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Bog Bodies Investigated in the Light of Forensic Medicine

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THE BORREMOSE FIND

A body found in the summer of 1948 during peat-cutting in Borremose, a fen near Aars in Himmerland, Denmark, was transported in a large purpose-made box together with its surrounding peaty soil to the National Museum in Copenhagen, Denmark, where a thorough examination of the contents of the box was carried out by the assistant curator, B. Brorson Christensen.[1]

The body was lying on its stomach, face downwards, in the bog, and was partly covered by a woollen skirt (Fig. 1) cf. E. Munksgaard, this volume). The occiput was "scalped", and the scalp was lying close to the left side of the head. However, this injury possibly occurred during peat-cutting. No sticks, stones or ornaments were found. After the body had been turned over on to its back, it was apparent that "the head is almost completely crushed; the lower part of the face, chin, cheeks, etc. are preserved, but pressed entirely out of shape. The soft parts of the head have either disappeared or have been "dislocated". There are consequently no contiguous or recognizable remains of nose, eyes or ears. The scalp with its hair has been torn off, and the greater part of it is lying above or in prolongation of the rest of the head. The hair, which appears to have been of medium length, is a tangled mass, in which it has not been possible during soil-removal and cleaning to find any trace of plaiting or any form of hairstyle. The bones of the cranium are crushed, and have no natural cohesion. They are mixed with scraps of yellowish cerebral substance within and above the soft parts of the lower face referred to above" (Fig. 2).

Brorson Christensen believed that it could be established that the head was shattered before the body was placed where it was found, since it was lying face downwards and the back of the head was relatively the least damaged part.

The neck was so poorly preserved that it could not be determined whether the body had been hanged or strangled. The left arm was lying in a gentle curve downwards around the left leg, which was drawn forcibly upwards. The right arm was bent, and the right hand partly covered the remains of the face.

The body was in a relatively poorer state of preservation than the limbs, which showed no signs of warding-off injuries. The breasts were, however, preserved, but quite small. The state of nourishment was considerably above the average, and she has subsequently been referred to as "the Borremose fat girl". The abdominal organs were too damaged for examination, but no fetal remains were found. The bones were generally rubbery.

Carbon-14 analysis of the heart and lung remnants dated the Borremose woman to about 770 B.C. (± 100 years), i.e. the body was about 2,700 years old and dated from the transitional period between the Late Danish Bronze Age and the Early Danish Iron Age. A similar analysis of the surrounding sphagnum (peat moss) showed that this was about 80 years more recent than the body, probably because of the growth of the peat or the flow of liquids. The National Museum placed the body in a zinc box in an aqueous phenol solution of about 1% containing glycerine; this was replaced after four months by a 2% aqueous solution of formaldehyde.

The finding of the body was described (1969) by P.V. Glob as the third Borremose find during post-war peat-cutting. In 1972, Professor P.V. Glob gave permission for three loose pieces of tissue to undergo histological examination at the Øjenpatologisk Institut (Institute of Eye Pathology, Copenhagen),[2] but the matter was put aside because of pressure of time.

In 1977, we decided in co-operation with Assistant Curator Elisabeth Munksgaard of the National Museum to attempt a proper autopsy of the Borremose woman at the Retsmedicinsk institut (Institute of Forensic Pathology, Copenhagen).[3]

We wished to see how far we could progress with all that modern technology has to offer. A number of departments at the Rigshospital in Copenhagen became

Fig. 1. The Borremose woman's body (Borremose III) as she lay in the bog, partly covered by a woollen skirt. Note the "scalp" close beside the left of the head (arrow).

Fig. 2. Woman's body, Borremose III, photographed during excavation. The body is turned so that the side that faced downwards in the bog is facing upwards in the picture.

involved, and the autopsy was carried out in the presence of museum staff, experts from the Criminal Investigation Police Department and a number of interested doctors and dentists.

X-ray photographs of the body's bones (Gregers Thomsen) found these to be almost completely decalcified. They had also shrunk considerably, measurements of the length of the bones resulting in a body height of 143 cm, which scarcely corresponds to reality. A subsidence of the bones around the right knee joint had probably occurred as a result of the peat's significant pressure on the body over the years (cf. Fig. 2).

