Manchester mummy.

Here radiocarbon measurements showed a difference of about 1000 years, for different parts of the windings around the corpse.

E: The Bushman artefact.

Recently, one discovered in Natal (South Africa) a painted artefact, dated by experts about 1200 AD. The age of the artefact was confirmed by radiocarbon dating at Oxford.

Later, it became known, that the artefact was the recent work of an elderly lady.

Following, Dr. Hedges (Oxford), the confusion was caused by the composition of the paint, containing components with a very low ^{14}C content.

Note:

The radiocarbon experts reject the same argument, about the composition of the linen for the Shroud. They refuse to consider the influence of any invisible repair or contamination.

F: The Carpentras cloth 1991.

By co-incidence Dr. M. Cl. Van Oosterwyck bought a synthetic tablecloth. After unpacking the cloth, she found some fire damage, at the folds.

The white and dark zones were radiocarbon dated: 5700 and 4900 rc years bp.

A rejuvenation of about 800 years, caused by the heat of the fire.

G: The Bayeux tapestry.

This world famous cloth, made at the order of Odon de Conteville (half brother of Guillaume the Conqueror, but in 1730 attributed by the writer Lancelot, (member of the "Academia) to Queen Mathilde of England, is historically dated XI Th. Century. (Exhibition of the cloth on July 14 1077 in the cathedral of Bayeux.) The cloth is noted in an inventory, dated 1476.

Following the laboratory of Lyon the age is 1385 – 1635 (Ly 3047) and even as late as 1425 – 1900 (Ly 3048).

Following Prof. Evin, undetected repairs may cause this probably erroneous date. Anyway, the cloth is not removed from the museum of Bayeux and the date is still XI Th. C.

H: The Wölfli tablecloth.

In Zurich a modern tablecloth, bought in 1950, by the mother in law of Dr. Wölfli, was radiocarbon dated to be from the XVII Th. Century.

*****

Of course today ^{14}C technology is much better.

In a scientific paper, Zurich published the exceptional good results of a test on a standard sample.

Four runs were made:

	Counted ^{14}C	Counted ^{12}C (x 10^12)	Ratio	Error %
	53575	46510	1.1519	0.43
	53550	46605	1.1491	0.43
	45134	39158	1.1526	0.47
	40570	35409	1.1438	0.49
Mean	48207	41920	1.1499	0.50

For every laboratory one has to take in account a specific systematic error, in function of the machine, sample preparation and pre-treatment.

Example: Only about 25 % of the carbon atoms are actually counted.

To avoid errors, the ratio $^{14}C/^{12}C$ is used.

But even a the most precise ^{14}C measurement cannot be a guarantee for a precise dating. Simply because we do not know the ^{14}C at origin and the history of any artefact, not kept in a closed system.

The levels of ^{14}C in the air are known to vary over time and that can affect the results of carbon dating.

Example.

In co-operation with Mr. Mario Moroni, we conducted an experiment in blind.

Three identical samples of MODERN linen were prepared for a test in blind.

Sample 1 was used as reference and send to Oxford.

Sample 2 was heated at 180 °C for 60' and send to Miami.

Sample 3 (A piece of Sample 2) was afterward boiled in fresh olive oil at 100 °C for 30' and send to Toronto. (Historically, following Count de Lalaing, the Shroud was boiled in oil, tested by fire and washed several times. Document made up in 1503 AD.)

The results, were given in % of ^{14}C of standard samples of modern carbon.

Oxford : 155 %

Miami (N°-MM 1995/1): 157+- 0.6 % modern carbon %

Toronto (TO 5208): 120 +- 50 rc. Years bp 98 % of standard sample.

Oxford confirmed the result, because today the ^{14}C content in the atmosphere is about 150 % of the amount measured in 1950 !

(Following Arizona, the ^{14}C content of today atmospheric CO_2 are only 110 %.)

The Miami result confirmed that heating may influence slightly the ^{14}C content. But certainly not enough to explain a shift of 1300 years.

The aberrant Toronto result was never explained, but shows how careful one must be, by judging ^{14}C results.

The Toronto graph showed not less than SEVEN intersections with the Stuiver & Pearson calibration curve. The age range for all seven points, for 95.5 % confidence is 1665 – 1955.

Cal. A.D. Age 68.3 %
1700 1680 – 1755
1720 1680 – 1755
1820 1805 – 1935
1845 1805 – 1935
1860 1805 – 1935
1920 1805 – 1935
1955 1954 - 1955

The graph shows an overall calendar age range of 1650 – 1950.

Because only solutions with a probability > 50 % are used, the calendar age range is only 1680 – 1950.

Note:

Here the Isotrace Laboratory of Toronto (Canada) gave some information, about the RAW results. This information I asked in vain from Oxford, Zurich and Arizona.

Following Brian Walsh, an American researcher, the reason for this strange result, may be the fact, that the normal AAA cleaning procedures, used by the laboratories, does NOT remove hydrocarbons from linen.

He tested a number of cleaning procedures. Hydrocarbon was only removed by petroleum ether. (Used by the British Museum)

Moroni, in co-operation with Prof. F. Barbesino conducted some other experiments.

Historical age RC age RC age
I° BC – I° AD 2210 +- 55 bp Heated 2240 +- 60

Here no influence of heat. Note the difference between historical and radiocarbon ages.

The same test was conducted on a cotton cloth, worn by a victim of the atomic bomb in Nagasaki.

Historical age RC age RC Age
O 300 +- 50 Heated 140 +- 40

Here the cotton is rejuvenated by heat about 160 years.

Prof. Rinaudo conducted an irradiation experiment. He strongly irradiated linen, consequently radiocarbon dated by the laboratory of Toronto.

Based on the measured content in ^{14}C, the linen was to be dated in the far future.

Of course, the tomb of Christ was not a laboratory, equipped with powerful tools emitting high voltage beams ……

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STATISTICAL ANALYSIS.

The disintegration of radioactive material does not follow any law.

We do not know how the amount of radioactive material that will disintegrate in the next hour. We only know, that after a certain period of time half of the radioactive material will be disintegrated.

In the case of the radioactive isotope ^{14}C the half-life is 5730 +- 30 years.

Because radioactivity is in essence a problem of probabilities, a statistical analysis is mandatory.

In the early days of radiocarbon age determinations were usually presented in the form A +- E, where A is the estimate of the radiocarbon age bp (= before 1950) and E is the standard error, based on the scatter of results.

For ONE measurement, the number of disintegrations recorded, served to determinate the counting error.

Measured counts = 5 disintegrations per 1 minute.

Standard 13.5 counts per minute Age: (5730/0.693) x ln (13.5/5) = 8212

Error, if one measured 1 hour (300 counts) = 1/300^0.5 = 5.8 % = 8212+-460

Error, if one measured 1 day (7200 counts) = 1/7200^0.5 = 1.2 % = 8212+-95

The conventional A +- E represents a 68 % confidence and (A – 2E A + 2E) represents a 95 % confidence.

It is possible to introduce other components of variance, caused by variable magnetic fields, sunspots, material and other phenomena.

The easiest way is to introduce the often-unknown factors in the form of

$$A +- (E^2 + G^2 + F^2 + M^2 + X^2)^{0.5}$$

Were E = counting error, G = variable magnetic field, F = sunspot , M = material and X = Unknown phenomena.

For ages > 2700 G = 60 for ages > 2700 years G = 70 F & M = 50.

Example: Shroud = 691 +- $(31^2 + 60^2 + 50^2 + 50^2)^{0.5}$ = 691 +- 98

For the Shroud, (flax being a plant with short growth period) no such additional uncertainty has been added. There is little guidance published on this, although it has been suggested that 15^2 years should be added to the overall uncertainty.

This is the reason, why one should use large samples and count over a long period.

In AMS one counts the carbon isotopes present and measures the isotopic ratios $^{14}C/^{12}C$, $^{14}C/^{13}C$ and $^{13}C/^{12}C$. In theory, the ratio $^{13}C/^{12}C$ should be equal to the constant ratio of 1.11 %. Here counting time is very short, but one uses a number of "pure carbon targets".

Classic statistical analysis.

Before any statistical test is applied one must verify the NORMALITY of the distribution of the dates, by means of a test INDEPENDENT from the distribution.

Example:

The paired Wilcoxon test.

First one determine a reference factor:

[(Number of data A) x (Number of data B)]/2 = F

Than one writes down all data, the largest on the left. Under the results of laboratory with the highest value one write the numbers of result for laboratory B, in till all results a are marked. Then one adds all numbers and determines the ratio F/Sum. Values below 1.5 refer to a normal distribution. Values above 2 refer to a NOT normal distribution

Example: The paired data for the Shroud, as given in Table 1 of Nature

Oxford -Arizona: F = (3 x 4)/2 = 6

795 745 730 701 690 606 591

4 4 4 = 12 Ratio 12/6 = 2 → No normal distribution.

Oxford – Zurich: F (3 x 5)/2 = 7.5

795 745 733 730 722 679 639 635

5 5 4 = 14 Ratio 14/7.5 = 1.9 A borderline case.

Zurich-Arizona (5 x 4)/2 = 10

733 722 701 690 679 639 635 606 591

4 4 2 2 2 = 14 Ratio 14/10 = 1.4 → Normal.

****

Before a statistical test is applied the level of significance must first be selected.

