THE ANALYSIS OF CAULKING MATERIAL IN THE STUDY OF SHIPBUILDING TECHNOLOGY

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ABSTRACT: An analysis was made of 182 caulking samples that belong to 98 different shipwreck(fragments) excavated in the Netherlands from 1942 onwards. These ships represent several different types and were built between the second half of the 9th century and the beginning of the 20th century.

The caulking samples consist of mosses, other plant species, hair and amorphous material. Also taking into account mixtures and considering *Sphagnum* separately, we recognized ten different categories of caulking material. Besides *Sphagnum*, 35 different bryophytes could be identified: 1 liverwort, 7 acrocarpous mosses and 27 pleurocarpous mosses. With the exception of unintentionally gathered species, these mosses are easily gathered, owing to their relatively large size and their growth-form in connection with abundance. Caulking samples from ships that were built between the 9th and the middle of the 13th century are composed of mosses that were purposely gathered in (deciduous) woods. From the 13th century onwards, mosses were gathered in wetter environments. From the 14th century onwards, most moss samples contain only one species. *Sphagnum* becomes predominant and also *Drepanocladus aduncus* and *D. exannulatus* remain well represented. One possible explanation is that the availability of woodland mosses in sufficient amounts decreased. However, it is more likely that, along with the improvement of the caulking technique, the following properties may have become increasingly important: 1) long fibres; 2) absorbency and 3) absence of contaminants.

Both the identification of mosses and pollen analysis can provide information on the type of environment and the possible area where the caulking material was gathered. The composition of some caulking material indicates that it was gathered from a variety of locations. This can be explained by the large quantities required for the caulking of a single ship. Also the replenishment of stock supplies will have produced mixtures of species from different origins.

KEYWORDS: The Netherlands, Middle Ages, post-medieval period, maritime archaeology, archaeobotany, pollen analysis, shipbuilding, caulking, moss, hair, oakum.

1. INTRODUCTION

When wooden ship hulls are made of loose elements such as planks, it is important to prevent penetration of water through the seams. This could be achieved by filling up the seams with various kinds of material. Two different terms are used for this filling. A general term is 'caulking material'. A wide variety of materials is mentioned in the literature: mosses, cotton, paper, putty and hair, leaves, grass and hazel twigs (McGrail, 1987; Vlierman, 1996a). A more specific term is 'oakum' (Dutch: *werk*; German: *Werg*), referring particularly to fibres of hemp (*Cannabis sativa*) and flax (*Linum usitatissimum*). Caulking material could either be coated or impregnated with tar or pitch, or it remained uncovered, especially if the wood was not allowed to dry out when the ship was hauled up.

Caulking material was used not only when ships were built, but could also be applied during a ship's repair. Special techniques and instruments were developed for caulking, such as a caulking-mallet and caulking-iron. The iron clamps (Dutch: *sintelnagels* and *sintels*) that were used for clamping the small wooden slats over the caulking material show a significant transformation in shape during the Hanseatic period (c. 1150-1550), thus facilitating the dating of shipwrecks (Vlierman, 1996a). It is evident that in all Dutch shipwrecks of the later Middle Ages only moss was used as a caulking material in combination with *sintels* or other fastenings. For that reason, Vlierman (1996a) introduced the term *gesinteld mosbreeuwsel* to replace *gesinteld werk* as used by Sopers (1974).

Material that serves the purpose of caulking must have special qualities. First of all, it should prevent the penetration of water and it must be easily pushed into the narrow joins. Moreover, it must last for many years which means that it must withstand fluctuations in temperature and salinity and must be immune to microbiological decay. A more practical criterion for the choice of caulking material is the availability of sufficient amounts, since a considerable quantity of caulking material is necessary for the caulking of a moderate-sized ship.

The use of caulking material has a long tradition in shipbuilding technology in different parts of the world. Caulking has been practised in northwestern Europe from the Bronze Age onwards (Wright & Churchill, 1965; Dickson, 1973). Strabo mentioned that the Gallic tribe of the Veneti caulked or covered their ships with seaweed, so as to prevent the wood from drying out (Geography IV.4.1). Pounded reed (probably *Phragmites australis*) was used in Gallia (Belgium) where it grew abundantly and had the quality of remaining viscous to some extent (Pliny: Natural History XVI.158). The use of indigenous species can be illustrated by some examples from other parts of the world. In ancient Egypt, papyrus (*Cyperus papyrus*) has been used for caulking, as described by Herodotus (Book II.96). The traditional wooden lateen sailing ships known as 'Arab dhow' that were used for trade in the Indian Ocean from medieval times onwards, were sometimes caulked with cotton (*Gossypium* sp.) or fish-oil mixed with oakum (Yajima, 1976). Although an oakum-like substance made from date palm (*Phoenix dactylifera*) fibres is mentioned by ibn-Jubayr, most Arabic authors only mention the use of a mixture of pitch or resin and whale- or shark-oil (Hourani, 1995).

Despite the use of caulking material on a large scale, analyses of its composition are sparse. Fortunately, many samples of caulking material have been collected during excavations of Dutch shipwrecks from 1942 onwards. From this collection, which is stored at the Nederlands Instituut voor Scheeps- en onderwater Archeologie (Lelystad, the Netherlands), samples from six different ships have been botanically analyzed and published (Bottema, 1983; Touw & Rubers, 1989). The present study deals with the analysis of the complete collection, with special emphasis on moss and pollen analysis. For the sake of completeness, samples from the above-mentioned six shipwrecks have also been incorporated in this study.

The present article summarizes the results of both the identification of bryophytes and pollen analysis. A more detailed report will be published separately, including information on the ships, a complete list of the botanical composition of each sample, all the available pollen diagrams and radiocarbon datings in relation to dendrochronological evidence.

2. MATERIALS AND METHODS

A total of 182 samples, originating from 98 different shipwrecks, were screened for their composition. Those samples that contained moss species were selected for further examination. Small samples were completely investigated, whereas from larger samples several representative subsamples were taken. Of each sample a small subsample remained untouched for future research (see appendix 1).

