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A problematic source of organic contamination of linen

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Abstract

Microscopic observations of a putative sample of linen from the Turin Shroud and samples of the linen wrapping of an Egyptian mummified ibis reveal that individual fibers of the cloth are surrounded by a coating produced by bacteria. Fungal material is also found among the threads. T he question is whether the presence of this coating materially affects the age of cloth as obtained by carbon dating from what would be obtained if the actual cellulose of the flax from which the listen was made was dated. In particular what would be the affect on the age of the Turin Shroud? To obtain some answers to this question AMS radiocarbon measurements were made at the NSF Arizona AMS Facility at the University of Arizona on the collagen in bone and tissue samples from this ibis and of samples of the linen wrapping of the ibis cleaned by standard methods.

1. Introduction

The Turin Shroud is a linen cloth the color of old ivory measuring 4.4 by 1.1 m. It bears the faint front and back, head to head, imprint of a naked man. This remarkable image depicts all the stigmata of the crucifixion of Jesus Christ as described in the Bible. As a result, it is thought by many to be the actual burial cloth of Jesus. The shroud's known history dates back to about the year 1357 when it was displayed in a church in Lirey, France. The shroud, or some version of it, eventually passed into the hands of the House of Savoy. The shroud was stored in a silver chest in a chapel in Chambery, France and in 1532 a fire raged through the chapel. Part of the chest melted and gouts of molten silver burned through the shroud, fortunately outside the image, in a symmetric fashion due to the way it was folded in the chest. The shroud was doused with water before further damage could occur and the burn holes were later patched. In 1578 the seat of the House of Savoy was moved to Turin, Italy and the shroud moved with it.

In 1983 the last king of Italy, Umberto II, a member of the House of Savoy, willed the shroud to the Vatican. It is presently stored in a silver reliquary in a glass case behind the main altar of the Cathedral of John the Baptist in Turin, under the custody of the Archbishop of Turin.

2. Radiocarbon dating of the shroud

The advent of accelerator mass spectrometry (AMS) in 1977 [1] with its ability to radiocarbon date extremely small samples opened the possibility of establishing the year when the flax, from which the shroud's linen was made, was harvested. This could be done using only a few square centimeters of shroud cloth.

As a result of considerable complex planning [2], permission was granted by the Vatican for some ten square centimeters of shroud cloth to be removed for carbon dating by AMS. Most of this sample was divided between three AMS Laboratories in Oxford, England, Zurich, Switzerland and Tucson, Arizona. These three laboratories completely independently measured the date of the harvesting of the flax. There was excellent agreement between them for this date and for the age of three control samples. The date obtained for the linen sample from the shroud was 1260-1390 AD, at a 9596 (2σ) confidence level [3]. What made this result particularly credible to most scientists and, indeed, to many non-scientists was that it bracketed the historic date of 1357 AD.

3. The effect of organic contamination on the radiocarbon age of the shroud

The shroud samples measured by the three AMS laboratories came from essentially the same place on the shroud. Although the three laboratories used somewhat different methods of cleaning the linen samples they received (3], in general, the cleaning involved sequential washings in HCl, NaOH and HCl with rinsing in between in distilled water. In some cases a solvent was also employed. If there were some organic contamination present

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in the samples that increased the content of carbon-14 compared to stable carbon and that was not removed by the cleaning methods employed it could produce a date that was too recent. Some sources (mostly implausible) of such organic contamination have been invoked to change the shroud's date from the fourteenth to the first century. It should be noted, however, that the amount of organic contamination to produce such a major change in age is considerable. For example, if the organic contamination occurred as a result of the 1532 fire and if the shroud really dated to the first century, 79% of the carbon in the linen would have had to come from the fire and thus dated to the year 1532 and only 21% from the shroud itself for the combination to produce the historic date of 1357 AD. There is, however, one possible source of organic contamination that could change the shroud's true age to one that is younger and it merits further study.

There is additional interest in this question because there is some evidence that the linen wrappings of Egyptian human mummies yield radiocarbon dates that are younger than the bores of the mummies. In particular Manchester mummy 1770 yielded a linen wrapping date that was 340 ± 120 years younger than collagen from the human mummy bone [4]. Whether this was a result of re-wrapping of the mummy, poor preparation of the collagen sample or bacterial contamination is being studied [5].