In the case of the Shroud, a theoretical frequency less than 1 in 20 times (95 % level) was considered to be significant. A smaller probability would indicate that the difference was not due entirely to chance alone.

A 95 % test is often a two-tail test, for one should use the coefficients for 2.5 % and 97.5 % confidence.

Classic statistical analysis.
To avoid confusion, NO Greek or arithmetical symbols are used.
Example: In books on classic statistics μ = True but unknown mean.
s^2 = Variance
Note that the Variance following Ward & Wilson is the squared error.
Based on the 12 data given in Table 1 of Nature.
Sub means +- error:
Arizona
701 + 690 + 606 + 591 = 2588/4 = 647
Sum of squares = $(701 - 647)^2+(690-647)^2+(606-647)+(591-647)^2 = 9582$
S^2 = Variance = 9582/(4-1) = 3194
Standard deviation = (9582/3)^0.5 = 57
Standard error = 57/4^0.5 = 28

Oxford
795 + 745 + 730 = 2270/3 = 757
Sum of squares = $(795-757)^2 + (745-757)^2 + (730-757)^2 = 2317$
s^2 = Variance = 2317/(3-1) = 1158
Standard deviation (2317/2)^0.5 = 34
Standard error = 32/3^0.5 = 19

Zurich
733 + 722 + 679 + 639 + 635 = 3408/5 = 682
Sum of squares =
$(733-682)^2+(722-682)^2+(679-682)^2+(639-682)^2+(635-682)^2 = 8268$
s^2 = Variance = 8268/(5-1) = 2067
Standard deviation = 2067^0.5 = 45
Standard error = 45/5^0.5 = 20

Unweigthed mean (Based on the three sub-means)
(647 + 757 + 682)/3 = 695 (Nature: 691+-31)
Sum of squares:
$(647-695)^2 + (757-695)^2 + (682-695)^2 = 5777$
s^2 = Variance = 5777/(3-1) = 2888
Standard deviation: 2888^0.5 = 54
Standard error: 54/3^0.5 = 31

Weighted mean (Assuming equal weight for all 12 data) =
2588 + 2270 + 3408 = 8266/12 = 689 or
[(4 x 647) + (757 x 3) + (682 x 5)]/12 = 689 (Nature: 689+-16)
Sum of squares =
$(795-689)^2 + (745-689)^2 + (730-689)^2 + (733-689)^2 + (722-689)^2 + (679-689)^2 +$
$(639-689)^2 + (635-689)^2 + (701-689)^2 + (690-689)^2 + (606-689)^2 + (591-689)^2 =$
41232

s^2 = Variance = 41232/(12-1) = 3748
Standard deviation: (41232/11)^0.5 = 61
Standard error: 61/12^0.5 = 18

T test value (97.5 %) = 4.303
Only the t values > 4.303 are calculated.

Unweighted mean.	Weighted mean;
(795-695)/31 = 3.23 < 4.303 OK	(795-689)/18 = 5.89 > 4.303 = Reject
	(689-606)/18 = 4.61 > 4.303 = Reject
(695-591)/31 = 3.35 < 4.303 = OK	(689-591)/18 = 5.44 > 4.303 = Reject

This test, based on the scatter of results, indicates clearly why one presented the UNWEIGHTED mean under the unjustified name WEIGHTED mean.

Error range based on a two-tail Chi^2 test value (95% confidence and (3 –1) degrees of freedom) (Chi^2 97.5 % = 7.38 & 2.5 % = 0.0506)
Formula:
Variance/(Chi^2 97.5% x (n-1) < True variance < Variance/(Chi^2 2.5 x (n – 1)
3748/(7.38/2) = 1016 < Variance < 3748/(0.0506/2) = 146620
Standard deviation 1016^0.5 = 32 < S. Deviation < 146620^0.5 = 383
Standard error 32/3^0.5 = 18 < S. Error < 383/3^0.5 = 221
Error range:
68 % confidence: (689-221) → 468 - 910 ← (689 + 221) → ~ 1040 ←→1480 AD
95 % confidence: (689-433) → 256 -1591← (689 + 433) → ~ 360 ← →1700 AD
Note:
Prof. Jouvenroux (University of Aix-Marseille. France) came to the about the same era, applying the Bienaymé-Tchebychev formula.
(Acts Shroud Symposium Rome 1993)

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Following Nature, to assess the radiocarbon data for the Shroud, one assumed that a theoretical frequency of less than 1 in 20 (95 % confidence level) will be considered to be significant. This corresponds with a t-coefficient of 1.96 (for 120 data). For 12 data (11degrees of freedom) t = 2.228

T Test.
Formula: t = (X – True Mean)/(Standard error)
Mean = 691 Standard Error = 31 t = 2.228
For X = 795 745 733 730 722 701 690 679 639 635 606 591
T = 3.35 ←----------OK----------→2.74 3.23

If the calculated t value is higher than that which would occur by chance alone 1 time in 20, the hypothesis would be assumed to be FALSE.
In Nature, in order to enlarge the error range as much as possible, one used t = 2.6. But still 3 out of 12 data show a higher t value.
If one uses the error 13, obtained following the Ward & Wilson method, than only FOUR dates: 720, 701 690, 679, have t values lower than 2.23.

Another test is the F-test. This is a much more "powerful" test.
Here for 3 laboratories and 12 dates and 95 % confidence F = 4.26 (Stat. Tables)

Zu.	Ar.	Ox.	Sub. Total	Sub. Mean
733	701	795	Ox. 2270	757
722	690	745	Ar. 2588	647
679	606	730	Zu. 3408	682
639	590		Tot 8266	689
635				

Sum of squares:
$(2270^2/3) + (2588^2/4) + (3408^2/5) - 8266^2 = 21066$

Total:
$795^2 + 745^2 + 733^2 + 730^2 + 722^2 + 701^2 + 690^2 + 679^2 + 639^2 + 635^2$
$+ 606^2 + 591^2 - (8266^2/12) = 41232$

Residual:
$41232 - 21066 = 20166$

Table of variances

Source of Variance	Sum of squares	degree of freedom	Mean square	F Ratio
Between	21066	3 – 1 = 2	21066/2 = 10533	10533/2241 = 4.7
Residual	20166	12 – 3 = 9	20366/9 = 2241	4.7 > 4.26 = REJECT
Total	41232	2 + 9 = 11		

Conclusion:

Corresponding to a 95 % level with 2 and 11 degrees of freedom, the F ratio would have to be larger than 4.26 to be significant. (By chance alone F should be nearly equal to 1). This test states there is a significant difference between the three laboratories. However, the test does not state which specific one or more laboratories are different.

There exist a number of testing an hypothesis to be true or false.
A: Hypothesis: Calculated mean +- error = true mean +- error.
F = {[((Variance A) x (na –1)) + (Variance B) x (nb –1)]/(na + nb – 2)}^0.5

t calculated = (Mean A – Mean B)/ [F(1/na + 1/nb)]^0.5
t from tables (In function of the degrees of freedom)
If t cal > t table the hypothesis is false.

Oxford –Arizona (t tables = 2.6)
F = {[(2 x 1158) + (3 x 3194)]/ (3 + 4 –2) }^0.5 = 49
t calculated = (757-647)/ [49 x (1/3 + 1/4)^0.5] = 2.94 > 2.6 = Reject

Oxford – Zurich (t tables = 2.4)
F = {[(2 x 1158) + (4 x 2072)]/ (3 + 5 – 2)}^0.5 = 42
t calculated = (757 – 682)/[42 x (1/3 + 1/5)^0.5] = 2.44 ~ 2.4

A borderline case.

Arizona – Zurich (t tables = 2.4)
F = {[(3 x 3194) + (4 x 2072)]/(4 + 5 – 2)}^0.5 = 51
t calculated = (682 – 647)/[(51 x (1/4 + 1/5)^0.5] = 1.02 < 2.4 = OK

B: Hypothesis: Calculated mean = True mean. Different errors.
This test is used for the assessment of test performed in different laboratories.

Chi² test.
Here one does not use the classic method, but the relatively new method developed by the Australian scientists Drs Ward & Wilson.
To test the hypothesis that the series of determinations are consistent (i.e. all have effectively the same age) on determines the POOLED mean Ap where

$$Ap = [\text{Sum } (Ai/E^2i)]/[\text{Sum } (1/E^2i)]$$

And the test statistic T gives:

$$T = [\text{Sum } (Ai - Ap)^2]/[\text{Sum } (1/E^2i)]$$

Which has Chi² distribution on n – 1 degrees of freedom under the null hypothesis.
If the determinations are judged not to be significant different then they can be combined the pooled age being Ap, given by formula (*) and the variance of the pooled age being given by:

$$V(Ap) = \text{Sum } (1/E^2i)^{0.5}$$

If the determination are judged to be significantly different, in case if the Chi² (Calculated value) is larger than the Chi² test value given in the Statistical Tables, they should NOT be combined, but need careful reconsideration.
To determine objectively which observation(s) is/are outliers, a clustering type of approach involving the likelihood ratio is recommended.
Following Prof. Hoel (University of California) even in the case of POSITIVE Chi² values close to the limit, one should NOT draw conclusions, but asks for more and better samples.

W & W Calculations for the Shroud, based on table 1 (Nature)
Note: Because the computer does not round-off sub-results, small differences may occur, when compared with manual calculations.