Moss samples were examined under a dissecting microscope. Owing to the tamping of the caulking material, it was sometimes necessary to soak the material in tap water for some time before examination could be performed. Representative specimens of all different species were isolated and identified under a high-power microscope. Problem species were checked with herbarium specimens from the Herbarium Groninganum (GRO). *Sphagnum* ('bog' or 'peat' moss) was only sporadically identified to the level of species. The identification of *Sphagnum* species not only is problematic because of the variability of these aquatic moss species, but is also hampered by the severe fragmentation in many samples.

Each moss species was quantified by establishing its frequency in a sample according to five different classes. Besides moss species, also some seeds and stem fragments were found and identified.

A selection of 21 caulking samples were further investigated by pollen analysis. This selection was based on the assemblage of the moss species and the type of the ship. Subsamples of c. 1 ml were prepared according to standard procedures described by Faegri & Iversen (1975). Pollen of aquatic plants, spores and algae were excluded from the pollen sum.

Finally, 19 caulking samples were submitted to the Centrum voor Isotopen Onderzoek (University of Groningen, the Netherlands) for radiocarbon dating.

3. RESULTS

The locations of the shipwrecks from which caulking samples were investigated are shown in (fig. 1). Although a reasonable spread of locations is evident, the greatest concentration is found along the shores of the IJsselmeer lake and in the province of Flevoland which was reclaimed from this lake that was formerly open water connected with the sea.

Most shipwrecks were found in situ. Exceptions are reused ship fragments from Amsterdam, Deventer and Rotterdam. In Amsterdam parts of a cargo-vessel were found under one of the towers of the Nieuwezijds Kolk 'castle' (Vlierman, 1995), whereas in Deventer fragments of two different barges were used as a riverbank revetment (Vlierman, 1996b). In Rotterdam reused shipwood concerns samples 11, 12 and 25.

The shipwrecks represent eight different types of ship and their building periods cover the second half of the 9th century up to the early 20th century (table 1). However, their chronological distribution is not even. For example, the 10th and 11th centuries are represented only by barges, whereas *waterschepen* are limited to the 16th and 17th centuries.

Fig. 1. Location of shipwrecks from which caulking samples were investigated.

Table 1 also shows the composition of the caulking samples, in which the following categories are distinguished: 1) mosses, with *Sphagnum* ('bog' or 'peat' moss) separated from the other moss species; 2) other plant remains, such as stem and root fragments of vascular plants; 3) hair and 4) amorphous material. In addition to these homogeneous samples, also six different combinations of the first three categories were found.

Sphagnum was only sporadically identified to the level of species. In those cases it proved to be *S. cuspidatum*, a floating or submerged moss which grows in oligotrophic pools. Most of the other mosses could be identified to the level of species, producing a list of 35 species (table 2). The moss remains that were identified as *Homalothecium* cf. *sericeum* have leaves c. 2 mm long which are clearly dentate. The related species *H. lutescens* has longer leaves with almost smooth margins, making it a less plausible candidate. In addition to the moss species, also six vascular plants are represented in the caulking samples by seeds or small stem fragments: *Rhynchospora alba*, *Eriophorum*, *Rumex acetosella*, *Dactylis glomerata*, *Calluna vulgaris*, *Erica tetralix*, *Betula* and *Carpinus betulus*.

The caulking sample of *Neckera crispa* from an extended logboat of Utrecht type, excavated in the Lange Lauwerstraat in Utrecht (sample No. 7) and dated to the first half of the 12th century (Vlierman, 1996a), concerns a different sample from the one published by Touw & Rubers (1989). The latter belongs to a boat that was found in the Van Hoornekade. An erroneous dating of c. 500 BC is mentioned by Touw & Rubers, but dendrochronological and archaeological research indicate that the boat was built in the 11th century AD (Vlek, 1987).

Sample 87 from a 19th century vessel, found in the former IJsselmeer, cannot easily be identified as caulking. The sample consists of dark brown threads, about 0.1-0.2 mm thick. The threads show branching at 1-4 mm intervals. Often the branching is accompanied