The bones of the face were crushed and its soft parts split open. The cranium was reconstructed by the Technical Department of the Danish Police Force. Examination of the cranium's bones and sutures indicated that this was a woman aged between 20 and 35 (J. Balslev Jørgensen). The calvarium had apparently suffered no fracture while the woman was alive (Fig. 3).

Like the bones, the teeth were extensively decalcified, and most of them had fallen from their sockets, undoubtedly after death. Professor dr. odont. P.O. Pedersen of the Copenhagen Dental School and the dentist J. Keiser-Nielsen took part in the investigation. They decided that the teeth remains permitted no conclusion as concerns the woman's dental health.

The skin had been "tanned" brown, the hair was reddish-brown, and all the nails – like the epidermis – had

flaked off. During detailed investigation of the peat, however, Brorson Christensen succeeded in finding six of the nails lying beside the body.

The hair of the head lay across the domed section of the cranium, and some of it lay along the neck. The hair was still fixed to the flaked-off upper skin layer (epidermis), but there was no trace of haemorrhage in the cranium. »Scalping« while the woman was alive must therefore be considered unlikely. There were no "warding-off injuries" on hands or forearms. Examination of the interior of the body was very disappointing, since almost all the organs were absent. In the case of the abdominal organs, this is undoubtedly due to putrefaction. The thoracic cavities had already been opened at some time during storage at the National Museum, and parts of the organs had probably been included in the carbon-14 analysis. It was, therefore, quite impossible to determine whether there had been an intake of blood into the air passages. No sign of advanced pregnancy could be detected.

About 65 tissue samples were removed from the remains of the internal organs and from the skin during the autopsy as specimens for the Institute of Eye Pathology.

The procedures employed were the same as in normal microscopy, but the transit of the tissue from a formalin solution to paraffin was very slow and gradual over a period of a month. After cutting, the paraffin sections were stretched on a water bath, but at 42° only and for a few seconds in order not to split the crumbling tissue. The sections were coated with albumen glycerine, as they showed a great tendency to fall off. Many different methods of stain were tested. It proved necessary to employ double staining-times throughout. Viggo Eskelund's combined Alcian blue-elastin-v. Gieson stain (Eskelund 1957) proved to be most suitable, particularly in distinguishing the body's structures from the sphagnum peat. Among other good stains we should mention Masson-trichrom connective-tissue stain, Unna-Pappenheim's methyl-green-pyronin stain and Heidenhain's iron-hematoxylin, azan variant, the latter two particularly in the staining of red blood cells. In total, some thousands of sections were examined.

Microscopy of the skin showed quite well-preserved connective-tissue structures, hair follicles and hair anlages. Sphagnum (peat moss) was often to be observed grown into the deeper layers of the skin. (Fig. 4). Between the connective-tissue fibrils, occasional pollen

Fig. 3. The cranium after reconstruction.

grains of the "ling family, but not heather", possibly cowberry or cranberry, were to be seen (cf. Fig. 4 insert). Only autumn pollen was found in the body.

Between the connective-tissue fibrils, lines with marked "cross striations" were sometimes to be seen, which directly suggested striated musculature. Electron-microscopy showed, however, that this was probably connective tissue (collagenous fibrils), some of which had broken into small discs. The transverse bands characteristic of striated musculature were lacking. So-called "cross striations" are frequently found in mummies, but in our opinion electron-microscopy must determine the issue.

Tissue from the skin, musculature and remains of the viscera proved to be too poorly fixed to find blood vessels or blood.

Three small pieces of tissue found in 1972 in the bottom of the zinc box were in a better state of preservation. One of the loose pieces was decayed cerebral tissue with peat culm and other more amorphous bog remains grown into it. The second piece of tissue, a torn-off ear, contained well-preserved blood vessels with round bodies 1 micron in size (Fig. 5). The third loose piece of tissue proved to be a collapsed eye, partly covered by well-preserved eyelids with eye socket attached. Under microscopy, there could be recognized