Sub pooled ages and variances:
Arizona:

$$Aa = \frac{591/30^2 + 690/35^2 + 606/41^2 + 701/33^2}{1/30^2 + 1/35^2 + 1/41^2\ 1/33^2} = 647$$

$$Va = [1/(1/30^2 + 1/35^2 + 1/41^2 + 1/33^2à]^{0.5} = 17$$

Chi² test (4-1 = 3 degrees of freedom = 7.81)

Ta = (591–647)²/30²+(606 – 647)²/41²+(690–647)²/35²+(701-647)²/33² =
8.67 > 7.81 = Reject.
The NEGATIVE Chi² test for Arizona indicates, that these dates need careful consideration and should not be used in any further calculation.

Oxford

$$Ao = \frac{795/65^2 + 745/55^2 + 730/45^2}{1/65^2 + 1/55^2 + 1/45^2} = 749$$

Vo = [1/(1/65² + 1/ 55² + 1/45²)]^0.5 = 31

Chi² test (3-1 = 2 degrees of freedom = 5.99)
To = [(795 –749)²/65²] + [(745 – 749)²/55²] + [(730 – 749)/45²] = 0.68 < 5.99 = Ok

Zurich

$$Az = \frac{733/61^2 + 722/56^2 + 679/51^2 + 639/45^2 + 635/57^2}{1/61^2 + 1/56^2 + 1/51^2 + 1/45^2 + 1/57^2} = 676$$

Vz = [1/(1/61² + 1/56² + 1/51² + 1/45² + 1/ 57²)]^0.5 = 24

Chi² test (5-1 = 4 degrees of freedom = 9.49)
Tz = (733–676²/61²+(722–676)²/56²+(679-676)/51²+(639-676)²/45²+(635-676)²/57² = 2.56 < 9.49 = OK

Pooled mean +- error:

$$Ap = \frac{647/17^2 + 749/31^2 + 676/24^2}{1/17^2 + 1/31^2 + 1/24^2} = 672$$

Vp = [1/(1/17² + 1/31² + 1/24²)]^0.5 = 13

Chi² test (3 – 1 = 2 degrees of freedom = 5.99)

[(749 – 672)²/31²] = 6.17 (Oxford) → 6.17/8.36 = 74 % = outlier ?
[(676 – 672)²/24²] = 0.03 (Zurich) = OK
[(672 – 647)²/17²] = 2.16 (Arizona) = OK.
Total Chi² = 8.36 > 5.99 = Reject Chi² Nature = 6.4 %
Significance level = 2.718^-(8.36/2) = 1.2 % sig. level Nature = 5 %
Note 2.718 = e base number nat. logarithm.
This means that there only 12 chances in 1000, that the samples have the same ages. The very high fraction of Oxford, 74 % of the total Chi² test value indicates that these dates are not CONSISTENT with the other two laboratories. In other words: The three samples coming from the SAME small part of the Shroud are NOT HOMOGENEOUS in ^{14}C and therefore not representative for the whole Shroud;

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AN INTERCOMPARISON OF SOME AMS & SMALL GAS COUNTER LABORATORIES.

R. Burleigh, M. Leese & M. Tite. Research Laboratory British Museum.

(Radiocarbon Vol. 28 N° 2A 1986. p. 571-577)

Anonymous test, c-coordinated by the British Museum, between 4 AMS (Arizona, Bern, Oxford & Rochester) & 2 Small gas-counters (Harwell & Brookhaven.)

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Originally the laboratories dated TWO samples. The first results received for sample 2 suggested that the material was of much recent date than expected. By agreement with all participating laboratories a THIRD sample was issued to replace Sample 2.

Table 1: Results reported by the laboratories.

1: Egyptian ca 3000 BC			2: Peruvian ca 1200 AD			3: Peruvian 1000/1400 AD		
Date	error	$d^{13}C$	Date	Error	$d^{13}C$	Date	Error	$d^{13}C$
3440	145	-26.6	80	110	–23.3	460	190	-
4100	110	-25.5	300	100	-22.0	600	100	-22.0
4170	90	-24.2	450	80	-25.6	620	100	-26.1
4230	100	-27.0	450	90	-26.2	970	130	-22.0
4340	170	-	530	140	-22.8			
4350	110	-22.0						
4308	100	-24.1						
4517	140	(-24.1)						

Statistical techniques used are largely those used by Clark (1975) and Otlet et al (1980), except for the outlier test.

It was not felt that the individual dates should be weighted according to the inverse squared errors (as commonly recommended), because not all laboratories provided complete information about how the errors were computed and they may include different sources of error.

Outliers.

The relative spreads of the dates for each sample are shown in the diagrams below (each sample has its own scale). Values suspected as being possible outliers are indicated in brackets and were tested for significance. The values closest to the suspected outlier and the end points of the ranges are also shown.

Sample 1

(3440) ---------- 4100 ---------- 4517

Sample 2

(80)----------(300) ---------- 450 ----------530

Sample 3

460 ----------670 ----------(1550)

Table 2 Results of outlier tests.

Sample	Candidate outlier	test statistic	Probability of higher value of O	Calculation
1	3440	O = 0.6	<1 % (significant)	4100-3440/4517-3440=0.64
2	80	O = 0.8	>5 % (not significant)	450-80/530-80=0.82
3	1550	O = 0.6	<1 % (significant)	1550-670/1550=0.80

Table 3: (Here the author added sample 4, the results for the Shroud.)

Sample	Chi²	Degrees of Freedom	Probability of higher value of X^2
1	9	6	> 10% (not significant)
2	11	4	< 5 % (significant)
3	1	3	>>10 % (not significant)
4	8.56	2	<< 5 % (significant)

It is concluded from this test that there is no evidence that the measurements of samples 1 and 3 are significantly more variable than expected, on the basis of the quoted errors. Measurements on sample 2, on the other hand are more variable than their quoted errors would suggest.

Note: The same goes for sample 4, the Shroud sample (Table 2. Nature).

But here sample 2 was replaced by a new sample, where in the case of the Shroud, one reworked the statistical analysis !

Where Dr. Wölfi (Zurich) agrees to admit in general: "The ^{14}C method is not immune to inaccurate dating when non apparent problems exist in samples from the field. The existence of significant indeterminable errors occurs frequently".

(Radiocarbon N° Vol. 28 2A Pages 719-725)

But radiocarbon experts refuse to consider, that such "indeterminable error" may have influenced the radiocarbon dating of the Shroud of Turin.

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THE NATURE REPORT.

Abstract:

Very small samples from the Shroud of Turin have been dated by AMS (Accelerator Mass Spectrometry) in laboratories at Arizona, Oxford and Zurich. As controls three linen whose ages had been determinate independently were also dated.

The results provide conclusive evidence that the linen of the Shroud of Turin is mediaeval.

Note 1:

It may be useful to compare this statements with the footnotes, pre-printed on the OFFICIAL radiocarbon dating report of the University of Oxford.

The footnote reads:

(I) : It should be borne in mind that the measurement has been made on organic material and that this cannot be regarded as a guarantee of the articles date of manufacture.

(II) : When the Laboratory is informed that the sample has been treated with preservative of fungicide care is taken to remove this. It should noted however that the undetected presence of such contaminants may effect a radiocarbon result.

(III) : This result is given in good faith, however the Laboratory takes no responsibility for financial loss incurred through an erroneous report being given.

AUTHOR'S NOTE:

These footnotes do reflect exactly the opinion on radiocarbon dating results of many historians and archaeologists.

It seems unbelievable, that in the case of the Shroud, Oxford does not take in account any of the warnings given on their own documents.

The Shroud of Turin, which many people believe was used to wrap Christ's body, bears detailed front and back images of a man who appears to have suffered whipping and crucifixion.

Note 2:

This is not correct. The words "appears to have" should have been written "HAS suffered whipping, crucifixion and the WHOLE passion according to the FOUR Gospels." As proven behind any reasonable doubt by Dr. Barbet and several other scientists.

It was first displayed at Lirey in France in the 1350s and subsequently passed into the hands of the Dukes of Savoy. After many journeys the shroud was finally brought to Turin in 1578 where, in 1674, it was placed in the Royal Chapel of Turin Cathedral in a specially designed shrine.

Note 3:

This not correct.

The document cited here is the UNDATED draft of a "Memorandum" written by Pierre d'Arcis, bishop of Troyes, about 1390. Here reference is made to a statement of the late Henry de Poitiers, bishop of Troyes (+1370), who advised against the veneration of the Shroud, some 35 years ago.

In that era, Geoffroy de Charny, build indeed a small wooden church in the village of Lirey. But in none of his many writings, Geoffroy de Charny noted a single word about a Shroud.

A display of the Shroud is cited in several documents:

"Journal of the crusader Robert de Clary" (1204 AD) who saw the Shroud in Constantinople.

The "Codex Pray (1196 AD).

The "Imagine Edessana" (944 AD), written when the Shroud was transferred from Edessa to Constantinople;

The "Journal of Arculph de Perigeuex (675 AD), who saw the Shroud in Jerusalem.

A bull of Pope Eusebius (309 AD), ordering that Holy Mass shall be celebrated on [puro lineo] pure linen, as the linen, used to bury [corpus domini nostri Jesu Christi in sindone linea munda] in a Shroud of clean linen.

And of course, the oldest texts about the Shroud, in the FOUR Gospels.

One may wonder, why one give more weight to the Memorandum of bishop d' Arcis than to the historical documents cited here.

