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Artikel: The conservation of the Bronze Age logboat of Erlach (Lake of Biel) in the National Museum of Denmark

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The Conservation of the Bronze Age Logboat of Erlach (Lake of Biel) in the National Museum of Denmark

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During the years 1993–96 a 3550 year-old logboat from the Lake of Biel, Berne, Switzerland, was impregnated and freeze-dried at the National Museum of Denmark, Dept. for Conservation, Section for Organic Materials.
This conservation process comprised the freeze-drying of the largest whole archaeological object carried out in Denmark. The result was very satisfactory and involves interesting aspects of stabilization and freeze-drying of large archaeological finds.

1. Introduction

In 1991 the water police of Biel which is situated northwest of Berne, informed the archaeological authorities that they had come across a long shaped wooden object, which might have their interest.
It was soon apparent to the archaeologist that it was a logboat. Logboats have been made since the Stone Age and up to recent time. For that reason a dating of the find was important. The interest increased when the first examination showed that the logboat, which was remarkably well preserved, had been hewn with bronze tools, and that no stone or iron tools had been used.
In 1992 the logboat was raised from the bottom of the lake, where it had been well protected. In this connection a number of samples were taken for dendrochronological examination. The estimate of these samples fixes the age to about 1553 B.C. At the same time the logboat was documented by exact measuring and photography.[1]
As no decision for further treatment was taken, the logboat was buried below the subsoil water level near the shore.

The logboat is 7.85 m long and about 0.9 m wide. It was hewn from an oak log over 1 m wide and more than 200 years old. The logboat was nearly finished when it fell into 3550 years of oblivion. Therefore this find gives an extremely good opportunity to examine the production technique.
Quite clear work marks from bronze axes and drills are seen all over the boat. In the front the work of hewing the last wood is not finished, but cuts from drill and axe are clearly showing the final thickness of the boat and what was to be removed. A thorough description of the logboat has been made by the archaeologists, who were in charge of the excavation.[2]
For that reason it was a great wish of the archaeological department in canton Berne to have the logboat conserved. This was not possible in Switzerland, where sufficient facilities and experience are not available. So the National Museum of Denmark, Department for Conservation, Section for Organic Materials[3], was chosen to carry out this task.

Fig. 1: Erlach - Heidenweg 1993–96. Conservation of the logboat. The logboat is remarkably well preserved with clear work marks of bronze tools.

2. Transport

93-11-2–10	Re-excavation of the logboat and all preparings for its transport to Denmark.
93-11-8–10	Transport by van to the Conservation Laboratories of the National Museum of Denmark in Brede.
93-11-10	Received the logboat at the Organic Materials Section at the National Museum of Denmark.
93-11	Cleaned the logboat by a gentle wash. At the same time the main part of the fungi, caused by the storage in the ground, was removed. New large cracks in the longitudinal direction were compared with the first pictures of the boat. The cracks were mainly caused by the storage after excavation. There is a photo documentation of all the steps of the logboat's conservation.

1 Suter/Francuz/Verhoeven 1993; Verhoeven/Suter/Francuz 1993.
2 Verhoeven et al. 1994.
3 The National Museum of Denmark, Department of Conservation, Section for Organic Materials, Brede, DK-2880 Lyngby, Denmark.