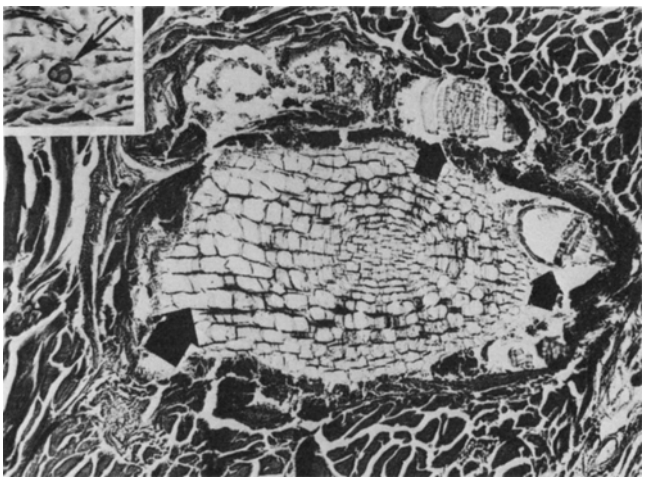

Fig. 4. Skin from the scalp, with sphagnum (peat moss) (large arrow) grown into it and hair follicles (small arrows). Eskelund's Alcian blue-elastin-van Gieson stain. Enlargement × 110. Insert: Pollen grains of the "ling family, but not heather". Same stain and enlargement (arrow).

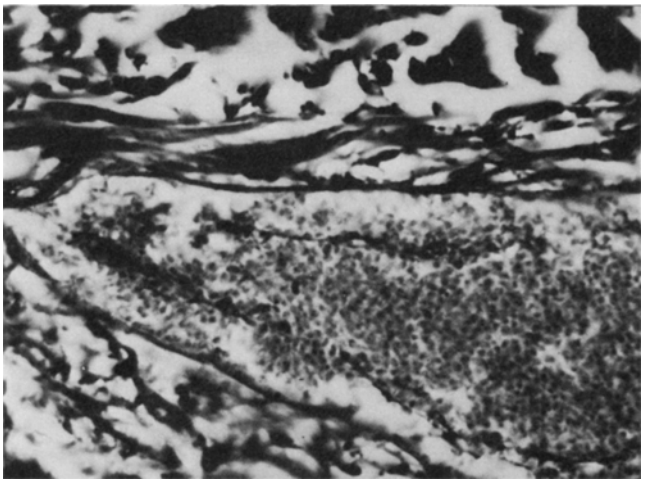

Fig. 5. Section of blood vessel from the detached ear with round bodies of 1 micron size, each with a central dark spot surrounded by a lighter zone, possibly the remnants of burst red blood cells. Unna-Pappenheim's methyl-green-pyronin Stain. Enlargement × 1,100.

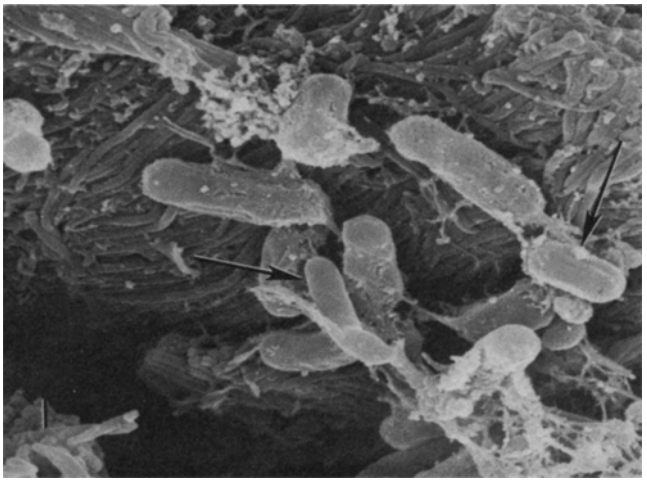

Fig. 6. Scanning electron-microscopy of the inside of the eye's sclera with regular granules 3–4 microns in length, probably melanin granules from the retina (arrows). Enlargement × 6,000.