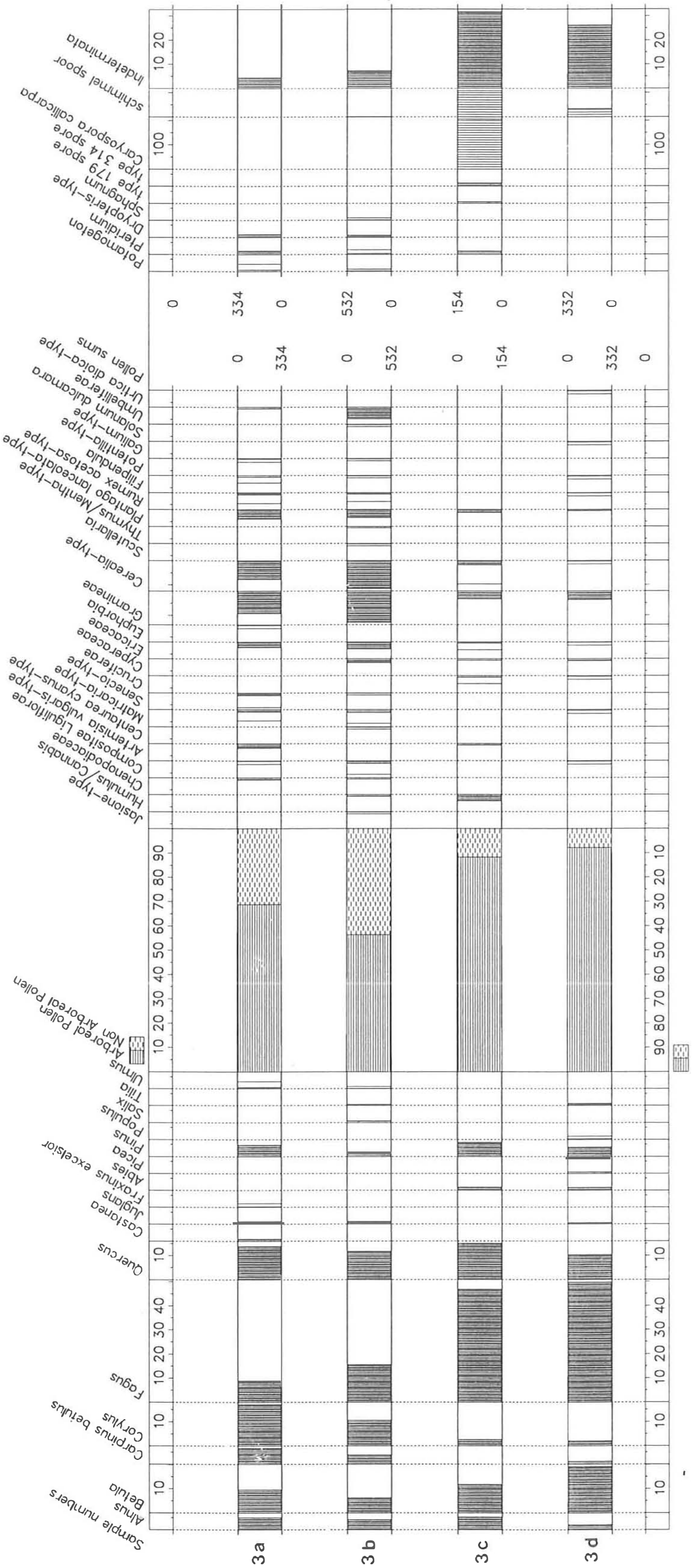

Fig. 2. Pollen diagrams of four caulking samples from a barge found at Tiel.

Table 1. Building period of ships (N = 98) and composition of caulking samples (N = 182). Abbreviation: LM = Late Middle Ages.

	Centuries																				
	9	10	10 11	11	12	13	13 14	14	14 15	15	LM	15 16	16	16 17	17	17 18	18	18 19	19	19 20	?
Barge	-	2	1	2	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Cog	-	-	-	-	-	3	-	3	2	1	-	-	-	-	-	-	-	-	-	-	-
Cargo-vessel	1^{2}	-	-	-	-	3^{2}	2	-	1^{2}	2	1	3	7	-	$8^{2,1}$	-	7	1	6^{1}	-	$1^{2;3}$
Fishing-boat	-	-	-	-	-	-	-	-	-	-	-	-	2	1	2	-	-	-	-	-	-
Log-vessel	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Punt	-	-	-	-	-	2^{2}	-	-	-	1^{2}	-	1	-	-	-	-	1^{1}	-	-	-	-
Veenderijschuit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Waterschip	-	-	-	-	-	-	-	-	-	-	-	-	8	3	2	-	-	-	-	-	-
Ship fragment(s)	-	-	-	-	1	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	1
Unknown	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1^{1}	-	-	-	-	1	5
Sphagnum	-	-	-	-	-	6	1	6	6	4	3	3	3[illegible]	3	10^{1}	-	4	1	-	1	1
Sphagnum/ other mosses	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Sphagnum/ other plants/hair	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-
Sphagnum/ other plants	-	-	-	-	-	-	1	-	1	2	1	-	1	-	2	-	1^{1}	-	1	-	-
Other mosses	-	4	4	2	1	12	2	-	2	-	1	-	3	-	-	-	-	-	2	-	1^{2}
Other mosses/ other plants	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other mosses/hair	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other plants	-	-	-	-	-	3	1	-	1	2	-	1	5	2	5	-	3	-	1	-	-
Other plants/hair	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Hair	1	-	-	-	-	-	1	-	1	-	-	2	-	1	3^{1}	-	6	-	1^{1}	-	4
Amorphous	-	1	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-
Unknown	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-

[1] Dating of one ship or caulking sample uncertain.
[2] Identification of one ship uncertain.
[3] Middle Ages.

by slight thickenings in the form of rings. The sample of these threads is associated with about 50 transparent, juvenile mussel shells, some of which are still attached to each other. The shells measure about 2-5 mm and belong to the edible mussel *Mytilus edulis* (identification by R.G. Moolenbeek). It is not easily demonstrated that the threads and the shells are contemporaneous.

The tiny shells are so fragile that it is almost impossible that they survived caulking. If they had been hammered in between planks together with the threads they would have been smashed.

A possibility that was considered for the identification of the threads is that they are *byssus* threads from mussels. These are the threads that mussels form to attach to a substrate. The *byssus* threads could have held mussels onto the hull of the ship. Mussels (*Mytilus edulis*) collected on the coast of Groningen on a basalt-clad dike had their *byssus* threads extended mostly to each other, to broken shells and to the underlying basalt blocks. The straight ends of these *byssus* threads did not resemble the material in the 19th-century sample. Where the threads were fastened to the substrate they showed branching but they did not display the thickened rings.

Although only whole centuries are mentioned in table 2, including transitional phases, more detailed information on the dating of the samples has been used to put the samples on this time scale. This means that, within a century, the oldest samples are positioned to the left and the youngest to the right.

Figure 2 presents the results of the pollen analysis of four caulking samples. These samples originate from the same shipwreck (viz. Tiel, Tol-noord; sample Nos 3a-d in table 2). A discussion of the moss species from the caulking samples will follow in the next section.

4. DISCUSSION AND CONCLUSIONS

4.1. Characterization of caulking samples

The number of moss species in caulking samples varies from one to twelve. Well over fifty percent of the investigated caulking samples contain just a single moss species. The majority of these samples (82%) consist of

Table 2. Presence of mosses and vascular plants in caulking samples. Caulking samples with only *Sphagnum* are not presented. Moss frequency is indicated by a number: 1. Single leaf/stem fragment; 2. Few fragments; 3. Moderate number of fragments; 4. Large number of fragments; 5. Sole moss species. Remains of vascular plants are indicated with 'x'. An asterisk (*) indicates that the identification to the level of species is uncertain.