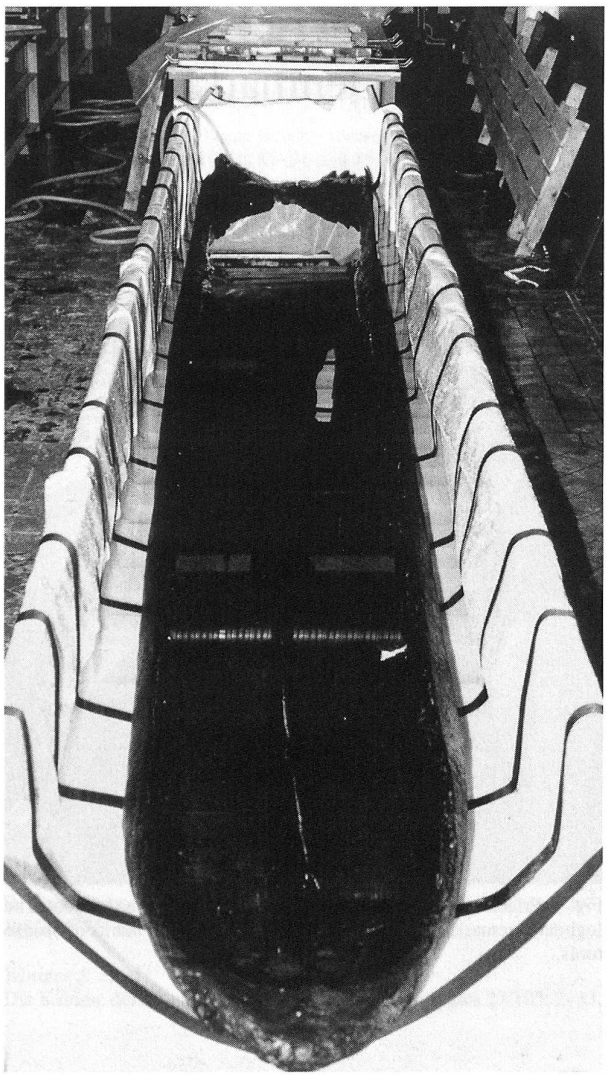


Fig. 2: Erlach - Heidenweg 1993–96. Conservation of the logboat. The logboat in the impregnation tank before adding low and high molecular PEG.

The transport of the logboat was taken care of in accordance to instructions from the Section for Organic Materials by the responsible archaeologist, who also followed the boat on the journey to Denmark.
The logboat was covered with wet cloths and a layer of plast to prevent the surface from drying up. Then the logboat was packed in a solid wooden box where it was supported in length by soft plastic plates cut into shape.[4] The transport was done in a well balanced van, purpose-built for objects which have to be handled with care.

3. Preliminary Planning of the Conservation Process

A conservation process was planned according to the information of the condition and size of the logboat that was received from the archaeologists in 1993.

It was evident from the beginning that the conservation process should consist of an impregnation followed by a freeze-drying. The impregnation prior to the freeze-drying is necessary to add stabilizing agents in a sufficient amount, but not more, so that the object retains its shape, colour and appearance as close to the original as possible. The concentrations and duration of impregnation were based on the assessment that the density of the wood increased from 0.2 g/ccm in the outer layers to 0.45 g/ccm in the sound inner core. A later measurement of a fragment showed a somewhat higher density. The bulking and stabilization in a solution of polyethylene glycol (PEG) 400 and PEG 2000 were estimated according to the earlier version of the diffusion computer model developed at the Section for Organic Materials. This version is later on modified.[5] The data for the planned impregnation is presented in table 1.

Table 1: The preliminary plan for the polyethylene glycol (PEG) impregnation process according to the impregnation models based on an assessed density of the degraded wood.

Day	PEG 400 g/ccm	PEG 2000 g/ccm
1	0.25	0.00
150	0.25	0.10
240	0.25	0.20
360	0.15	0.20
420	0.15	0.20

The freeze-drying was planned to take place at –25°C at a relative humidity of 50%. The drying time was expected to take three months.

4. Conservation treatment

4.1 Impregnation treatment

93-11-29	Impregnation started in a solution of 0.09 g/ccm polyethylene glycole (PEG) 400 and 0.08 g/ccm PEG 600. 0.005 g/ccm sodium benzoate was added as a fungicide.
93-11-30	Added 0.005 g/ccm potassium sorbate. The total amount of fungi- and bacteriocid was then 1% w/w.
94-03-17	The concentration was increased by adding 0.1 g/ccm PEG 2000.
94-06-30	Added 0.1 g/ccm PEG 2000 and 0.005 g/ccm potassium sorbate.
94-09-22	Added 0.08 g/ccm PEG 2000.
94-10-03	Heated the impregnation bath to 48°C for 24 hours.
95-02-22	Heated the impregnation bath to 58°C.
95-02-22	Added 0.08 g/ccm PEG 2000, to an end-concentration of 0.36 g/ccm PEG 2000.
95-02-25	Continuous heating at 45°C, to improve the diffusion of PEG.

A high start concentration of low molecular PEG as it was calculated (see table 1) does not seem to damage the structure of the wood, and has the advantage that it gives a higher diffusion velocity.