4. Bacterial contamination of linen

Examinations of some ancient textile samples by one of us (L.A.G.- V.) with an optical microscope have shown that most of the thread fibers have extraneous deposits that cover their surface. These coatings may be composed of microorganisms (bacteria and fungi) and non-cellular het erogeneous materials. We speculate that the latter are mostly organic in nature and were deposited as exopolymers by the bacteria and fungi that invaded the textile fibers over time. The name bioplastic coatings has been given to these natural accretions produced by the activity of microorganisms. They are not uniform in thickness but, in general, seem to completely coat the fibers. Such coatings have not been previously observed nor confirmed by other investigators.

Several threads from a putative sample of linen from the Turin Shroud were examined for the presence of these deposits. Many microcolonial black fungi and bacteria were found. They formed filamentous structures that surrounded the fibers, that is to say, the individual fibers of the cloth are surrounded by a bioplastic coating. If the bacteria producing this coating obtain some or all of their sustenance from carbon dioxide in the air they might introduce additional "C to the cloth [6].

Similar observations of bacterial deposits have been made on samples of the linen wrapping of an Egyptian mummified ibis and the presence of this bioplastic coating was established. This coating is not removed in the standard cleaning procedure that is recommended for treating cloth prior to carbon dating. The question is whether the presence of this coating materially affects the age of the cloth as obtained by carbon dating from what would be obtained if the actual cellulose of the flax from which the linen was made were dated.

It is worth noting that, because these bacterial infestations form surficial coatings, if they affect the radiocarbon date at all, they are most likely to have their maximum impact on the radiocarbon measurements of the ages of cloth as opposed, for example, of parchment. The surface to volume ratio of cloth vastly exceeds that of other organic artifacts.

5. Carbon dating of ibis mummy material

Samples of the wrapping cloth, bone and tissue were removed by one of us (A.R.D.) from a mummified Egyptian ibis. The operation was carried out in the University of Texas Health Science Center at San Antonio. These samples were hand carried to the NSF Arizona AMS Facility at the University of Arizona in Tucson. Collagen was extracted from the bone and tissue. The cloth was cleaned in two different ways following similar procedures used by Arizona to clean the linen cloth samples from the shroud they received in 1988 [3]. These four ibis samples (2 collagen and 2 cloth) were radiocarbon dated at the Arizona facility [7].

The rational for these measurements is that the bone and probably the tissue collagen should not be affected by bacterial or fungal contamination and thus should yield the true age of the mummy and also of its cloth wrapping, assuming that the carbon content of both carne from the carbon dioxide in the air. This assumes, in addition, that the mummy was not re-wrapped some time after the death of the mummified body. If the radiocarbon age of the cloth is appreciably younger than the collagen then (a) the mummified object was re-wrapped or (b) the bioplastic coating adds additional ^{14}C and causes the radiocarbon date of the cloth to be too young or (c) the mummified object obtained its carbon from a source having a ^{14}C to stable carbon ratio smaller than that of the plants from which the cloth was made. The latter ultimately obtain their carbon content from carbon dioxide in the air.

The four measurements on the Arizona AMS facility yielded the following radiocarbon ages [7]:

(1) Mummy wrapping cleaned with acid-base-acid wash and soxhlet extractions in hexane, ethanol and methanol with a final wash with distilled water, 2255 ± 75 years BP.

(2) Mummy wrapping acetone cleaned followed by acid-base-acid and distilled water, 2200 ± 55 years BP.

(3) Collagen extracted from ibis bone, 2680 ± 50 years BP.

(4) Collagen from tissue attached to ibis bone, 2570 t 80 years BP.

The results can be discussed as follows:

(1) Mummy wrapping. In order to calibrate the ages, the data from (1) and (2) above was combined to give a mean radiocarbon age of 2220 ± 50 years BP. This yields a calibrated age range of 384-199 BC at a 1σ confidence level and 400-170 BC at a 2σ confidence level [8].

(2) Bone and tissue samples. The data of (3) and (4) above were combined to give a mean radiocarbon age of 2625 ± 55 years BP. Assuming the same tree-ring calibration, this gives a calibrated age range of 829-795 BC at a 1σ confidence level and 900-770 BC at a 2σ confidence level [8].

Using the 2σ values the minimum difference between the two ages is 370 years and the maximum is 730 years with the cloth being this much younger than the collagen. It has been noted [7], however, that if this particular ibis had been raised on a diet of seafood from the Mediterranean Sea a marine correction must be applied to the collagen ages [8]. This would give an age range for the collagen of 390-328 BC at the 1σ level and 460-200 BC at the 2σ confidence level [7]. In this case there would be no discrepancy between the age of the ibis and the cloth. Furthermore the results for both the ibis and the wrapping cloth would be in excellent agreement with the expected age of 330-30 BC [9].