Centuries	10				10 11				11		12		13												
Samples	3				4				5	6	7	8	9	10	11	12			13	14		15	16	17	
	a	b	c	d	a	b	c	d							d	a	b	c	b	a	b			a	b
Isothecium myosuroides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhynchospora alba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ditrichum flexicaule	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polytrichum commune	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpidium scorpioides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eriophorum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plagiomnium affine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rumex acetosella	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dactylis glomerata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polytrichum formosum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isopterygium elegans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mnium hornum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypnum jutlandicum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isothecium alopecuroides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eurhynchium striatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Cratoneuron commutatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5*	-	-	-	-
Sphagnum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	5	-	-	-
Calliergon giganteum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-
Rhytidium rugosum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Plagiochila asplenioides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Plagiomnium undulatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Carpinus betulus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-
Drepanocladus aduncus	-	-	-	-	-	-	-	-	-	-	-	4	-	-	5	-	-	-	-	5	-	-	4	-	-
Rhytidiadelphus squar/subp	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
c.f.Herzogiella seligeri	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Hypnum cupressiforme	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calliergonella cuspidata	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudoscleropodium purum	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thuidium delicat./phil.	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	3	-	-	-	-	-	-	-	4	2
Neckera complanata	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calluna vulgaris	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-
Erica tetralix	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-
Homalothecium sericeum	-	-	-	-	-	-	-	-	-	2*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Antitrichia curtipendula	-	-	-	-	-	-	-	-	2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Betula	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Drepanocladus exannulatus	-	-	-	-	-	5	5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Neckera crispa	-	-	-	-	5	-	-	-	4	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hylocomium brevirostre	-	-	-	2	-	-	-	-	3	1	-	-	3	2	-	3	-	-	-	-	-	-	-	3	4
Rhytidiadelphus loreus	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurozium schreberi	2	4	-	-	-	-	-	-	-	4	-	-	4	4	-	-	4	4	-	-	-	-	-	2	-
Dicranum scoparium	2	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	2	-	-	-	-	-	-	1	2
Rhytidiadelphus triquetrus	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	1	-
Hylocomium splendens	3	1	-	-	-	-	-	-	-	1	-	-	3	3	-	-	-	1	-	-	-	-	-	3	-
Thuidium tamariscinum	3	3	5	4	-	-	-	-	2	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sphagnum, sometimes contaminated with small fragments of herbs or trees that grow in peat or heath vegetations. The composition of caulking samples that contain moss species other than *Sphagnum* is quite variable. Almost half of these samples consist of only one species, whereas the others are a mixture. The most diverse caulking sample (table 2, No. 6) originates from a barge found in Utrecht and in addition to leaves of *Erica tetralix* and *Calluna vulgaris* contains twelve different moss species. Moss species that are found in

		13	14	14			MA		16							16	17		18	19			Centuries
		14		15												17			?				
	18	19	21	25	26	27	37	40	42			43	45	48	56	60	75	76	84	86	88		Samples
c	a	a	b	b		b	a			a	b	c		b	a	a	c		c				
-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Isothecium myosuroides
-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Rhynchospora alba
-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Ditrichum flexicaule
-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Polytrichum commune
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	Scorpidium scorpioides
-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	Eriophorum
-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Plagiomnium affine
-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	Rumex acetosella
-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	Dactylis glomerata
-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Polytrichum formosum
-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Isopterygium elegans
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Mnium hornum
1*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Hypnum jutlandicum
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Isothecium alopecuroides
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Eurhynchium striatum
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Cratoneuron commutatum
-	-	-	-	5	-	-	3	-	-	-	-	-	5	5	5	2	5	5	5	4	-	-	Sphagnum
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Calliergon giganteum
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Rhytidium rugosum
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Plagiochila asplenioides
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Plagiomnium undulatum
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Carpinus betulus
-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	4	-	-	-	-	-	1*	Drepanocladus aduncus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Rhytidiadelphus squar/subp
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	cf. Herzogiella seligeri
-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Hypnum cupressiforme
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Calliergonella cuspidata
-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pseudoscleropodium purum
-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Thuidium delicat./phil.
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Neckera complanata
-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-	x	x	x	-	-	Calluna vulgaris
-	-	-	-	x	-	-	x	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	Erica tetralix
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Homalothecium sericeum
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Antitrichia curtipendula
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Betula
-	5	-	-	-	-	5	-	-	5	-	5	5	-	-	-	-	-	-	-	-	5	-	Drepanocladus exannulatus
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Neckera crispa
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Hylocomium brevirostre
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Rhytidiadelphus loreus
2	-	1	3	-	4	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Pleurozium schreberi
2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Dicranum scoparium
2	-	1	1	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Rhytidiadelphus triquetrus
-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Hylocomium splendens
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Thuidium tamariscinum

more than five caulking samples are: *Drepanocladus aduncus* (7x), *Dicranum scoparium* (7x), *Thuidium tamariscinum* (7x), *Rhytidiadelphus triquetrus* (8x), *Hylocomium splendens* (8x), *Hylocomium brevirostre* (9x), *Drepanocladus exannulatus* (11x) and *Pleurozium schreberi* (13x).

Most of the mosses are pleurocarpous; only seven species are acrocarpous: *Plagiomnium affine*, *Polytrichum commune*, *Ditrichum flexicaule*, *Polytrichum formosum*, *Mnium hornum*, *Dicranum scoparium* and *Plagiomnium undulatum*. Acrocarpous mosses are of erect habit, whereas pleurocarpous mosses form intricate mats or wefts. Nevertheless, the acrocarpous mosses found in the caulking samples are characterized by their growth in relatively large turfs. Both large size and growth-form, together with abundance, constitute favourable conditions for the gathering of mosses on a large scale.

Of special interest is *Plachiochila asplenioides*, which was found in caulking sample No. 12a and originates from a shipwreck (probably a cargo-vessel) unearthed in Rotterdam. This is the only liverwort that has been found. Only three records of this species are mentioned by Dickson (1973). Partly, this rare occurrence of liverworts in subfossil records can be explained by their being less common and more delicate than mosses. Possibly, also the growth-form plays a role, making it unattractive to gather. Although *Plachiochila asplenioides* is quite large, with shoots up to 10 cm long, and lush tufts have been recorded e.g. in the former Beekbergerwoud around c. 1850, and in floating rich-vens (Gradstein & Van Melick, 1996), its single stem fragment indicates that it was unintentionally gathered along with *Thuidium delicatulum/philibertii* and *Hylocomium brevirostre*.