4 Verhoeven et al. 1994, Fig. 11–17.
5 Jensen 1996.

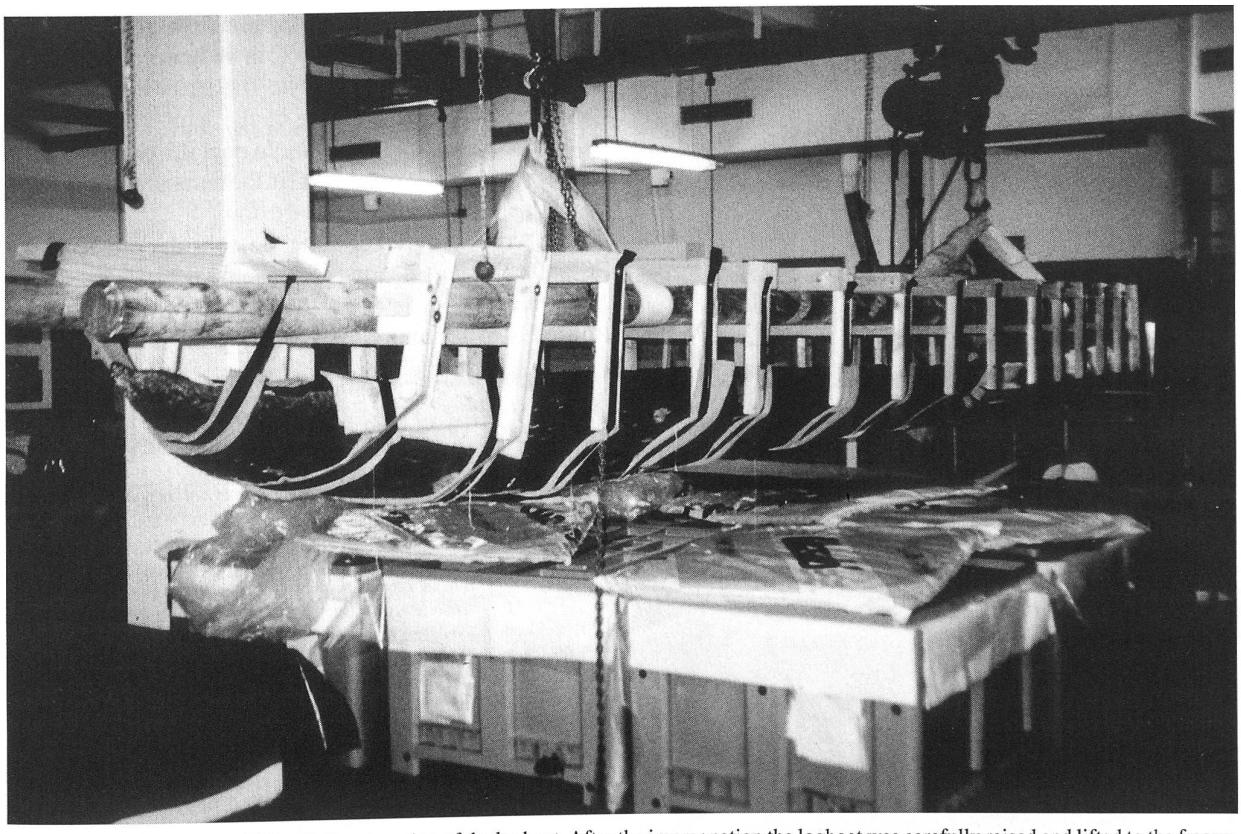


Fig. 3: Erlach - Heidenweg 1993–96. Conservation of the logboat. After the impregnation the logboat was carefully raised and lifted to the freeze-drying chamber.

However, if you have to reduce the concentration later on by adding water, there will be a surplus of liquid which may cause economical and practical problems, if there is no immediate use for it, and if you have large quantities, as it was the case.

In order to avoid problems with excess fluids it was decided to reduce the planned start concentration and use a constant concentration during the entire process. To make up for the reduced diffusion velocity the immersion time was extended instead.

In accordance to the planned impregnation, PEG 400 should be used as the low molecular PEG. The estimated amount of used low molecular PEG was approximately 750 l. Since 300 l PEG 600 were in surplus from a previous purchase and due to the fact that the molecular size is still low, the actually used mixture was a blend of PEG 400 and PEG 600, and does not express a deliberate attempt to attain a better impregnation.

After the impregnation process had started it was also decided to increase the concentration found by the computer model. The reason for this was that it has been the experience from the impregnation and drying of some thousand objects every year that the concentration from the computer program usually needs to be raised a little. From experience it was estimated that the development of cross-grain cracks with a size of 0.1–1.5 cm could be reduced if the concentration of PEG was increased with 5% more than the initially planned.

The changes chosen in relation to the final plan, were therefore a longer impregnation period and an increased concentration of PEG 2000 in the later phase. Table 2 shows the used concentrations and time for the entire impregnation process.

Table 2: The impregnation treatment of the logboat.

Day	PEG 400/600 g/ccm	PEG 2000 g/ccm
1	0.17	0.00
109	0.17	0.10
214	0.17	0.20
298	0.17	0.28
451	0.17	0.36
515	0.17	0.36

From the start a fungicide consisting of 0.005 g/ccm sodium benzoate and 0.005 g/ccm potassium sorbate was added to the impregnation bath. The total amount of fungicide was then 1%. After a period of 7 months further 0.005 g/ccm potassium sorbate was added. Sodium benzoate and potassium sorbate were chosen because they have inhibitory effect on microorganism even though they are not very toxic. This is the reason for their use in food. There was only a small local growth of fungi. In proportion to the long period of impregnation the fungicide has had the desired effect. More toxic, and more effective, fungicides are environmentally and economically problematic.