Photography of the Shroud by Secondo Pia in 1898 indicated that the image resembled a photographic "negative" and represents the first modern study.

Subsequently the shroud was made available for scientific examination, first in 1969 and 1973 by a committee appointed by Cardinal Pellegrino (1) and then again in 1978 by the Shroud of Turin Project (STURP) (2). Even before the first investigation, there was a possibility of using radiocarbon dating to determine the age of the linen from which the shroud was woven. The size of the sample then required, however was ~ 500 cm², which would clearly have resulted in an unacceptable amount of damage

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Note 4

TWO eminent Shroud scholars proposed indeed radiocarbon dating of the Shroud to Ex-King Umberto of Italy, Fathers Otterbein & Rinaldi (Holy Shroud Guild of America). At the advise of Dr. W. Libby, the inventor of ^{14}C dating, the proposal was rejected, because of large size of the samples needed.

It was not until the development in the 1970s of small gas-counters and Accelerator-mass-spectrometry techniques (AMS), requiring samples of only a few square centimetres, that radiocarbon dating of the shroud became a real possibility.

To confirm the feasibility of dating the shroud by these methods an inter-comparison, involving four AMS and two small gas-counters, and the dating of THREE known-age textile samples, was coordinated by the British Museum in 1983. The results are reported by Burleigh et al (3)

Note 5:

This is not correct. The Burleigh et al report states: "The 6 laboratories received TWO samples".

In fact, sample 2 could NOT be dated satisfactorily. Because the ^{14}C dating was conflicting with historical evidence, the results were rejected. Sample 2A was replaced by another sample 2B.

The laboratory that made the biggest mistakes will become one of the THREE CHOSEN laboratories, selected for the final radiocarbon dating of the Shroud.

Following inside information, the laboratory of Zurich dated sample 1 about 1000 years too OLD and sample 2 about 400 years too young. The reason was the application of a new pre-treatment procedure.

But one may wonder, how one can explain errors in different directions by the same procedure ?

Please read the "Burleigh et al report." given above.

Following this inter-comparison, a meeting was held in Turin in September-October 1986 at which seven radiocarbon laboratories (five AMS and two small gas-counters) recommended a protocol for dating the shroud. In October 1987, the offers from three AMS laboratories (Arizona, Oxford and Zurich) were selected by the Archbishop of Turin, Pontifical Custodian of the shroud, acting on instructions from the Holy See, owner of the shroud.

Note 6

The letter to Card. Ballestrero, signed by Card. Casaroli, (Vatican) was kept secret, until the last moment.

At the same time, the British Museum was invited to help in the certification of the samples provided and in the statistical analysis of the results. The procedures for taking the samples and treating the results were discussed by representatives of the three chosen laboratories at a meeting at the British Museum in January 1988 and their recommendations (4) were subsequently approved by the Archbishop of Turin.

Note 7:

Originally, the "Papal Academy" and the "Colonnetti Institute" (Metrology) at Turin were involved in the statistical assessment of the results.

One may wonder why the British Museum was chosen to assess the radiocarbon results !

In fact one should have invited a number NEUTRAL professional statisticians, from prestigious Universities, acquainted with the assessment of radiocarbon dating results.

The elimination of leading laboratories like Rochester, Brookhaven and Harwell was a surprise for the scientific world.

Prof. Gove (Rochester) and Prof. Harbottle (Brookhaven) tried to stop the project, but the "chosen" laboratories were so pleased with the situation, that they did not follow the "siren-song" from over the ocean.

In a letter to Sir David Wilson, Director of the British Museum, Prof. Gove wrote: "I am astonished you would permit the British Museum to risk having his reputation called into question in what has became a somewhat shoddy enterprise. I fear, sadly, that Mike Tite has taken on a responsibility which he and the British Museum may live to regret."

Very strange was also the elimination of all small gas-counters laboratories. Probably, one tried to avoid a new "Pete Marsh" situation.

REMOVAL OF SAMPLES FROM THE SHROUD.

The sampling of the shroud took place in the sacristy at Turin Cathedral on the morning of 21 April 1988. Present were representatives of the Church, British Museum, Oxford, Arizona and Zurich.

The samples were cut by G. Riggi, assisted by two textile experts (Prof. Testore Departement of Materials Turin Polytechnic in Turin and G. Vial of Musée des Tissues d'Etude des Textiles Anciens in Lyon.)

The shroud was separated from the backing cloth along its bottom left-hand edge and a strip (~10mm x 70 mm) was cut from just above the place where a sample was previously removed in 1973 for examination. The strip came from a single site of the main body of the shroud, away from any patches or charred areas. Three samples, each ~ 50mg in weight, were prepared from that strip.

Note 8:

The place were the samples were taken is very close to a large water stain.

The description is almost identical, as described in "L'Osservatore Romano" and the "EHT Zurich Yearbook 1988". On page 48 one reads:

"von ein etwa 1 cm breiter und 7 cm langer Streifenwurden in drei etwa 50 mg schwere Proben unterteilt ….."

Translation: "a strip, about 1 cm wide and 7 cm long, was divided in THREE samples, weighing each about 50 mg."

Prof. Riggi gives another description: "The strip of 8 cm² was reduced to 7 cm², because of the contamination of the linen by threads of another nature that could influence the dating. The three samples were cut from the strip of 1 x 7 cm.

A theoretical weight of 7 cm² x 23 mg/cm² = 161 mg.

The laboratories received only:

52 (Oxford) + 52.8 (Zurich) + 53.7 (Arizona) = 158.5 mg.

None of these sources notes the presence of a sample in TWO pieces.

Dr. Tite who actually placed the samples in the containers, was unable to answer any question about any anomaly in the sample taking operations.

In Arizona, one was not surprised to find a sample in TWO pieces.

It took about TWO years, before Arizona confirmed the facts.

Let there be no doubt, if one makes the same deviations from the protocol, in any doping or legal case, the validity of the investigation will become very doubtful.

I have studied the video of the entire operation.

There is no doubt that Prof. Riggi did not cut a strip of 1 x 8 cm, but a strip of ~8.1 x 2.6 cm (estimated) from the main body of the Shroud. The sample had the shape of irregular trapezium, in fact a rectangle missing in one of the corners; the "Raes sample", which was a kind of irregular triangle of ~6.1 x 1 cm.

Following Prof. Riggi, the weight of the strip was 497 mg.

Based on the official specific weight of the Shroud (23 mg/cm²) one can estimate the surface of the trapezium: 497 mg/23 mg/cm² = 21.61 cm².

To obtain a rectangle we have to add the void corner: 21.61 + 3.05 = 24.66 cm².

This is NOT in agreement with the surface of a rectangle of 8.1 x 2.6 = 21.06 cm²

Following the recording on video, the weight was 478.1 mg, while other sources mention a brut weight of 540 mg.

Following the Testore report, from the this piece was cut a strip of 8.1 x 1.6 cm weighing 12.96 mg. This corresponds with a the official specific weight of 23 mg mg/cm².

The same confusion goes for the Zurich and Oxford samples.

To avoid any confusion, I will quote again the GERMAN text, taken from E.H.T Yearbook 4988, page 48. Under a photo of the sample one reads: "Masse des Turiner Grabtuch (Zurich) 1.4 x 1.8 cm. Abbildung mit mm. Massstab."

Translation:

"Dimensions of the Turin Shroud (Zurich) 1.4 x 1.8 cm. Representation with a mm. Measuring rod."

From the weight of the Zurich sample 52.8 mg, one can determinate the specific weight to be: 52.8 mg/(1.4 x 1.8) cm² = 20.95 mg/cm².

This is not comparable with the OFFICIAL specific weight of the Shroud: 23 mg/cm².

Author's note:

I have verified the Zurich and Oxford dimensions on a 4.25 times enlarged photo.

The Zurich photo shows a about regular rectangle of 1.3 x 1.6 cm. A surface of 2.08 cm². This gives a specific weight of 52.8/2.08 = 25.4 mg/cm². About 10 % heavier than the official specific weight of 23 mg/cm².

The Oxford sample is NOT a rectangle, but of rather irregular shape.

The part above the centre of the herringbone is about a rectangle of 1.25 x 1.05 cm. Surface = 1.3125 cm²

The part below the centre of the herringbone is about a rectangular trapezium, with dimensions:

Height = 0.59 cm. Lower side = 1.25 cm. Upper side = 1.45 cm. Surface = 0.797

Total surface = 0.797+1.3125 = 2.11 cm² Specific weight = 52/2.11 = 24.6mg/cm²

About 7 % heavier than the official specific weight of 23 mg/cm².

Based on these figures one may wonder, what caused this gain in weight? Contamination by pollens, fungi, smokes or maybe repairs ???

But this not all !

If one places the samples next to one another, taking in account that the place of the Oxford sample is fixed, because of the fold in the sample and the Shroud, than the edges or the centres of the herringbone do not match.

In the Zurich sample the centre of the herringbone divides the sample in two parts, showing ratios of 43.5 % and 56.5 %.

The Oxford sample shows ratios of 38.6 % and 61.4 %.

Please note that the weights of the TWO Arizona samples, given by the TWO Italian experts (?) are NOT compatible.

Following Riggi : 50.1 mg & 3.6mg = 53.7 mg

Following Testore: 39.6 mg & 14.1 mg = 53.7 mg.

One (or both ?) must be mistaken .

Based on a Arizona photo, showing the TWO parts, Testore was probably right.