Caulking samples that consist of hair are found in both medieval and post-medieval shipwrecks. Besides pure samples, hair also occurs together with mosses and other plants. Oakum, on the other hand, is conspicuous by its absence despite the attention it is given in written sources (see for a review of relevant literature: Vlierman, 1996a). As far as flax is concerned, two possible explanations may be put forward. Flax is known for its poor preservation and is certainly underrepresented in the archaeobotanical record. Empty seams in shipwrecks could therefore be indicative of the use of flax as caulking material. It is also possible that although waste products from flax-processing industries were available on a large scale, the economic value of this versatile material was still considerable. Consequently, it may have been rather too costly a product for caulking ships.

4.2. Composition of caulking samples in relation to building period

From table 1 it becomes clear that caulking samples from ships built between the 9th and the middle of the 13th century are composed of mosses that were purposely gathered in woods. If collected in the Netherlands, this would point to sandy soils, either the eastern part of the Netherlands or the dunes along the coast. The composition changes from the middle of the 13th century onwards. Mosses are now mostly gathered from wetter environments such as mires, peatbogs, heathland, fenbogs, ditches, oxbow lakes and reedland. This is accompanied by a predominance of *Sphagnum*. The other two mosses that are relatively well represented are *Drepanocladus aduncus* and *D. exannulatus*. The former is characteristic of marshy areas in the clay district (western part of the Netherlands and along rivers), whereas the latter is indicative of bogs and brook valleys in the eastern part of the Netherlands). This seems to be in accordance with a recently found stock of caulking material in the attic of a farmhouse, which consisted of *Drepanocladus fluitans* (pers. comm. W. Baas and H. During), a moss which also grows in moist places on boggy or peaty soils though it is also found in drier environments.

A second change concerns a shift from mixed moss samples to (almost) pure moss samples, which takes place in the beginning of the 14th century (table 2).

Two possible explanations may be put forward for these changes. One possibility is that moss species that were used in the first instance, gradually became rare. Consequently other, still abundant species were gathered instead. This not only suggests that mosses were gathered in the vicinity of the shipyards, but also that, initially, terrestrial mosses were preferred to mosses from swampy areas. Moreover, it implies that the ships whose caulking material has been investigated were built either in the eastern part of the Netherlands or along the coast. Sufficient quantities would still have been available in more remote places, but transport would have been problematic and expensive.

Indeed, quite a number of mosses that are present in caulking samples of early shipwrecks contain moss species that now are rare or even endangered in the Netherlands: *Hylocomium brevirostre*, *Neckera complanata*, *Neckera crispa*, *Rhytidium rugosum*, *Drepanocladus exannulatus*, *Antitrichia curtipendula*, *Calliergon giganteum*, *Cratoneuron commutatum*, *Ditrichum flexicaule*, *Rhytidiadelphus triquetrus*, *R. loreus* and *Thuidium delicatulum/philibertii*. Assuming that these mosses were indeed gathered in the Netherlands, it implies that for example *Hylocomium brevirostre* must have been quite common up to the end of the 16th century. It is questionable, however, that intensive gathering of these mosses was the decisive factor in the presumed diminishment of these species. If so, it may even have been the case that special regulations were issued to prevent overexploitation. Indeed, plants that are today protected by law in the Netherlands are not primarily characterized by their rarity but by having a market value. This also applies to the moss species *Leucobryum glaucum*, which is not mentioned in the Floron Red Data List 1990 (Siebel et al., 1992) but is now protected by law because it is in heavy demand for making Christmas bouquets. Alternatively, mosses may have become rare as a result of the disappearance of complete biotopes, lowering of the water table and the increasing air pollution and eutrophication, to which many of the above-mentioned species are sensitive. In this connection it is worth mentioning that large pleurocarpous moss species such as *Hylocomium brevirostre*, *H. splendens*, *Rhytidiadelphus triquetrus* and *R. loreus*, being indicative of woodland fringes and north-facing exposures with a low nutrient availability, were replaced by *Brachythecium rutabulum* and *Eurhynchium praelongum* as a result of eutrophication (Siebel et al., 1992). Although the last two species are easily collected and very common today in all parts of the Netherlands, they are absent in all of the caulking samples.

A second explanation for the shift in the composition of caulking samples may be that the caulking technique was improved. This could mean that greater demands were placed on the caulking material. The following properties may have become increasingly important: 1) long fibres; 2) absorbency and 3) absence of contaminants. To prevent loss of caulking material, especially during caulking into seams along the bottom part of strakes, the caulking material was twisted. Sarrazin & Van Holk (1996) report that this was done by wetting moss a little and subsequently rolling it over the thigh. The longer the particles, the better the strands would twist. Although caulking material is not intended to be exposed to water, it may at some time become so. In such cases, its dry condition ensures that it will swell and thus fill up the seam to a maximum. For the same reason it was unadvisable to caulk in rainy weather. Another advantage of dry caulking material is that it lacks elasticity, making it much easier to press into the seams. Caulking samples that lack contaminations are easier to twist and have a maximum swelling potential.

Sphagnum and *Drepanocladus* meet these conditions to a considerable degree and it seems very likely that their preference from the 13th century onwards is in line with more advanced caulking practices. The predominance of *Sphagnum* in caulking material can be explained by its excellent absorbent qualities due to the many large hyaline cells, which have no function in photosynthesis but can absorb much water. Beijerinck (1934) demonstrated that a dry specimen of *S. papillosum* could absorb an amount of water equal to 41 times its own body weight.

For the replica of a cog, built by the 'Stichting Kamper Kogge', *Sphagnum* was used for caulking. The use of this moss is in accordance with the composition of the caulking material of a cog which was found near Nijkerk (the Netherlands) and served as a model. It was decided to clean the *Sphagnum* before drying. Sieving it over a coarse mesh to get rid of small particles and removing contaminants such as roots of heather, pine-needles and bilberries by hand took two workers almost one month. Even odd specimens of *Polytrichum* sp. were picked out. Up to 25-30% of the original volume was removed in this way, leaving c. 1850-2000 litres of pressed Sphagnum for caulking a boat measuring 20x9 m. Apparently, such an investment is considered worthwhile for the sake of improved absorbency.

A similar input of labour can be deduced from the almost pure caulking material of a Bronze Age boat from eastern England, consisting of *Neckera complanata*, with only a slight admixture of *Eurhynchium striatum* (Dickson, 1973). According to Dickson, collecting an almost pure stock of this species cannot have been easy, even if the species were commoner than it is today. One can only guess at the motive.