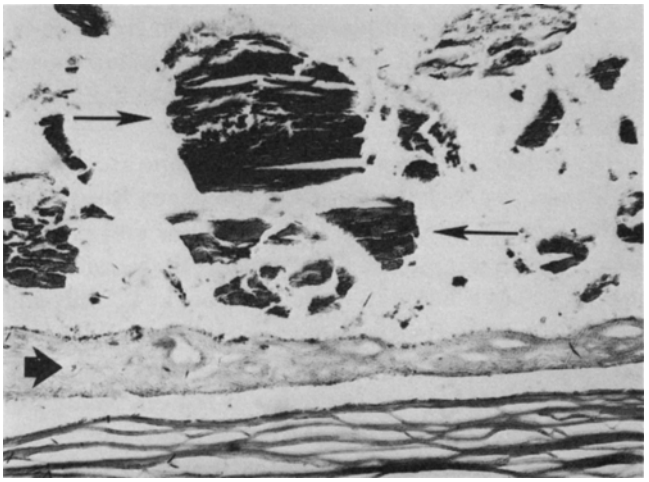

Fig. 7. Inside of the eye. Below, sclera; in middle, choroid (large arrow); at top, thread-like structures, probably splinters of wood (small arrows). Eskelund's Alcian blue-elastin-van Gieson stain. Enlargement × 45.

between the sclera's upper and bottom layers a choroid (membrane) coated with melanin granules of the same size and type as the retina's, which was confirmed by electron-microscopy (Fig. 6). In addition, some distinctive, dispersed, thread-like structures surrounded by remains of bog water were to be observed. We consider that an origin from the body itself or from the skirt can be excluded, and we therefore believe that they are foreign bodies. They are not textile remains; more likely splinters of wood. (Fig. 7).

Between what were assumed to be foreign bodies and the sclera there was an unusually well-preserved choroid with blood vessels. Some of the vessels contained bodies of the same size and appearance as in the vessels of the ear.

Great forensic interest lay in establishing whether there were signs that violence had occurred during life, and in particular whether the condition of the face had been caused by, for example, one or more bludgeon blows to the face while the woman was still alive. The

determination of this question must rest upon the so-called vital reaction, for example whether the tissue remains of the face show under microscopic examination traces of the leaking of blood from burst blood vessels in the tissue. Heidenhain's iron hematoxylin stain and Unna-Pappenheim's stain give the round bodies of about 1 micron in the choroid of the eye and in the blood vessels of the ear a blue-violet tint, which is different from the other small particles in the area. Corresponding granules could not be recovered outside the blood vessels. Transmission electron microscopic tests on the ear were unable to demonstrate blood vessels, and no more tissue from the eye was to be found.

However, it was possible to carry out scanning electron-microscopy on paraffin sections already prepared from the choroid. The choroid's blood vessels were clearly to be seen, with bars extending into the vessels' lumen. This may be a part of the blood vessels' wall, but may also be sphagnum remains that have grown into it. Some round bodies of uniform size – about 1 micron – with a slightly humpy surface were also to be seen. They were 7–8 times smaller than a normal red blood cell, but it certainly deserves to be considered whether they might be the shrunken remains of burst red blood cells.

The forensic serologist, Klavs Henningsen, tried suspending human blood cells in water at 4° for a week, when they burst, but the remains of the blood cells did not change in size. Direct comparison with the circumstances of the Borremose body is for obvious reasons impossible. Staining for hemoglobin and endogenous peroxidase in the choroid has been negative; neither has it been possible to determine the blood group in bone marrow from the sternum, but this may be because all the tissue was formalin-fixed.

To summarize, we consider it very probable that the small round bodies in the blood vessels of the eye and ear are remains of burst red blood cells, and that no haemorrhage has occurred from the vessels into these tissues. This also indicates that the severe cranial injury occurred after death.

THE VESTER THORSTED FIND

On 4 June 1913, the body of a man dressed in only a leather coat was found during peat-cutting at Vester Thorsted, Denmark. The body was lying a good two feet below the present surface of the bog, and quite close to

Fig. 8. Cranium of a bog body from Vester Thorsted.

the natural sandy bottom. A large branch was lying across the body, and the local police authority – represented by the district judge at Kolding – had to consider the possibility that the person concerned had been killed and buried in the bog. The judge therefore arranged for the body to be sent to the Institute of Forensic Pathology in Copenhagen for autopsy and for answers to a number of specific questions, including the cause and manner of death.

The judge, however, appears to have suspected that this was an old body, and at the same time he asked the National Museum (through the curator, J. Olrik) to take a part in the matter. In addition to the statement made by the forensic pathologist, statements were also provided by the National Museum in regard to the deceased's clothing and the date on which it must be assumed that the deceased was placed in the bog.