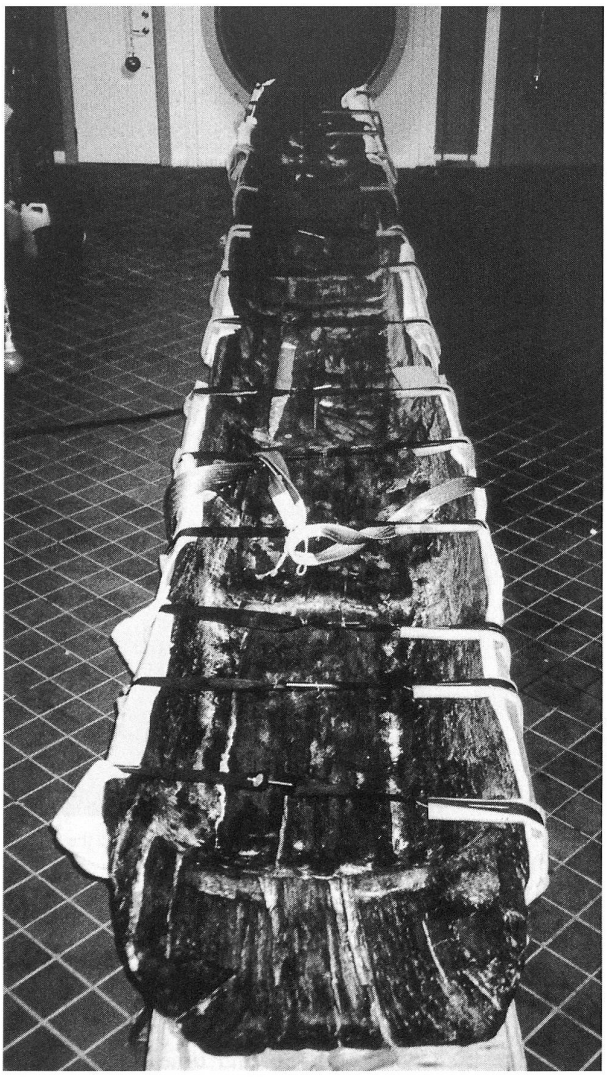


Fig. 4: Erlach - Heidenweg 1993–96. Conservation of the logboat. The logboat was weak after impregnation. For that reason it was buckled safely with the webs used for the transport for pre-freezing and freeze-drying.

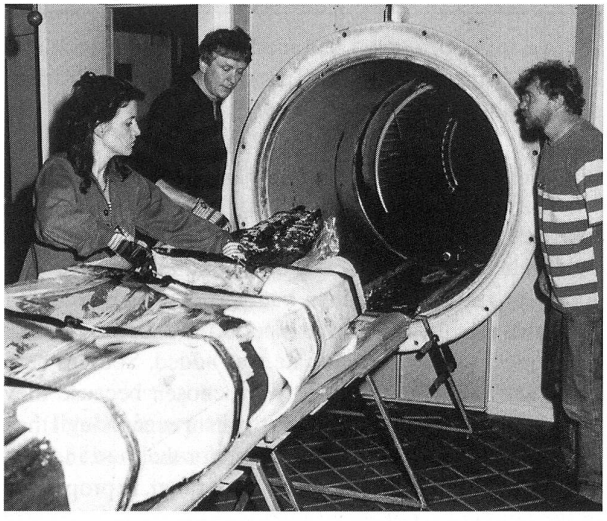


Fig. 5: Erlach - Heidenweg 1993–96. Conservation of the logboat. The freeze-drying was ended in November 1995 when the logboat was taken out of the chamber.

In the last part of the impregnation the temperature was raised from about 20°C to 58°C in 48 hours and after that kept at 45°C for about 50 days. The purpose of the short period with a high increase of the temperature was to counteract a possible microbiological development. The increased temperature of 45°C in the remaining period was used to ensure an efficient diffusion.
There were many other things to consider. For instance even though the Section for Organic Materials has a very large purpose-made freeze-drying tank, it had to be extended with 1.5 m to a total length of 8.5 m.

4.2 Freeze-drying

95-04-27	After impregnation the logboat was prepared for freeze-drying. The logboat, as well as the water/PEG mixture, seemed to be in good condition. The logboat was weak after the impregnation, with a tendency to flatten out. It was possible to buckle the logboat safely with the webs used for the transport from the impregnation bath. Freezing of the logboat started.
95-05-08	The temperature of the logboat was lowered to –22°C and of the wall of the chamber to –35°C. To start the freeze-drying the pressure was lowered to 0.2 mbar and for that reason the temperature at the surface of the logboat decreased to –33.5°C. The freeze-drying was carried out with a temperature at the surface about –31 to –32°C, and at a pressure of 0.18 to 0.8 mbar.
95-05-04	An interruption of the freeze-drying process for photo documentation.
95-11-16	Freeze-drying brought to an end based on the measuring carried out from 95-10-27 to 95-11-06 on fragments taken from the logboat. The fragments had been kept at 50% RH and at room temperature. The humidity of the logboat was measured at 9–11% and at 8.2–9.2% for the green wood used for the support of the logboat.
96-01-03	The relative humidity was extremely low due to the long period of constant frosty weather.