Clearly, Italian textile experts and radiocarbon scientists are not used to take good measurement.

When I asked the opinion of Dr. Hedges about this confusion, I replied: "Indeed we should given a better description of the samples." (Private letter)

The samples were then taken to the adjacent Sala Capitolare where they were wrapped in aluminium foil and subsequently sealed inside numbered stainless-steel containers by the Archbishop of Turin and Dr. Tite. Samples weighing 50 mg from two of the three control samples were similarly packaged. The three containers containing the shroud (to be refereed to as sample 1) and two control samples (samples 2 and 3) were then handed to representative of each of the three laboratories together with a sample of the third control sample (sample 4). Which was in the form of threads. All these operations, except for the wrapping of the samples in foil and their placing in containers, were fully documented by video film and photography.

Note 9:

This is really UNBELIEVABLE. How can integer scientists, like Dr. Tite, co-ordinator and representative of the British Museum, act in this way?

NEUTRAL process-servers or public notaries should have carried out all these operations. In fact, Cardinal Ballestrero and Dr. Tite should have been the very last persons to touch the samples.

No wonder that the most wild rumors were spread around.

The laboratories were not told which container held the shroud sample. Because the distinctive three-to-one herringbone twill weave of the shroud, it was possible for a laboratory to identify the shroud sample.

If the samples had been unraveled or shredded rather than, being given to the laboratories as whole pieces of cloth, then it would have been much more difficult, but not impossible top distinguish the shroud from the controls. (With unraveled or shredded samples, pre-treatment cleaning would have been more difficult and wasteful.)

Note 10:

This is really incorrect.

First of all, radiocarbon experts are very seldom textile experts.

In 1973, Prof. Gilbert Raes, a well-known textile expert, was not able to identify the Shroud sample from the side strip sample. Note that he was working on samples about 3 times larger, than the ones examined by the radiocarbon experts.

None of the laboratories reported any problem with sample 4, which was in the form of threads.

In fact, during the preparation of the operation, Prof. Gove proposed this sampling method, to assure a truly representative sample of the whole Shroud, by taking threads from different parts of the Shroud.

The Italian engineer E. Brunati made the following statement, during his lecture at the Cagliari Shroud Symposium (April 20, 1990): "The report issued in the British magazine *Nature* is clearly untrue, where it speaks of abandoning the blind test procedure."

At the same Symposium, the French Prof. O. Pourrat gave a lecture about "True blind radiocarbon dating of the Shroud is feasible." One has simply to follow the classic methodology used to evaluate therapeutic medicinal trials, based on controlled, randomised and blind procedures, using placebos.

Because the shroud had been exposed to a wide range of potential sources of contamination and because of the uniqueness of the samples available, it was decided to abandon blind-test procedures, in the interests of effective sample pre-treatment. But the three laboratories undertook not to compare results until after they had been transmitted to the British Museum. Also at two laboratories (Oxford and Zurich), after combustion to gas, the samples were recoded so that the staff making the measurements did not know the identity of the samples.

Note 11:

In the report in "L'Osservatore Romano", one reads nothing about Turin agreement for abandoning the blind test procedure !

Following the Riggi report, Dr. Tite who delivered the TWO control samples, did NOT KNOW their origin and age. (Blind testing for the Shroud dating was decided at the Trondheim Conference.)

This indicates, that the decision to abandon blind testing, was already taken BEFORE 21 April, without the consent of Prof. Riggi or any other Turin representative.

Experts know that blind testing is mandatory, to assure correct application of the procedures and consequently correct results.

CONTROLS

The three control samples, the approximate ages of which were made known to the laboratories, are listed below. Two were in the form of whole pieces of cloth (sample 2 & 3) and one in the form of threads (sample 4)

Note 12:

Here again blindfold testing is abandoned.

Normally, the laboratories should test in total blind. The "blind code" is only to be revealed on the final day, at a public meeting, after the laboratories did publish their results.

In the report in "L'Osservatore Romano" one reads nothing about a sample in the form of threads or a FOURTH sample.

Sample 2: Linen (sample QLT/32) from a tomb excavated at Qasr Ibrim in Nubia, by Prof. J.M. Plumer for the Egypt Exploration Society in 1964.

On the basis of Islamic embroidered pattern and Christian ink inscriptions, this linen could be dated from the eleventh to twelfth centuries.

Note 13:

On the same basis, was dated the pseudo Shroud of Caduoin (France).

But the possibility that one embroidered or made inscriptions LATER on the much older linen was never examined.

Sample 3: Linen from the collection of the Department of Egyptian Antiquities at the British Museum, associated with an early second century AD mummy of Cleopatra from Thebes (EA 6707). This linen was dated in the British Museum Research

Laboratory using liquid scintillation counting, giving a radiocarbon age of 2010+-80 yr BP (B.M. 2558). This corresponds to a calendar age, rounded to the nearest 5 years of 110 cal BC – AD 75 at the 68 % confidence level (5), where cal denotes calibrated radiocarbon dates.)

Note 14:

The mummy of Cleopatra from Thebes is that of a young girl, who died at the age of 11, in the era of Emperor Hadrian (117 – 138 AD).

The dating given by the British Museum and the laboratories of Oxford, Arizona and Zurich is thus NOT as good as presented.

Sample 4: Threads removed from the cape of St. Louis d'Anjou, which is held in the chapel of the basilica of St. Maximim (Var. France.) On the basis of the stylistic details and the historical evidence the cope would be dated at ~AD 1290-1310 (Reign of King Philip IV of France).

Note 14:

The history of this mysterious "fourth sample" is word telling.

Without consulting Turin, Dr. Tite decided to introduce a new control sample. In a letter dated 12-02-1988 (Reference: British Museum. MST/IMP) Dr. Tite asked the French Prof. J. Evin to provide him with a mediaeval linen sample, weighting ~120 mg., resembling a much as possible the weave and colour of the Shroud.

This choice for a linen dating XIII – XIV Th. Century, indicates that one assumed the Shroud to be of that era.

With the co-operation of Mr Gabriel Vial, a French textile expert, one started to search in vain, for linen, dating about XIII-XIV Th. Century AD.

After consulting in vain the Museum de Cluny (Paris. France), a suitable sample was found in St. Maximim.

This sample, taken from the cape of St. Louis d'Anjou, was brought in person by Prof. Evin and the French Textile expert Vial to Turin, on April 21.

After the Cardinal had already left the Sala Capitolare, Vial gave the sample in the form of threads to Dr. Tite, who REFUSED to accept the sample (which he himself had asked for!). In spite of the arguments of Prof. Riggi, the sample was accepted and distributed, wrapped in envelopes, to the laboratories.

MEASUREMENT PROCEDURES.

Because what degree dirt knew it, smoke or other contaminants might affect the linen samples, all three laboratories subdivided the samples, and subjected the pieces to several different mechanical and chemical cleaning procedures.

All laboratories examined the textile samples microscopically to identify and remove foreign material.

Note 15:

Following the long thanking list, where one reads: "Oxford thank P.H. South (Precision Processes Textiles LTD. Derby) for examine and identifying the cotton found on the shroud sample." Indeed, in Oxford one found cotton threads on the shroud sample.

In "Textile Horizons" one reads: "Prof. Hall noticed two or three fibres which looked out of place. The strange fibres, looking like human hairs, were send to Derby. Under the 200 x microscope the fibres were identified as cotton.

The cotton is a fine dark yellow strand, possibly of Egyptian origin and quite old. Unfortunately it is impossible to say how it ended up in the Shroud, which is basically made from linen. It may have been used for repairs at some time in the past or simply be became bound in when the fabric was woven …."

The conclusions of Mr. South are comparable with the conclusion of the Belgian Prof. Gilbert Raes, who examined a Shroud sample back in 1973. (1).

It seams unbelievable, but Prof. Hall did not pay much attention on the sentence "It may have been used for repairs ….." Where any repair would render any radiocarbon dating meaningless !

In Arizona one found a red and a blue thread on the Shroud sample.

Under the microscope, Zurich found not contamination.

From 52.8 mg sample one obtained ~21 mg pure carbon. A loss of about 10 %.

(Private letter Dr. Wölfli)

The findings in the THREE laboratories are in contradiction with earlier examinations by Prof. Raes, Max Frei, Paul Maloney, Prof. Riggi and Testore, who all reported heavy contamination.

Dr. Garza-Valdez, after finding heavy contamination on a illegal Shroud sample, invited Prof. Gove and Dr. Donahue to look through his microscope. Both scientists recognized that such a contamination may have influenced the radiocarbon dating.

One should also take in account the structure of linen.

About 2000 of these HOLLOW ribbon-like cellulose molecules do form a chain. These parallel bounded chains, do form a number of ethereal bounded glucose macromolecules.

The huge number of hollow fibres is the reason why cotton and linen can absorb a large amount of liquids. Following Dr. M. Cl. Van Oosterwyck, this may be the reason, why it is very difficult to remove contamination, fixed INSIDE the hollow tubes of linen.

Example: Loss in chemical cleaning of the not contaminated Zurich sample.

Chemical composition of cellulose is $(C_6\text{-}H_{10}\text{-}O_5)n$

The value of n varies for cotton = ~2000, for flax = ~2400.

6C = 72 10H = 10 5O = 80

Ratio $C/C_6\text{-}H_{10}\text{-}O_5$ = 72/162 = 0.444

The theoretical amount of pure carbon in a sample weighing 52.8 mg, is

(72 x 52.8)/162 = 23.47 mg.