Forensic examination of the body was carried out by Vilhelm Ellermann, an Assistant (later Professor) at the Copenhagen University's Institute of Forensic Pathol-

ogy. The investigation resulted in a very short statement to the judge, which read as follows: "It is impossible to determine whether the man found died a natural death; but there is nothing to indicate with certainty that he has been subjected to violence. In this connection, it is pointed out that it appears unnecessary to regard the holes in the clothing referred to in the judge's letter as tears or to assume that they were caused by a sharp weapon. As concerns age, it can only be stated that he was fully grown."

In his covering letter, the judge had also asked: "1) How long has the body been lying in the bog," and, "2) Are there specific marks of any kind on the body which may be taken as an indication of his nationality or identity?" Ellermann was wise enough to refrain from answering these two questions, but in the Institute's internal records he states that "the strange manner of the body's preservation was unknown to the Institute, and no description of similar finds is to be found in the reference books". However, the National Museum's statement on the matter contained no reservations. An examination of the leather jacket, which was probably of oxhide, compared it with other related bog bodies found in Jutland, the remains of which were preserved in the museum, and there was no doubt that the find in the Vester Thorsted bog belonged to the same group. The jacket in which the body had been wrapped was made from many pieces of hide and was sewn together with leather thongs. It was said to be typical of most of these finds, and those that included parts of bodies had gone through a process similar to that of the Vester Thorsted body, i.e. crumbling bones, compressed cranium, etc. (Fig. 8). The National Museum said in its statement that the very simple clothing which characterized these bog bodies indicated that the people concerned "were not members of respectable society". The statement ended by saying that they must be gypsies, and that the body was attributed to the zenith of the gypsy period in the 16th and 17th centuries. The statement considered whether it might be a certain labourer who disappeared in 1860, but this was believed to be less likely since at that time a labourer would scarcely have gone about in such a patched and primitive jacket of animal hide.

When the forensic pathologist Vilhelm Ellermann had submitted his statement to the judge, expressing the opinion that the finding of the body scarcely deserved the attention of the judiciary, he began to speculate more deeply about the strange body changes, which he obviously encountered here for the first time. He was of course familiar with a number of the processes that can take place in a body: putrefaction, autolysis, mummification, formation of adipocere, etc., and he divided these into two groups: the destructive and the preservative. It was clear to Ellermann that the strange changes that characterized the Vester Thorsted body must be attributed to the preservative group.

To discover the processes that might have been concerned, Ellermann now carried out a series of tests, since it was evident to him that behind this strange process of preservation there must be some special circumstances associated with bog peat. To this end, he collected peaty soil from a bog at Lyngbyvejen near to the Institute of Forensic Pathology and added distilled water to it. In this peat mush he placed human skin, which he then observed over a number of months. The first peat mush used by Ellermann gave a neutral reaction to litmus paper. To his disappointment, no changes similar to those in the bog body appeared in this skin, even after many months. On the contrary, the skin was transformed into a chalk-white mass – typical adipocere.

In his next test, however, Ellermann employed a different kind of peat, since he now undoubtedly realized that peat can be of many different kinds. For this test, he used peat litter purchased from a supplier in southern Sweden. The mush made from this gave a strong acid reaction to litmus paper, and after two years and four months human skin was now dark brown and tanned and bones heavily decalcified. Following this successful test, Ellermann, in co-operation with specialists on bogs, extended his knowledge of bogs and peat. He concluded in an article (1916) that: ... "Bog-tanning is formed by deposition in an acid-reacting raised bog. It is most natural to assume – an assumption supported by the tests performed – that sphagnum acid is the most important element in the process. The acid causes tanning of the skin so that it becomes exceptionally durable and decalcification of the bones, as well as tanning of their organic components. The tests indicate that bog-tanning can occur only in typical raised bogs, whereas bodies will decompose in the normal manner or saponify (i.e. become adipocere: author's Note 4)) in neutral-reacting forms of bog."

Ellermann's tests and reasoning demonstrate clearly that formation of adipocere and bog tanning are pro-

cesses with the common feature that they are both of a preservative nature. On the other hand, widely differing processes are concerned here. Adipocere formation occurs typically in running water containing oxygen and lime, while bog tanning occurs exclusively in a strongly acid environment, poor in lime and oxygen.