The freeze-drying process was carried out with a radiation temperature of –22°C to –24°C, while the temperature of the chamber wall was –35°C.
The pressure was kept at 0.18 to 0.8 mbar. The relative humidity (RH) was measured by an ice psykrometer.[6]
By adjusting the radiation temperature and thereby the sublimation temperature the RH was kept between 34% and 44%.
The freeze-drying process was ended in November 1995. In February 1996 the logboat was taken out of the chamber. Unfortunately this was during a long cold period with a very low RH of about 28%–35% in the ensuing 2 months. With the storage facilities of the Section for Organic Materials it was not possible to regulate the humidity. The result of the change in humidity from 40% in the chamber to 30% in the air was a small opening of the cracks. Even though these cracks closed somewhat later at a rising RH it caused a great strain for the object, which would have been avoided if the freeze-drying process had been terminated in another time of the year, or if adequate storage facilities had existed.

6 Jensen et al. 1993.

5. Cleaning and Restoration

96-02	Removed surplus PEG with pure ethanol. Glued fragments with a thermo-setting glue, Jetmelt 3792. The same glue was used as a filler, before retouching the cracks. The retouching was done with stable earthen colours.
96-06-04–06	Preparations for the logboat-transport back to Switzerland.
96-06-06–07	Transport of the logboat by van to Berne.
96-06	Unpacking and storage of the logboat in stabilized conditions (RH about 58%).
in 1999/2000	Exhibition of the logboat.

The logboat was cleaned by removing the surplus of PEG with pure ethanol. The solubility of PEG with ethanol is sufficient for the removal of PEG and the following evaporation caused no damaging effect of the surface. The mechanical cleaning process was done with due precaution.

A few lost fragments were put in place with thermo-setting glue, Jetmelt 3792.[7] The supplication requires a preheating of the surface. Used carefully the glue is very strong and gives at the same time some flexibility and will not damage the object.

To increase the stability of the logboat some of the longitudinal cracks were filled up with the same glue. It is an advantage to use the same material all over and Jetmelt 3792 is very suitable as a filler.

The samples which were used for dendrochronological determination had been cut directly out of the boat. Left-over material was glued to the original place. In two places greater parts of the samples were lacking. These holes were filled up with plaster.

The glue joints and the plaster were retouched with acrylic and earthen colours which are very stable.

The restoration treatment after the freeze-drying is a time-consuming work which requires much experience.

Fig. 6: Erlach - Heidenweg 1993–96. Conservation of the logboat. The final restauration of the logboat began in February 1996.

6. Evaluation

The logboat was stable after freeze-drying and at normal RH. The shape was entirely unchanged and no twisting had occurred.

There were however cracks in various places of the surface. The greatest problem was that the original longitudinal cracks had become somewhat enlarged. There are a few longitudinal cracks, which are natural from the tension of the wood, but the largest run for about a third of the length and is some centimeters in the widest places. These cracks would not have been prevented by a higher concentration of high molecular PEG, but were due to the degraded condition of the wood and the increased weight caused by the stabilization. A lesser problem were some narrow cross-grain cracks on the surface in the front of the logboat with a length of 0.1–1 cm.

It cannot be said with certainty which effect the heating of the impregnation bath has had. However, as far as it can be seen the heating up to 45°C does not break down the PEG-molecules, and may be considered advantageous as it furthers the diffusion.