Four caulking samples from a Danish shipwreck, the building period of which was dated to the second half of the 13th century, consisted of cow hair and *Sphagnum cuspidatum* mixed with some unidentifiable leaves of other *Sphagnum* species (Robinson & Aaby, 1994). The building period and composition of these caulking samples fit in with the change in composition of the Dutch samples.

Besides economic motives and selective preservation, as mentioned above, the absence of oakum in the investigated caulking samples may also be explained by the relatively short fibres in the waste product, making it labour-intensive to process and, eventually, causing a substantial loss of caulking material for a second time. To prevent this kind of loss, short-fibred hemp or flax could have been used for caulking the upper part of strakes in particular, where it has to be hammered downwards. The absence of these fibres in the analyzed caulking material, however, does not support this hypothesis and selective sampling seems unlikely in a study of such a scale. Differences in preservation between fibres of hemp and flax in waterlogged contexts do not seem to be relevant. Also the rare identification of these fibres in subfossil records (e.g. Körber-Grohne, 1967; Pals & Van Dierendonck, 1988; Dörfler, 1990) is probably due to the fact that processing areas of flax are seldom excavated.

Hair that is present in caulking samples, on the other hand, is mostly of considerable length. Probably it originates from horses and cows. Unfortunately, this category of samples is relatively poorly dated, so that no clear picture of its use through time can be assembled.

4.3. Composition of caulking samples in relation to type of ship

Although the type of ship is biased to some extent by its building period, there seems to be no correlation between the composition of the caulking samples and the type of ship. For example, the large number of caulking samples from the cargo-vessels, which cover almost the whole period under investigation, represent most of the combinations that were summarized in table 1. And a similar trend is shown by the samples from the *waterschepen*, mainly used for fishing, which were all dated to the 16th and 17th centuries.

4.4. Origin of caulking materials

Both moss and pollen analysis can provide evidence on the type of environment and the possible area of origin where the caulking material was gathered. As was stated above, it is evident that, as far as mosses are concerned, they were probably gathered at relatively short distances from where the ships were built.

In this connection, the four samples that originate from the barge fragments excavated at Tiel (table 2: No. 3a-d; fig. 2) are an illustrative example. Both mosses and pollen diagrams clearly show that these caulking samples were gathered from two different locations. Samples 3a and 3b consist of a mixture of five mosses, with *Pleurozium schreberi*, *Rhytidiadelphus triquetrus*, *Hylocomium splendens* and *Thuidium tamariscinum* present in both samples. Samples 3c and 3d, on the other hand, are dominated by *Thuidium tamariscinum*, the former being a pure sample and the latter contaminated with some stem fragments of *Hylocomium brevirostre* in sample 3d. All these mosses point to a deciduous forest on sandy soil, but probably not in the Dutch dunes, judging by the present distribution of *Rhytidiadelphus loreus* (in sample 3b) and *Hylocomium brevirostre*. The pollen diagrams of samples 3a and 3b indicate the fringe of a mixed forest with cereal fields nearby. The arboreal pollen percentages of samples 3c and 3d are considerably higher and show a predominance of beech (*Fagus sylvatica*). Of particular interest is the presence of silver fir (*Abies alba*) in both pollen diagrams. This tree is a neophyte in the Netherlands and its occurrence in caulking samples that are dated to the second half of the 10th century points to woodland in central Germany and implies that the vessel was built in that area. Possibly, all four of these samples originate from the same forest, in which samples 3a and 3b were gathered near clearings, whereas samples 3c and 3d originate from open, wet locations within the forest.

The interpretation of the pollen content of moss samples is complicated by the fact that moss may contain pollen that represent a long period. Although this may be counteract spurious peak representations of certain species, the pollen may reflect a period which is not contemporaneous with the life of the moss plant. Bottema (1995) demonstrated that pollen of vegetations at least one century old can be found in present-day moss samples. This timespan far surpasses the age of the moss plants themselves and Bottema assumes that transport of old pollen from soil sediments into nearby tufts of moss probably occurs through splash water.

If the botanical composition of caulking samples from the same ship indicates that they were gathered from different localities, it is not surprising to find representatives of different environments mixed within the same sample. One of the caulking samples (No. 12c) from a possible cargo-vessel excavated in Rotterdam may serve as an example for this degree of mixture. The sample is dominated by *Pleurozium schreberi*, which is strongly calcifuge, but also contains a single specimen of *Rhytidium rugosum*, which in the Netherlands is only known from the coastal dunes, thus being indicative of calcareous substrata. Its only occurrence in the Netherlands outside this area is dated to the Pleistocene (Cappers & Van Zanten, 1993). Although Weeda (1996) discusses some localities within its worldwide distribution where *R. rugosum* is not limited to calcareous substrata, it seems unlikely that it was gathered together with *Pleurozium schreberi*. Also the pollen diagram deviates by its high percentage of *Sphagnum* (14%), indicating the nearby presence of peat. In all other moss samples that do not contain *Sphagnum*, the percentages of *Sphagnum* spores are always less than 5%.

The fact that caulking samples from one and the same ship were sometimes gathered from different localities may also explain why the moss species found in the caulking samples of two vessels found at Meinerswijk (Arnhem, Nos 9 and 10) differ from the species (viz. *Scorpidium scorpioides*) that was found in two caulking samples from the same ships that were investigated earlier (Bottema, 1983). This is especially notable in the case of boat No. 9, on which repairs with *gesinteld mosbreeuwsel* were carried out.

In view of the large amount of caulking material that is necessary for a single ship, it is not surprising that even in the close surroundings of a shipyard a variety of habitats were exploited. Moreover, stock supplies will have been replenished at regular intervals, which may also contribute to the heterogeneous nature of the caulking samples.

4.5. Dating of caulking material

Like wood, moss remains from caulking material too are suitable for radiocarbon dating. Whereas wood has the disadvantage that a single plank may cover several decades, and heartwood in particular will make radiocarbon dates older, tufts of most moss species are only a few years old. Hence, mosses may be preferred to wood if conventional radiocarbon dating is used for detecting a ship's building period.