A significant loss of about 10 % !

For the complete details on pre-treatment, conversion into graphite targets and specific measurements procedures, please see the Nature report.

Each laboratory measured the graphite targets made from the textile samples, together with appropriate standards and blanks as a group (a run). Each laboratory performed between three and five independent measurements for each textile sample, which were carried out over a time period of about one month.

Note 16:

If one compares the dates given in Table 2, than one will remark that Zurich dated sample Z.3.1, only THREE times, because the loose weave of the linen led to his disintegration, during strong and weak chemical pre-treatment. Arizona dated all sample FIVE times, except for the Shroud, which was dated only FOUR times. Strangely, no explanation is given.

The reason was found much later.

In fact Arizona, dated the Shroud EIGHT times.

During FOUR sessions, TWO runs were made, using the same standards and blanks. In theory, during each session, one should find about the SAME errors

The results were:

Combined:

Session 1 = 606+-41 & 574+-45 $606/41^2 + 574/45^2$

$---------- = 591 +- 30$

Error: $[1/(1/41^2 + 1/45^2)]^{0.5} = 30$ $1/41^2+1/45^2$

Session 2 = 753+-51 & 632+-49 $753/51^2 + 632/49^2$

$---------- = 691 +- 41$

Error: $[1/(1/51^2 + 1/49^2)]^{0.5} = 41$ $1/51^2 + 1/49^2$

Session 3 = 540+-57 & 676+-59 $540/57^2 + 676/59^2$

$---------- = 606 +- 35$

Error: $[1/(1/57^2 + 1/59^2)]^{0.5} = 35$ $1/57^2 + 1/59^2$

Session 4 = 701+-47 & 701+-47 $701/47^2 + 701/47^2$

$---------- = 701 +- 33$

Error: $[1/(1/47^2 + 1/47^2)]^{0.5} = 33$ $1/47^2 + 1/47^2$

Strangely, this combination was done without applying a Chi^2 test.

Chi^2 test for EIGHT data (Chi^2 For 8 – 1 = 7 degrees of freedom 14.07):

$(753 – 646)^2/51^2 = 4.402$

$(701 – 646)^2/47^2 = 1.369$

$(701 – 646)^2/47^2 = 1.369$

$(676 – 646)^2/59^2 = 0.259$

$(646 - 632)^2/49^2 = 0.082$

$(646 – 606)/41^2 = 0.952$

$(646 – 574)^2/45^2 = 2.560$

$(646 – 540)^2/57^2 = 3.458$

Total = 15.189

$Chi^2 = 15.19 > 14.07$ → Negative = Reject.

Following the "High Precision Calibration of the ^{14}C Time Scale" (Radiocarbon M. Stuiver & Paerson. Table 3-G)) a calibrated radiocarbon age of 540 corresponds to a calendar age of AD 1407. With an error of +-57 the calendar age range becomes AD 1317- 1348 and 1388-1431.

A calibrated radiocarbon age 574 corresponds to AD 1335 & AD 1396

With an error of +-45, the calendar age range becomes AD 1304-1358 & AD 1376-1405.

The negative Chi^2 test SHOWS CLEARLY that the dates are not consistent.

Such dates needs careful consideration and should not be combined.

Because the Shroud is historically dated before AD 1350, radiocarbon ages like 540 and 576 are clearly to young, Dr. Damon ASKED the British Museum if Arizona should make new measurements.

Probably inspired by some radiocarbon expert, familiar with the British Museum, the British Museum asked Arizona to COMBINE the two DEPENDENT runs made during the same session into one INDEPENDENT date. (See above.)

This was to be done following the Ward & Wilson method. Dr Damon noted to the British Museum, that such a combination, would cause unusually small errors. Which is only correct for the errors in Table 1, not for Table 2.

From heat experiments of Mario Moroni, we know that combination of aberrant dates at that time was customary at Arizona.

The reference sample was dated 1296+-53.

The heated sample was dated 1405+-65

When Moroni asked some explanations about the difference, Arizona proposed a new date: 1337+-48

By co-incidence the combination of the TWO dates results in:

$(1296/53^2 + 1405/65^2)/(1/53^2 + 1/65^2) = 1338+-48$

One the notes, concerning Oxford sample 2.2b, (Table 1): "One anomalous replicate (out of 6) for independent measurement 2.2b, if rejected it reduces date by 40 years. Final date actually reduces by 20 yr.", indicates that in Oxford, each sample was probably measured SIX times.

This means that one DEPENDENT result, for sample 2, out of SIX was ~1050 years old !

If one dated the Shroud also SIX times, then a error of 65 would be the mean of SIX errors of ~ 160 years ! A age fork of 630 – 955 RC. years (68 % confidence) and 470 – 1115 RC. years (95 % confidence).

Also the time period, stated in Nature is not correct. The first measurement was made end May by Arizona. Oxford measured the samples on 20-21 of July 1988.

The results of these INDEPENDENT measurements (Table 1) in each case represent the average of several replicate measurements made during each run (samples are measured sequentially, the sequence being repeated several times.)

Note 17:

Prof. Wölfli provided me a paper about the Zurich AMS procedure.

Each run is composed out of 10 … 20 very small sample targets, normally including TWO standards and TWO blanks. The samples are measured sequentially during about 10 seconds. The results are stored in a computer. Following the importance of the sample, up to FOUR runs is made.

Strangely, Prof. Wölfli and the other two laboratories refused to give information about the number of targets or runs made on the Shroud.

Any statistician knows that the number of measurements is KEY information by the assessment of the results.

The more measurements, the more weight is attributed to the result.

Each "independent measurement" given in Table 1 may be the averaged results of about 10 to 40 measurements.

Statistically spoken, a results of 795+-65, based on ONE run, will turn into 795+-32, if FOUR runs are made.

On the other hand, if the error 65 is the average of FOUR runs, than the errors on the "dependent" samples may be as high as 130 !

(For the specific measurements procedures see the Nature report.)

Table 1 Basic data (individual measurements)

Sample 1:

	$-d^{13}C$	Table 2 Computer Chi²
Ar	-25.0 591+-30 690+-35 606+-41 701+-33	646 +-31 647+-17 8.7 F
Ox	-27.0 795+-65 730+-45 745+-55	750 +-30 749+-31 0.7 P
Zu	-25.1 733+-61 722+-56 635+-57 639+-45 679+-51	676 +-24 676+-24 2.7 P
	Weighted mean :	689 +- 16 672+-13
	Unweighted mean:	691+- 31 691+-31
	Chi²:	6.4 F 8.56 F
	% Significance level:	5 1.2

Note: See the differences between Nature and the computer !

All Chi²results marked F are not acceptable. X = Border case. P =OK

Sample 2:

		Table 2 Computer Chi²
A	-25.0 922+-48 986+-56 829+-50 996+-38 894+-37	927+-32 927+-20 9.05 x
O	-27.0 980+-55 915+-55 925+-45	940+-30 938+-29 0.84 P
Z	-23.6 890+-59 1036+-63 923+-47 980+-50 904+-46	941+-23 941+-23 44.0 P
	Weighted mean :	937+-16
	Unweighted mean:	936+- 6
	Chi²:	0.1 P
	% Significance level:	90

Sample 3:

		Table 2 Computer Chi²
A	-23.6 1838+-47 2041+-43 1946+-55 1983+-37 2137+-46	1995-46 1995-20 22.3 F
O	–27.0 1955+-70 1975+-55 1990+-50	1980-35 1975-33 0.17 P
Z	–22.0 1984+-50 1886+-48 1954+-50	1940-30 1940-28 2.98 P
	Weighted mean:	1964-20
	Unweighted mean:	1972-16
	Chi²:	1.3 P
	% Significance level:	50

Note:

The very high (and therefore unacceptable) Chi² test value 22.3 for Arizona is not even noted by the statisticians who made the statistical analysis.

Sample 4:

		Table 2 Computer Chi²
A	-25.0 724+-42 778+-88 764+-45 602+-38 825+-44	722+-43 722+-20 16.7 F
O	-27.0 785+-50 710+-40 790+-45	755+-30 756+-26 2.3 P
Z	–25.5 739+-63 676+-60 760+-66 646+-49 660+-46	685+-34 685+-25 3.0 P
	Weighted Mean:	724+-20
	Unweighted Mean:	721+-20
	Chi²:	2.4 P
	% Significance level:	30

Note:

Again, one neglected the very NEGATIVE Chi² test value for Arizona.

Systematically, for the FOUR samples, the LOW Arizona errors were enlarged by a factor of about 2 !!

Table 3 Calendar age ranges at confidence levels 68 % & 95 %.

Sample	Mean (yr BP)		Error ranges
1	691+-31*	68 %	1273-1288 A
2		95 %	1262-1312 & 1353-1384 AD
2	937+-16	68 %	1032-1048 & 1089-1119 & 1142-1154 AD
		95 %	1026-1160 AD
3	1964+-20	68 %	11-64 AD
		95 %	9 BC – 78 AD
4	724+-20	68 %	1268 – 1278 AD
		95 %	1263 – 1283 AD

*** Confidence limits based on the unweighted mean, assuming a Student t5 distribution. Range estimated based on the dispersion.**

The errors, which are quoted in Table 1 at the 1 sigma level (sigma is standard deviation), include the statistical (counting) error, the scatter of results for standards and blanks and the uncertainty in the $d^{13}C$ determination. (Arizona includes the $d^{13}C$ error at a later stage, when combining sub-samples; Oxford errors below 40 year are rounded up to 40).