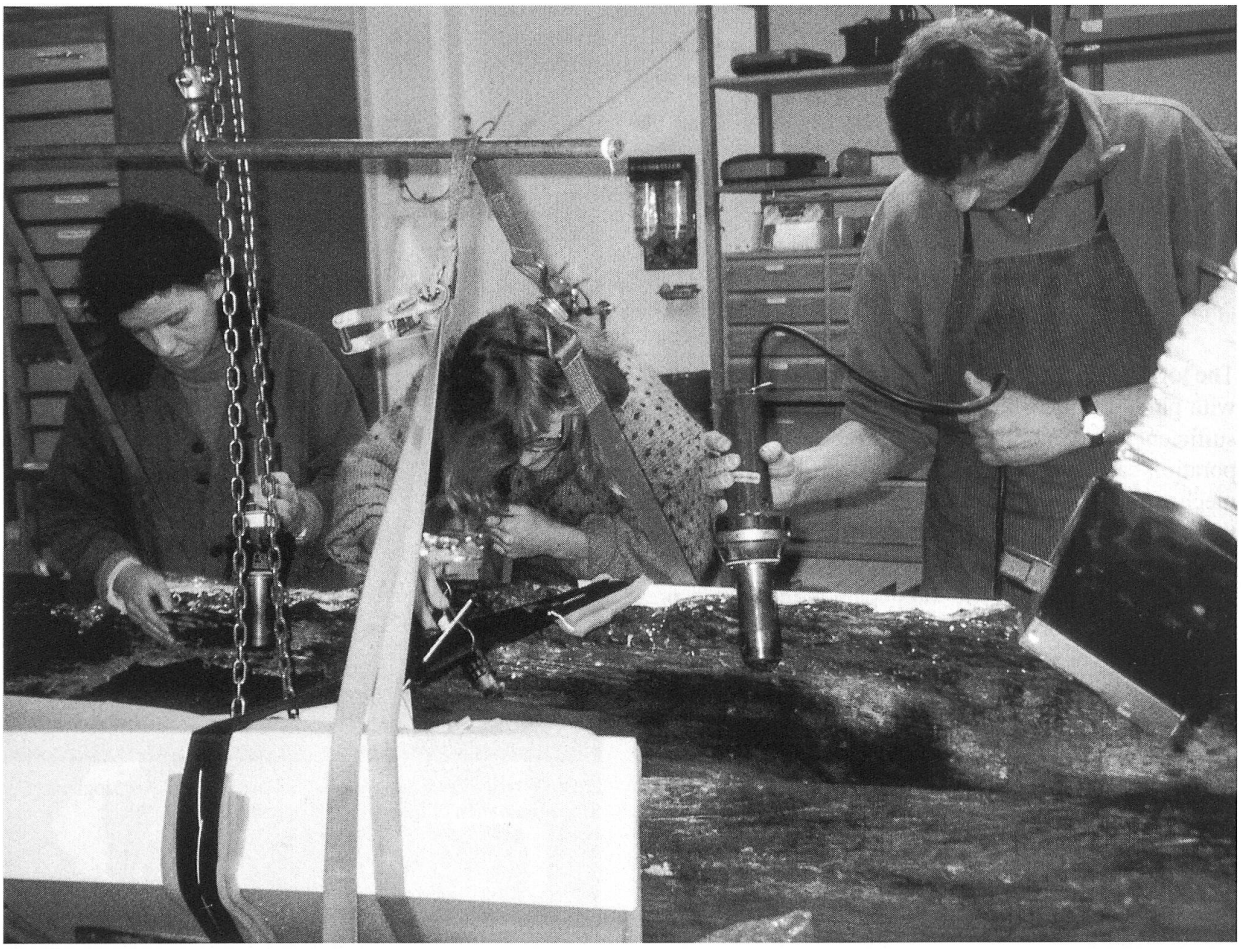
The idea of applying freeze-drying for such a large object may be said to be successful. The logboat is stable and has a natural look where the original character of the oakwood is preserved.

7. Discussion

The surface of the logboat was not greasy. Therefore the amount of low molecular PEG has not been too much.

Even though the amount of high molecular PEG was increased in relation to the first plan it could probably with advantage have been increased further to reduce development of the narrow cross-grain cracks. In that way some of the smaller cracks might have been avoided. It is not possible to give an exact measure of concentration which would have reduced cross-grain cracks, but a further raised concentration of 2–5% PEG would properly have limited the development of cross-grain cracks. From experience of other finds the securing of superficial toolmarks is satisfactory by using a relatively high concentration of PEG.