It was of course not by chance that Ellermann added water to his peat material. It must have been clear to him that chemical processes of the kind here concerned can occur only in an aqueous environment. As concerns the circumstances under which bodies were placed in bogs, however, it is possible to draw conclusions far more wide-ranging than Ellermann can have felt prompted towards at the time. In 1913, it was apparently believed that bodies such as that here concerned could not be more than about 300 years old. We know today that these bodies – including the Vester Thorsted body* – are often as much as two or three thousand years old. The circumstances of their origin have therefore become of far greater interest.

DISCUSSION

The raised-bog bodies undoubtedly present common features, and historians and prehistorians have explained them in various ways. In particular, when discussing their state of preservation, they have understandably tried to give life to their opinions by describing the situation surrounding the actual deposition of the dead or dying person in the bog.

However, the various theories appear not to take into consideration – or at least to do so to only an insignificant extent – the laws and disciplines of nature with which the process of burial must necessarily accord if the theory concerned is to be considered probable. A historian may assert, for example relative to the Borremose woman, that the body is that of an unfaithful woman who was surprised by her husband, and that for this reason she was driven into the bog – attentively followed by the village population – beaten with sticks and scalped before finally being laid in a hole in the bog soil: "Out there in the bog, the walkers slowly formed a circle around the two, and while the men began to dig her grave in the black peat the man came forward and once again recounted what he knew...". After the last crushing blow to the face she no longer moved and was thrown into the grave, which was then filled in (Lauring, 1972, p. 178).

It is beyond the scope of this paper to express an opinion on the probability of such a background to the assumed acts of violence. However, on the basis of the physio-chemical and biological phenomena referred to above, it can be demonstrated that "burial" in the bog cannot have taken place as described.

In the first place, the deceased cannot have been placed in a dry hole in the bog. The chemical effect on the body surface, which is a precondition for preservative "tanning", can only take place in an *aqueous* environment, and, so that it can compete with putrefaction which is a far more rapid process, it must begin immediately after death. Another reason is that in a dry hole the abundance of carrion-eating organisms which live in the earth crust would immediately attack the body and consume important parts of it within a very short time. What is particularly significant from the aspect of forensic medicine is the condition of the nails. If the deceased had been laid in a dry hole, the nails would have remained in place on the hands and feet of the deceased, and not, as in the case of the Borremose woman, be spread around in the peat. In a body in water, the upper layer of skin flakes off, together with the nails. In a dry body (mummified), the nails remain in position, firmly fixed by the parchment-like skin.

The well-preserved skin on the Borremose woman's extremities shows that she was not exposed to post-mortem injury in the form of bites by animals, large or small. Depending upon the season, a number of insects and other animals from fly maggots and ants to rodents and foxes will very quickly leave their traces on a body, and bodies in water containing only a moderate amount of oxygen will be attacked by a large number of carrion eaters, such as crayfish. As we have said, the Borremose woman's skin showed not the slightest trace of attacks of this nature, and only under absolute anaerobic conditions can attacks by carrion-eating organisms in water be excluded. These conditions are present in the acid environment found in the mud at the bottom of a pond or bog hole.

The question of the temperature at the time the Borremose woman was placed in the bog is certainly

* Carbon-14 analysis performed in 1984 dated the thigh-bone from the Vester Thorsted body to about 95 B.C. and his skin to about 145 B.C., both calibrated a. m. Clark (± 70 years).

interesting. It will be seen from many aspects of the above that putrefaction is the (competing) change which is the most crucial factor determining whether bog tanning or the formation of adipocere can in any way occur.

The formation of adipocere is caused by the decomposition of fatty substances in the subcutaneous tissue, forming fatty acids, which in turn, under the effect of lime and magnesium in the surrounding water, are saponified to form a chalk-white mass replacing the subcutaneous tissue. This process can be observed most markedly in bodies that have been lying in cold water for a long period. It is generally true of chemical processes that the higher the temperature the more rapidly they occur. The formation of adipocere should therefore in principle be far more frequent in bodies which have been lying in warm water. That this is not the case is because bodies which have been lying in a warm environment putrefy so quickly that the formation of adipocere cannot arise. Conversely, the putrefaction process comes to a stop at temperatures below 4°C (refrigerator temperature), and bog tanning will therefore occur only in bodies lying in cold water.