6. Discussion

The results indicate that the cloth is some 400 to 700 years younger than the bone and tissue collagen assuming no corrections for mechanisms that would decrease the carbon-14 to stable carbon ratio in the collagen over that for the cloth are merited. In this case the presence of the bioplastic coating would appear to have introduced appreciable additional ^{14}C into the cloth unless, of course, the ibis mummy in question was re-wrapped. There are hundreds of mummified ibises extant and the likelihood that any were re-wrapped, although possible, seems remote.

If, on the other hand, this particular ancient Egyptian Sacred Ibis (the species of ibis the ancient Egyptians mummified) was raised on a diet that contained some old carbon (depleted in ^{14}C), such as food of marine origin or land snails, then this could resolve the discrepancy in the radiocarbon measurements between the ibis mummy and its mummy wrappings. In this case, one would not have to invoke any effect of the bioplastic on the radiocarbon age of the mummy wrapping.

At present in the wild, the Sacred Ibis is widely distributed throughout Africa. It frequents fresh and brackish marshes, swamps, pasture lands and flood plains and feeds on insects, small fish and mollusks, frogs, small reptiles as well as young birds and carrion [10]. Although there is no known provenance for the ibis mummy involved in these measurements, it is likely it came either from Sakkara (south of Cairo), some 150 miles from the Mediterranean, or perhaps Hermopolis (the cult-center of the god Thoth whose cult-animal was the Ibis), which is on the Nile in Middle Egypt, some 250 miles from the Mediterranean. Such ibises were probably bred and reared in captivity at these sites. Pilgrims to the local temple would purchase them and they would be mummified at the site as an offering to the god and buried nearby in vast underground galleries. It is most unlikely that they would have been fed on a diet of seafood from the Mediterranean (or for that matter from the Red Sea some 100 miles away) because of the distances involved rather than from the other suitable food sources readily available in the vicinity. Furthermore the $\delta^{13}C$ for the collagen was about -21 per mil and for the wrapping -26.5 per mil [7]. Both are quite different from the value of zero expected for marine samples [11]. It is thus highly probable that no marine correction is required for the radiocarbon date of the ibis collagen.

One should not conclude from this, however, that no correction for potential alternate sources to the carbon-14 age of the ibis collagen is required. The very fact that some portion of the ibis diet probably involved food whose carbon content came, not from the carbon dioxide in the air, but from that in fresh or brackish water opens the possibility that it contains a lower ratio of carbon-14 to stable carbon than does the air. For example radiocarbon measurements on charcoal and snail shells from the Graeco-Roman period in Egypt [12] give an age for the former of 2870 years BP and, for the latter, 18,500 years BP indicating the snails obtained their food from old or very hard ground water in which they lived. There are many examples to be found of similar "old" lake and ground water, both in Africa and North America.

On the other hand the two possible ibis sites mentioned above are close to the Nile River and, in fact, one would expect most Egyptian ibises to be found near the Nile. The water of the Nile probably has a radiocarbon age close to that of the air above it. The radiocarbon to stable carbon ratio of the bone collagen of animals whose diet was aquatic plants and animals living in the Nile would be the same as that of the flax from which the wrapping cloth was made. In this case the fact that the bone collagen of the ibis has a radiocarbon age that is older than its mummy wrapping suggests that the bacterial infestation of the cloth is adding extra ^{14}C.

Given these two possibilities the latter seems more likely but, in any case, one cannot eliminate either with certainty. Hence one is forced to conclude that the ibis was not a propitious choice of mummy in which to compare cloth wrapping and bone collagen radiocarbon content specifically because their diet probably included food whose carbon content was aquatic in origin. A better choice would be mummified animals, whose diets comprised terres trial plants, such as bulls, which the ancient Egyptians also worshipped and mummified. An example of such a bull mummy exists and some bone collagen from it might be made available for radiocarbon dating. The wrapping was dated to be about 2000 years BP in the early days of accelerator mass spectroscopy [l 3].

Clearly more research on Egyptian mummies, both animal and human, is required. If it can be shown conclusively that a bacteria-produced bioplastic coating causes radiocarbon ages of cloth to be too young a method of separating the coating from the cellulose of the cloth must be found so the two can be radiocarbon dated separately. Research an ways to accomplish this is continuing.

Meanwhile, although the results of the present measurements include the possibility that the bioplastic coating observed on the cloth fibers of the wrappings of the ibis cause it to yield a radiocarbon age several hundred years younger than its true age, they are far from definitive. It would be premature to draw any conclusions about the true age of the Turin Shroud from these measurements.

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