7 Jetmelt 3792: 3M United Kingdom Pl.C., P.O. Box 1, 3MHouse, Bracknell, Berks. RTG 12 1JU, Tel: Bracknell (0344)426726.



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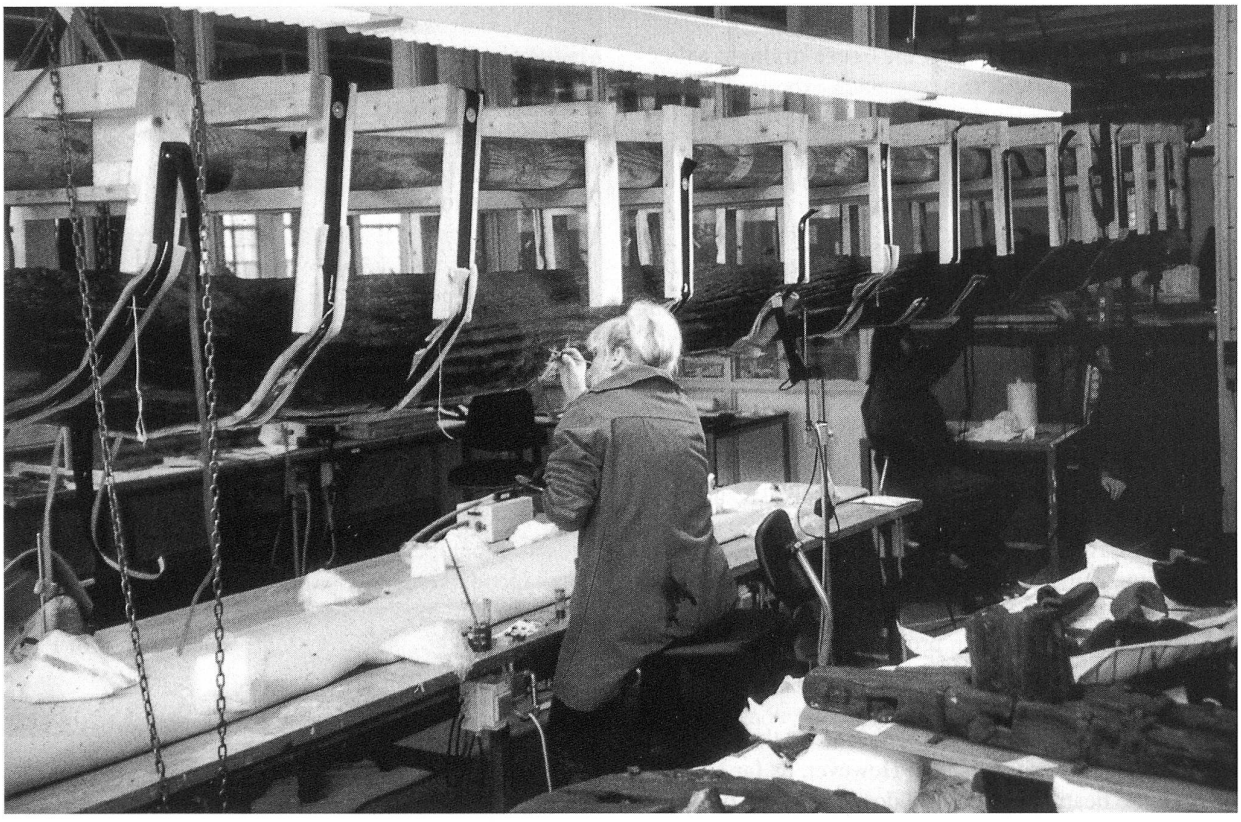

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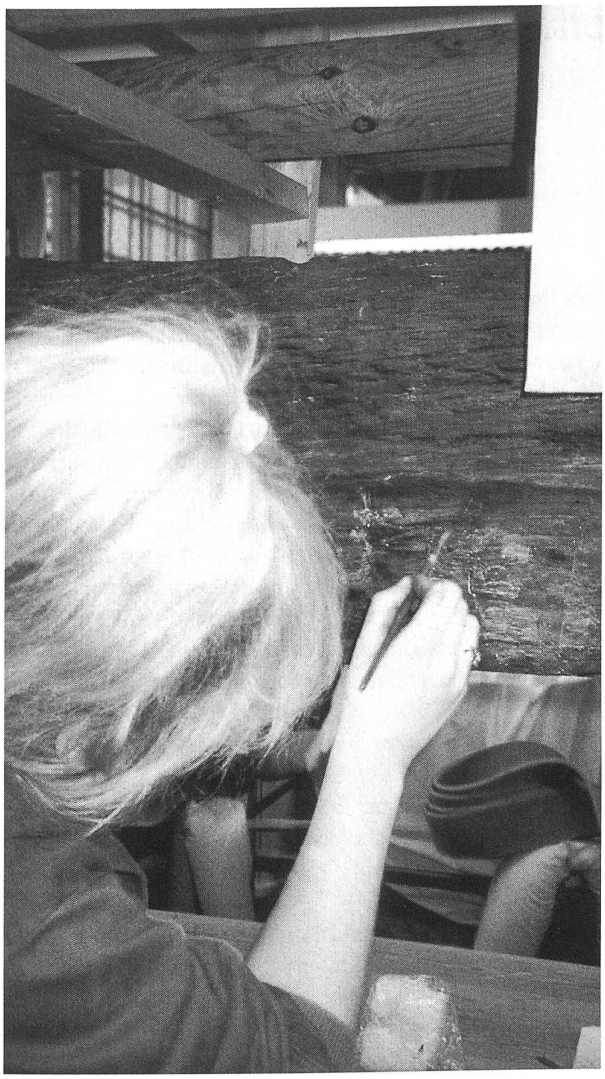

C

Fig. 7A–C: Erlach - Heidenweg 1993–96. Conservation of the logboat. Retouching after gluing and filling is a time-consuming work which requires great experience. The restaured logboat is of archaeological importance as well as it is a fine exhibit.