The temperature in bogs is low (cf. "ground mist"), but we have no information of the actual temperature at that time and at the different seasons at the bottom of water holes in Danish raised bogs. It is probable however that only bodies placed in the bog during winter had any possibility of passing through the strange preservative process which bog tanning represents. Other bodies may have been put into the same bogs during the summer and almost totally destroyed.

CONCLUSION

Our intention has been to consider whether we can with any reasonable degree of certainty, and from the medical and forensic aspect, assist in clarifying the circumstances surrounding the death of the Borremose woman about 2,700 years ago.

It will be seen from the above that we have found reason to support Ellermann and his investigations into another bog body dating from antiquity, and on this basis we venture to outline a conclusion in the case of the Borremose woman.

It is clear from Brorson Christensen's report that the Borremose woman showed signs of putrefaction in those parts of the abdominal wall where "the intestines are located very near to the surface". It is precisely in these areas that putrefaction can first be recognized, since the putrefactive bacteria living in the human colon begin to develop rapidly as soon as death occurs. The Borremose woman may therefore be seen as an example of the process of putrefaction being delayed sufficiently for tanning to prevail, and this "delay" was undoubtedly because of the temperature. Since the climate at the time was not significantly colder than at present, the Borremose woman must have died in winter.

It was of great interest from the viewpoint of forensic medicine to seek to establish whether there were signs that violence occurred while the woman was still alive, and in particular whether the condition of the face might be due to bludgeon blows while alive, (cf. the possible intraocular splinters of wood, Fig. 7.). Determination of this question must depend upon the vital reaction already referred to. No haemorrhage in the soft parts of the face could for instance be demonstrated. Had they occurred during life, facial injuries of the kind here concerned would undoubtedly have caused severe haemorrhage from the face downwards into the air passages. Blood quantities of such a magnitude could probably have been demonstrated with the aid of modern technology, but since the air passages were absent this could not be investigated.

Our investigations indicate that, although her face was smashed, probably by one or more heavy blows, nothing has emerged to suggest that this occured during life. As concerns the cause of death (hanging, drowning, etc.), we cannot express an opinion.

As is typical of bodies in water, the upper layer of skin (epidermis), the hair and the nails had been shed. These finds give good reason for assuming that this must be an example of a body in water. The body's exceptionally good state of preservation as a result of a long-term "tanning process" indicates that the water in which she was submerged (or sank) was cold, since otherwise the putrefaction process would undoubtedly have prevailed.

The unusually well-preserved skin, in particular on the arms and hands, leads to the conclusion that the woman can scarcely have been exposed to brute force, such as "blows with a stick". A very typical reaction to such violence is for the person concerned to raise his/her arms to protect the head, and typical marks are then

to be found on the back of the hands and forearms. These so-called warding-off injuries could undoubtedly have been established had they existed.

Systematic X-ray investigation of the entire skeleton revealed no fractures which it was certain had occurred during life, and the extensive cranial injury must be assumed to have occurred after death.

The cause of death has not been determined by the investigations. From the viewpoint of forensic medicine, and having regard to the very limited potential for investigation, no certain evidence has emerged to decide the manner of death (murder, suicide, accident, or natural death). Neither can it be established whether death occurred before the woman was deposited in the water (the bog).

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NOTES

1. B. Brorson Christensen's 1948 investigation of the Borremose woman's body and the other contents of the box are to be found in his report to the laboratory of the National Museum dated February 1949 (File No. 447/48), Borremose III.
2. The histological and electron-microscopic investigations of the Borremose body were carried out at the Institute of Eye Pathology. The three loose pieces of tissue (eye with eyelid, ear and cerebral tissue) have been given the File No. 728/72, and the other histological tissue samples from the body File No. 1200/77. The electron-microscopic studies (SEM No. 473 b) were carried out by O.A. Jensen and J.U. Prause.
3. The autopsy of the Borremose body was carried out at the Institute for Forensic Pathology.
4. As to adipocere, putrefaction, mummification, etc., see e.g. Polson 1965.

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