A degree of inaccuracy may be introduced to the stocking of mosses for many years. Also the impregnation of mosses with tar and pitch may influence the dating. This may be avoided by sampling caulking material from the inner part of the seams.

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APPENDIX 1: Locations of shipwrecks, type of ship, building period of ships, composition and specification of caulking samples. A and B following the centuries indicate first and second half, respectively.

Abbreviations:

Location: NOP = Noordoostpolder; O.Fl. = Oostelijk Flevoland; Z.Fl. = Zuidelijk Flevoland.

Type of ship: BA = Barge (*aak*); CO = Cog (*kogge*); CV = Cargo-vessel (*vrachtschip*); FB = Fishing-boat (*visserschip*); LB = Extended logboat; PU = Punt (*punter*); SF = Ship fragment; VS = *Veenderijschuit*; WS = *Waterschip*; FR = Fragment(s); ? = Unknown; > = Large; < = Small;

Composition caulking sample: 1 = *Sphagnum*; 2 = Sphagnum/other mosses; 3 = *Sphagnum*/other plants/hair; 4 = *Sphagnum*/other plants; 5 = Other mosses; 6 = Other mosses/other plants; 7 = Other mosses/hair; 8 = Other plants; 9 = Other plants/hair; 10 = Hair; 11 = Amorphous; 12 = Unknown.

No.	Location	Type of ship	Cent.	CM	Specification caulking sample
1	Wijk bij Duurstede	CV ?	9B	10	No number
2	Deventer	BA	10B	11	Ship remnant 1 (between VB 3 and VA 3), IJsselstraat (1983)
3a	Tiel	BA (FR)	10B	5	Tol-noord, ship remnant east, No. 1-0-261 (1996-2)
3b	Tiel	BA (FR)	10B	5	Tol-noord, ship remnant east, No. 1-0-263 (1996-2)
3c	Tiel	BA (FR)	10B	5	Tol-noord, ship remnant west, No. 1-7-291 (1996-2)
3d	Tiel	BA (FR)	10B	5	Tol-noord, ship remnant west, No. 1-7-292 (1996-2)
4a	Tiel	BA (FR)	10B/11A	5	Tol-zuid, from seam ship's wood, No. 3-0-6 (9-8-1996)
4b	Tiel	BA (FR)	10B/11A	5	-
4c	Tiel	BA (FR)	10B/11A	5	-
4d	Tiel	BA (FR)	10B/11A	5	-
5	Deventer	BA	11A	5	Ship remnant 2, IJsselstraat (1983)
6	Utrecht	BA	11A	5	Waterstraat, from bottom seam, no number
7	Utrecht	LB (FR)	12A	5	Lange Lauwerstraat, LL/1
8	Dordrecht	SF	12B	7	Voorstraat/Visstraat, no number (1983)

9	Arnhem	LB	13A	5	Meinerswijk 3, 3/16
10	Arnhem	PU (cf.)	13A	5	Meinerswijk 2, 2/3
11a	Rotterdam	BA	13	8	Lock 1 (barge bottom), north wall, No. 13-26/136AA
11b	Rotterdam	BA	13	8	Lock 1 (barge bottom), north wall, No. 13-26/133A
11c	Rotterdam	BA	13	8	Lock 1 (barge bottom), southern end, No. 13-26/129A-B
11d	Rotterdam	BA	13	5	Lock 1 (barge bottom), middle, No. 13-26/1366
12a	Rotterdam	CV ?	13	5	Lock II, sample of bottom, No. 13-26/1381
12b	Rotterdam	CV ?	13	5	Lock II, southeast wall, No. 13-26/1331
12c	Rotterdam	CV ?	13	5	Lock II, from oaken wall (crack repair), No. 169B
13a	NOP A 57	CO	13	1	A57/257, stern hook/garboard strake
13b	NOP A 57	CO	13	2	A57/85
13c	NOP A 57	CO	13	1	A57/255
13d	NOP A 57	CO	13	1	A57/256
14a	Z.Fl. OZ 43	CO	13	5	OZ43/66, seam E2/F
14b	Z.Fl. OZ 43	CO	13	5	OZ43/69
14c	Z.Fl. OZ 43	CO	13	1	OZ43/71
15	NOP Q 75	CO	13B	1	Z1959/XII 62
16	Rotterdam	PU	13B	6	13-26/1459, boat 2
17a	Amsterdam	CV	13B	5	Under northwest tower of the Nieuwezijds Kolk castle (bottom layer between bottom shelf, A)
17b	Amsterdam	CV	13B	5	Under northwest tower of the Nieuwezijds Kolk castle (keelstrake/ floorstrake, southern side)
17c	Amsterdam	CV	13B	5	Under northwest tower of the Nieuwezijds Kolk castle (top layer between bottom shelf, B)
18a	Rotterdam	CV (<)	13B	5	BOOR, boat 1, M 1
18b	Rotterdam	CV (<)	13B	1	BOOR, boat 1, No. 13-26/1458
19a	Hattem	CV	13B/14A	5	From scarf, No. 24
19b	Hattem	CV	13B/14A	5	No. 25
19c	Hattem	CV	13B/14A	8	No. 26
20a	NOP G 37	CV	13-14	1	Z1955/XII 428
20b	NOP G 37	CV	13-14	10	Z1955/XII 429
20c	NOP G 37	CV	13-14	4	Z1964/2 from rabbet stern, at the bottom
21a	O.Fl. N 5	CO	14A	1	ON5/45, from seam side
21b	O.Fl. N 5	CO	14A	1	ON5/44
21c	O.Fl. N 5	CO	14A	1	ON5/46
21d	O.Fl. N 5	CO	14A	1	ON5/47
22	Z.Fl. OZ 36	CO	14A	1	OZ 36/358
23	Z.Fl. NZ 43	CO	14B	1	Seam G2 c
24	Enkhuizen	SF	14B/15A	10	Drie Baanen, no number
25	Rotterdam	SF	14B/15A	5	BOOR, Crédit Lyonnais, 189
26a	Oosterhout	CV ? (<)	14B/15A	1	No. 4
26b	Oosterhout	CV ? (<)	14B/15A	5	No. 6
26c	Oosterhout	CV ? (<)	14B/15A	1	No. 14
27a	Z.Fl. NZ 42 II	CO	14B/15A	4	NZ42II/46
27b	Z.Fl. NZ 42 II	CO	14B/15A	1	ZN42II/47
27c	Z.Fl. NZ 42 II	CO	14B/15A	1	ZN42II/49
28a	Z.Fl. NZ 43	CO	14B/15A	1	ZN43/26
28b	Z.Fl. NZ 43	CO	14B/15A	8	ZN43/33
28c	Z.Fl. NZ 43	CO	14B/15A	1	ZN43/36
29a	Almere W 13	CO	15A	1	ZW13/79
29b	Almere W 13	CO	15A	1	ZW13/74
30a	NOP F 86	PU (cf.)	15	4	Z1960/II 168
30b	NOP F 86	PU (cf.)	15	4	Z1968/II 168
31a	Z.Fl. NZ 66W	CV	15	1	NZ66W/73, from bottom seam b.b. NZ 66w/73
31b	Z.Fl. NZ 66W	CV	15	8	NZ66W/57
31c	Z.Fl. NZ 66W	CV	15	8	NZ66W/60
32	O.Fl. B 55	CV	15B	1	OB55/35
33	Hellendoorn	PU	15B/16A	8	No. 5
34	NOP J 137	CV	15B/16A	10	Z1949/VII 14
35a	NOP O 28	CV	15B/16A	1	Z1955/IX 177
35b	NOP O 28	CV	15B/16A	10	Z1956/XII 433
36a	O.Fl. U 34	CV (>)	15B/16A	1	G1 4/5, from seam
36b	O.Fl. U 34	CV (>)	15B/16A	1	GC4/GB3 s.b
37	Arnhem	CV (?)	MA	5	Bijland, ZR 1959/XII 61