Note 18:

The remark about the $d^{13}C$ –25 o/oo of Arizona is strange, for the $d^{13}C$ given in Table 1, is exactly the international standard –25 o/oo.

This indicates that no correction for $-d^{13}C$ is required.

The error in ^{13}C determination is normally as low as 0.25 %.

In vain, I asked the Arizona laboratory and the British Museum, to show me on paper, how one arrived on the Arizona date 647+-31, given in Table 2

Following the Ward & Wilson method:

Pooled mean Arizona:

$$\frac{701/33^2 + 690/35^2 + 606/41^2 + 591/30^2}{1/33^2 + 1/35^2 + 1/41^2 + 1/30^2} = 647$$

Error:

$$[1/(1/33^2 + 1/35^2 + 1/41^2 + 1/30^2)]\text{^}2 = 17$$

Classic method: Mean =+- error = 647 +- 28

First I assumed that the "enlarging" was due to the application at a later stage of the Arizona $d^{13}C$.

This leads to a to large $d^{13}C$ error of $(17^2 + X^2) = 31^2 \rightarrow X = 26$

Probably, inspired by Ward & Wilson, one combined the quoted error with the standard error based on the scatter, as given by the classic method.

Standard error = 28 and W & W error = 17 Combined $(28^2 + 17^2)\text{^}0.5 = 33$

Because this is the case for all FOUR Arizona errors, one may assume that these low errors are the result of combining paired results.

More quantitatively, to establish whether the scatter among the three laboratory means was consistent with the quoted errors, a X^2 (= Chi^2) test was applied to the dates

for each sample, in accordance with the recommended procedure of Ward & Wilson (13).

Note 19:

As stated before, one should not only verify the results for the 3 laboratories given in Table 2, but one should apply a Chi² test to each laboratory result BEFORE it was placed in Table 2.

When the calculated Chi² value is larger than the tabulated Chi² value, these data are judged to be inconsistent and should not be used in any further calculation. (See above Table 1, with the Chi² test values.)

The results of this test, given in Table 2, shows that it is unlikely that the errors quoted by the laboratories for sample 1 fully reflect the overall scatter.

The errors might still reflect the uncertainty in the three dates relative to one another, but in the absence of direct evidence on this, it was decided to give the three dates for sample 1 equal weight in determining the final mean, and to estimate the uncertainty in that mean from the scatter of results.

Note 20:

Here one tries only to AVOID to state the fact, that a the TRUE weighted mean is 672+-13 and the TRUE Chi² test value is 8.56, much larger than the tabulated Chi² test value 5.99, for (3-1) degrees of freedom at 95 % confidence.

But instead of acting following the advice of Prof. Hoel (University of California) "Such data should NOT be used in further calculations", the British Museum started a deceptive mixing of both the Ward & Wilson and the classic methods.

I asked the advise of Drs. Ward & Wilson. They replied :"One should solely have used our method !"

As shown in Table 2, the UNWEIGHTED mean of the radiocarbon age of sample 1 and his uncertainty is 691+-31 yr. BP. (Before 1950)

Note 21:

This is not correct, the unweighted mean, based on the scatter, is 695+-31.

The weighted mean based on the scatter is 691+-31.

The confidence limits for sample where obtained by multiplying the uncertainty td, the value of a Student's distribution with a degree of freedom at the appropriate level. The value of d that lies between the inter- and intra-laboratory degrees of freedom – that is between (3-1) and (12-3) was estimated at 5 on the basis of an analysis of variance on the 12 individual measurements supplied by the laboratories. (14)

Note 22:

In vain, I asked Dr. Leese to explain this rather strange construction, showing me his calculations. This would have been much more simple than the lengthy bizarre explanation given in Nature.

Because the final result is the average of at least 120 measurements the value of td = 1.96.

Nevertheless I have tried in vain to made the analysis of variance.

Because one does not know, which "variance" Dr. Leese used, we will use THREE different possibilities.

Ward & Wilson variance:
Variance Arizona Error: 17 →17^2 = 289 Oxford Error 30→ 30^2 = 900
Variance Arizona Error: 31→ 31^2 = 961 Zurich Error 24 →24^2 = 576

$$\frac{[289/4 + 900/3 + 576/5]^2}{(289/4)^2/(4+1) + (900/3)^2/(3+1) + (576/5)^2/(5+1)} = 9 - 3 = 6$$

When one uses the Arizona error 31, than td becomes:

$$\frac{[961/4 + 900/3 + 576/5]^2}{(961/4)^2/(4+1) + (900/3)^2/(3+1) + (576/5)^2/(5+1)} = 11.8 - 3 = 9$$

Because it is not likely that the Ward & Wilson method is used, in the reference cited (14), we will also use the variance (s^2), determinate following the classic method. (See page 13)

s^2 = Arizona: 3194 Oxford: 1158 Zurich: 2067

$$\frac{[3194/4 + 1158/3 + 2067/5]^2}{(3194/4)^2/5 + (1158/3)^2/4 + (2067/5)^2/6} = 13 - 3 = 10$$

Individual measurements from different laboratories were weighted according to their inversed squared errors, but the contributions from different laboratories were weighted equally, thus ensuring consistency with table 2.

Note 23:
Still no explanation how one turned the Arizona error 17 into 31 !
The same goes for the errors on the other Arizona samples !

Thus for sample 1, where the error has been estimated from the scatter, 68 % and 95 % confidence limits for the TRUE radiocarbon date were found from the 1.1 and 2.6 sigma errors about the unweighted mean respectively, the factors being obtained from standard tables of the t5 distribution.

However, for sample 2, 3 and 4, the limits were obtained the usual way from 1 sigma and 2 sigma quoted errors about the weighted mean, assuming normality.

Note 24:
The t coefficient for 2 to 9 degrees of freedom and 95 % confidence are:
(2) 4.303 (3) 3.182 (4) 2.776 (5) 2.571 (6) 2.447 (7) 2.365 (8) 2.306 (9) 2.262
(Table Page .Perry Chemical Engineering Handbook)
Normally one uses for >120 measurements and 95 % confidence the factor 1.96.

Another problem is the "switch over" from the Ward & Wilson method to the classical method. Using the three means following W & W 647 - 750 – 676 one obtains the UNWEIGHTED mean 691+-31 (Table 2).

Following the classic method, from the three means 647 – 757 – 682 one obtains the UNWEIGHTED mean 695.

The WEIGHTED mean: [(647 x 4) + (757 x 3) + (682 x 5)]/12 = 689

Because we know that Arizona made 8 measurements, the TRUE mean are only 678, much closer to the REAL result 672+-13.

Here one tries clearly to "enlarge" the error as much as possible, in order to spirit away the fact that the errors quoted by the laboratories by far, do NOT reflect the overall scatter.

One seems to forget, that the errors quoted by the laboratories are the result of measurements of standard and blank control samples, made simultaneously during the SAME run with the SAME machines.

One may NOT ACCEPT a too wide scatter of results and REJECT at the same time to LOW errors.

Note that for samples 2, 3 and 4, the error limits about the weighted means were obtained assuming NORMALITY. This means that the distribution for the Shroud is ABNORMAL. In such cases, one should not draw conclusions, but examine the heterogeneity of the samples.

I asked the meaning of Drs. Ward & Wilson, about this "mixing". Following them, one should have used only their method.

Dr. Morven Leese and the British Museum replied very evasively.

For the conversion of radiocarbon ages into calendar ages (15), see Nature.

No additional uncertainty has been added to take account of the short growth period of textile samples, although it has been suggested that 15² years should be added to the overall uncertainty in the radiocarbon date for samples of growth periods less than one year, such as linen. In general, such additional uncertainty would wide the 95 % calendar limits by 2~4 years at either end. Except for sample 3, where the 9 cal BC limit would be changed to 34 BC.

Note 25:

This is a strange remark.

Indeed Graig (1954) Polach (1972), Wigley & Muller (1981) already proposed the following empirical correction for flax:

$$HL/\ln 2 \times \ln [(A° \times K)/Am]$$

Here A° = Activity at origin (13.5 dpm (disintegrations, per minute corrected to one gram modern carbon) and Am = Activity dpm. measured in the sample.

The factor K is rather complicated.

K = Kst/Km, where Kst = $(d^{13}C/d^{14}C)$st. and Km = $(d^{13}C/d^{14}C)$m

St = $d^{13}C$ Standard Ex = $d^{13}C$ Measured

$$d^{14}C = [(Am/A°) - 1] \times 1000 \text{ o/oo}$$

$$D^{14}C = d^{14}C - 2(d^{13}C + 25) \times (1 + d^{14}C/1000) \text{ o/oo}$$

In simple words: (No correction added) Assuming the Shroud is from the time of Jesus, one should measure an activity of 10.7.

Assume the measured $d^{13}C = 21.6$ o/oo

$$d^{14}C = (10.7/13.5) - 1 = -2047 \text{ o/oo}$$

$$d^{14}C = 2047 - 2(-21.6 + 25) \times (1 + 2047/1000) = 2039 \text{ o/oo}$$

Kst = 25/2039 Km= 21.6/2047 and K° = 1.16

Assuming $d^{13}C$ at origin = 25 o/oo and measured $d^{13}C$ = 21.6 o/oo, the apparent radiocarbon age of an object dating 1950 RC. Years bp, will be = 5730/0.693 x ln [(13.5 x 1.16)/10.7 = 691 yr. bp.