A moderate increase in concentration will not result in a darker appearance of the wood.

8. Conclusion

As a whole the result must be considered very satisfactory. Freeze-drying can with advantage be used for the drying of large archaeological objects by proper treatment. The further development of experience and knowledge might give us more certain answers about the optimum impregnation in combination with freeze-drying in the future. However the handling and treatment to conserve such large organic objects require craftmanship in addition to technical knowledge.

Fig. 8: Erlach - Heidenweg 1993–96. Conservation of the logboat. After applying the finishing touches the logboat will be ready for transport to Berne. It will be exhibited in 1999/2000.

9. Literature

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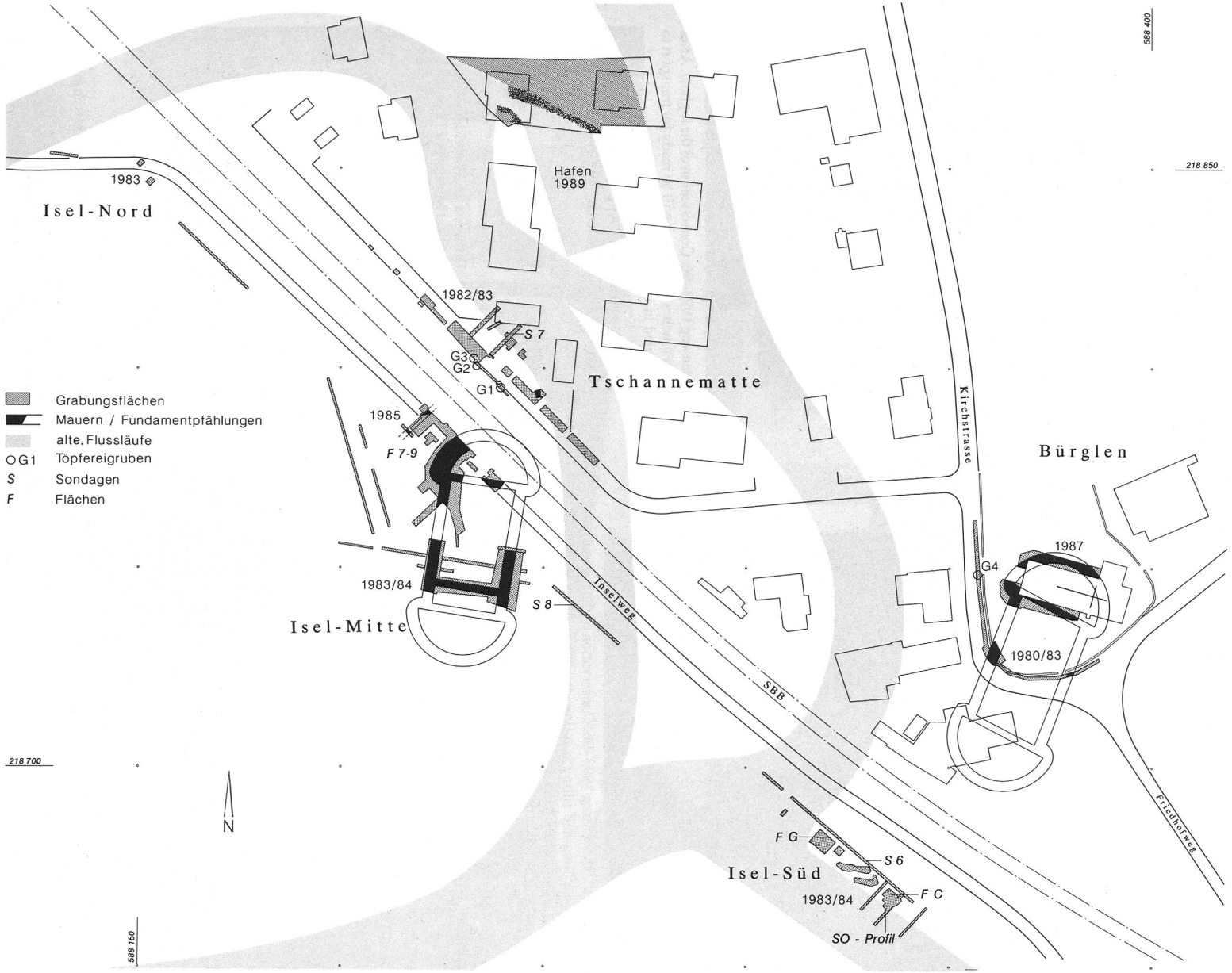

Abb. 1: Aegerten 1980–89. Übersichtsplan. M. 1:1400.