Other authors like Clark prefer to add 60 or 50 years to the error.

For an error of +-50, the final error becomes: $(50^2 + 60^2)^{0.5} = 78$ years

In the Ward & Wilson papers are given TWO cases.

Case 1 = All measures are made on samples from the same object.

Case 2 = All measures are made on different objects.

Here a number of possible "additional" errors are given for changing magnetic fields, solar activities, and the kind of material …..

Flax is an annual plant, harvested on grounds of which the ^{14}C concentration is unknown. In theory, the ^{14}C content of harvested flax cannot be altered.

But flax, retted for weeks, in water rich or poor in ^{14}C, may always be dated to YOUNG or the OLD, simply because the ^{14}C content at origin will be higher or lower than normal.

Other possibilities of contamination, are ion exchange or migration.

A striking, but rare, example of ion-exchange are pseudo-morphs of silk, found in Chinese tombs, where all carbon atoms were replace by copper atoms, maintaining the silk structure and appearance. Only SEVEN of such pseudo-morphs are known today.

(K. A. Jakes & L. B. Sibley American Chemistry Society 1984)

In the case of linen, strange matter, deposed on the inner walls of the infinite number of LONG HOLLOW flax (cellulose) fibres, will be very difficult to remove by chemical or ultra-sonic cleaning.

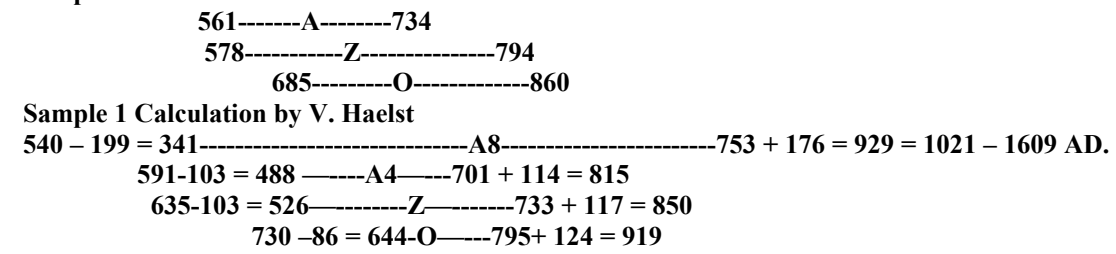
Recent tests by Brian Walsh, an American researcher of Richmond, show that the classical AAA cleaning methods do not remove all hydrocarbon residues from linen. The best results were obtained by using petroleum ether.

Archaeologists consider a single radiocarbon date, not to be "conclusive evidence" when in flagrant contradiction with other dating methods.

In spite of all these arguments, radiocarbon experts do not even consider any possibility of contamination of the Shroud sample.

Anyway, Ward & Wilson use additional errors, only in Case 2, where the radiocarbon dating of the Shroud is clearly a Case 1.

Figure 1 (Only for the Shroud)
Comparison Nature Errors (Table 1) and errors to obtain the mean 691+-31.
Sample 1 Nature 691+-31



Sample 1 Calculation by V. Haelst

The 95 % limits for the shroud are also illustrated in Figure 2, where it is apparent that the calibration of the radiocarbon date for sample 1 gives a double range. The correct transformation of probability distributions from the radiocarbon to the calendar scale is still subject to debate, they're being two different methods of dealing with multiple intercepts. However both methods agree that the major probability peak lies in the earlier of the two ranges, in the 68 % range at the end of the thirteenth century.

Note 26:

Due to the irregular curve, for the Shroud, the calendar date shows TWO ranges
Following Table 3 (Nature)
68 %: 1273 – 1288
95 %: 1262 – - - - - - - 1312 1353 - - - - - 1384
Following Stuiver-Pearson (Tables 1-B & 3-E. Radiocarbon)
Table 1-B.
Raw RC age = 779+-10 = Cal. BP 675 = AD 1260
Raw RC age = 648 +-14 = Cal. BP 660 = AD 1290
Raw RC age = 597 +-12 = Cal. BP 540 = AD 1390

The 95 % limits for the shroud are also illustrated in Fig. 2 where it is apparent that the calibration of the radiocarbon date for sample 1 gives a double range. The correct transformation of probability distributions from the radiocarbon to the calendar scale is still subject to debate, they're being two different methods for dealing with multiple intercepts. However both methods agree that the major probability peak lies in the earlier of the two ranges, in the 68 % range at the end of the thirteenth century.

Note 27:

This is another strange remark ! In any schoolbook is noted that any date within the properly established confidence limits, by the method applied has the probability to be the TRUE date.

In this case, one may say, with the same chance of being right, that the flax, used for the Shroud, has been harvested in 1390. Except naturally that this date is conflicting with historical evidence.

Sample 4 has a very narrow calendar range; this due to the steep slope in the calibration curve at this point, and is an occasional instance of calibration reducing rather than increasing a confidence range.

Sample 3 compares well with the data obtained by conventional radiocarbon dating; there is no evidence for a difference between the two methods. The dates for samples 2 and 4 agree with the historical evidence, which places them in the eleventh to twelfth centuries and late thirteenth/early fourteenth centuries AD respectively.

The results, together with the statistical assessment of the data, prepared by the British Museum, were forwarded to Professor Bray of the "Istituto di Metrologia "G. Colonetti" (Turin) for his. Comments. He confirmed that the results of the three laboratories were mutually compatible, and that, on the evidence submitted, none of the mean results was questionable.

Note 28:

I asked Prof. Bray for some explanations !

Regretting that he was not in a position to add anything to the information of Prof. Gonella or make comments on the different work, and that he did not "wish to overstep the limits of his task", he send me the following comment:

"Account being taken only of the final revised report obtained from Dr. Tite of the British Museum, the following comment can be made:

1) The results of the three laboratories are mutually compatible.

2) On the evidence submitted no average results APPEARS questionable.

3) The scatter of measurements values of sample 2, 3 and 4 is within the limits established for the method adopted, whereas for sample 1, the scatter is about equal to that limit value.

4) The difference (even if not large) obtained for the examined samples that the interference factors caused by the sample preparation or due to procedures for the application of the measurement methods, have influenced sample 1 to a greater extent.

Probably, also establishing could have reduced the scatter concerning sample 1:

a) A common testing procedure and sample treatment and cleaning, to determine universally the state of the measurand. (The samples to be measured)

b)Testing conditions.

c)The conditions of the measurement means on the basis of reference values to be chosen with equal spacing.

d)The method for evaluating measurement data and the associated uncertainties.

The above comments give special attention to the metrological aspects of the carbon 14 method; they do not take into account the choice of the measurement method adopted of the samples to be tested, because I was not involved either in test planning or the choice of the samples.

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Comment:

Prof. Bray would certainly make his students very unhappy, by noting the same remarks about their laboratory work report. In fact this is a severe critic against Dr. Tite, the co-ordinator of the radiocarbon dating.

In Nature one reads: "None of the mean results WAS questionable …"

Following Bray: "None of the mean results APPEARS ….."

Prof. Bray did not answer my SPECIFIC questions about:

The combination of 8 into 4 Arizona dates.

The arbitrary enlarging of the Arizona error from 17 to 31 years.

The "switch over" from the Ward & Wilson method to the Classic method.

The silent rejection of a number of clearly NEGATIVE Chi² tests.

The very bad Arizona Chi² test results for samples 3 & 4.

The strange absence of any contamination, reported by earlier examinations..

He refused to open his files, without the written permission of the British Museum. In vain, I asked the written permission of the British Museum.

CONCLUSIONS:

The results of radiocarbon measurements at Arizona, Oxford and Zurich yield a calibrated calendar age range, with at least 95 % confidence, for the linen of the Shroud of Turin of AD 1260~1390 (rounded down/up to the nearest 10 years). These results therefore provide conclusive evidence that the linen of the Shroud of Turin is mediaeval.

Note 29:

This is really jumping to conclusions.

Without any new fact or evidence one turns a NONE existing 95 % confidence into "CONCLUSIVE EVIDENCE".

A shift from 1.2 % confidence toward 95 % confidence.

The results of radiocarbon measurements from the three laboratories on four textile samples, a total of twelve data sets, show that none of the measurements differs from its appropriate mean value by more than two standard deviations.

The results for the three control samples agree well with previous radiocarbon measurements and/or historical dates.

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Than follows a long thanking list, in which this sentence cached my eye:

"Oxford thank P.H. South (Precision Processes (Textiles) for examining and identifying the cotton found on the shroud sample."

Note:

This manuscript, received on 3 December 1988, accepted on 18 January 1989 was already printed on 16 February. A rather short delay !

End

Epilogue.

References:

In the Dutch technical paper "Natuur en Techiek" I found a article about the Shroud of Turin, authored by Dr. Bottema (University of Groningen. Holland).

He noted that Oxford dated the Shroud about 1150 AD. Because a unknown photo of the Oxford samples was shown, it is clear, that Dr. Bottema received "inside" information from a former member of the Oxford AMS team.

This strange result, about 100 years older than the Oxford mean date 750, raises questions !

In vain I tried to open the Oxford files, in order to obtain more information.

Dr. Hedges and Dr. Bottema remained suddenly silent.

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