38a	NOP E 159	SF	L.M.	1	Z1965/VI 73
38b	NOP E 159	SF	L.M.	1	Between 1st and 2nd strake side, no number
38c	NOP E 159	SF	L.M.	1	Between 4th and 5th strake side, no number
39	Medemblik Zeebad	CV	L.M.A.	4	MB/11
40	Rotterdam	?	L.M.A.	5	5-33/11, ship's wood under tower
41a	Kessel		BA	16A	8 No. 3
41b	Kessel		BA	16A	8 No. 7
42a	Krabbendijke	CV	16A	5	NL1/3A
42b	Krabbendijke	CV	16A	5	NL1/3B
42c	Krabbendijke	CV	16A	5	NL1/3C
43	NOP M 40	CV	16A	1	Z1952/XII 439
44a	O.Fl. M 11	CV	16A	1	Sample 1
44b	O.Fl. M 11	CV	16A	1	GC2-C3/s.b
44c	O.Fl. M 11	CV	16A	1	M11/250
45a	O.Fl. L 89	CV	16A	1	Stern scarf, KP1-HS (1-8-1996)
45b	O.Fl. L 89	CV	16A	1	GA 5/SB, from scarf between S-24 and S-26 (25-7-1996)
45c	O.Fl. L 89	CV	16A	1	GA 3/BB, starboard side of strake (29-7-1996)
46	Workummer Nieuwland	CV	16A	1	FWN-71
47a	Z.Fl. NZ 74 I	WS	16A	3	NZ74I/98
47b	Z.Fl. NZ 74 I	WS	16A	4	NZ74I/96
47c	Z.Fl. NZ 74 I	WS	16A	1	NZ74I/97
48a	Z.Fl. NZ 74 II	WS	16A	1	NZ74II/73
48b	Z.Fl. NZ 74 II	WS	16A	1	NZ74II/71
49a	Z.Fl. MZ 22	WS	16A	1	MZ22/140
49b	Z.Fl. MZ 22	WS	16A	1	MZ22/141
50	Z.Fl. NZ 42	WS	16A	1	ZN42/120
51a	Z.Fl. NZ 44	WS	16A	1	ZN44/153
51b	Z.Fl. NZ 44	WS	16A	1	ZN44/154
52	Z.Fl. OZ 39	WS	16	1	ZO39/5
53a	NOP P 40	WS	16	1	Z1950/X 53
53b	NOP P 40	WS	16	1	Z1960/II 169
53c	NOP P 40	WS	16	1	Z1960/II 170
54a	NOP M 93	FB (<)	16	1	Z1960/II 171
54b	NOP M 93	FB (<)	16	1	Z1960/II 172
55	Wieringermeer	LW 58	FB	16	8 Z1951/V 37
56a	O.Fl. W 10	WS	16B	2	OW10/197
56b	O.Fl. W 10	WS	16B	1	OW10/198
56c	O.Fl. W 10	WS	16B	1	OW10/199
57a	Inschot	CV	16B	1	Zuidoost Rak, 031090 14
57b	Inschot	CV	16B	8	Zuidoost Rak, 031090 16
58a	Scheurrak SO 1	CV (>)	16B	11	Keel, inside/upper rabbet 1st strake VE SB
58b	Scheurrak SO 1	CV (>)	16B	1	From keel, bevelled halved joint
58c	Scheurrak SO 1	CV (>)	16B	11	From keel, above rabbet in front of 1st strake
58d	Scheurrak SO 1	CV (>)	16B	8	From keel, outside/bottom rabbet 1st hull strake, in rabbet
58e	Scheurrak SO 1	CV (>)	16B	11	From keel, outside/bottom rabbet 1st hull strake, only on bottommost edge
58f	Scheurrak SO 1	CV (>)	16B	1	VE. keel and stem, from halved joint keel/bottommost piece of stem
58g	Scheurrak SO 1	CV (>)	16B	1	VE. keel and stem, from seam between keel and upper piece of stem
58h	Scheurrak SO 1	CV (>)	16B	1	VE. keel, bevelled halved joint keel fragments
58i	Scheurrak SO 1	CV (>)	16B	1	VE. keel, bevelled halved joint keel fragments
58j	Scheurrak SO 1	CV (>)	16B	11	From groove SO1 15208
58k	Scheurrak SO 1	CV (>)	16B	11	VE. keel stem, from seam between upper part of stem and inset
59	NOP O 99	FB (<)	16B/17A	1	Z1952/VIII 52
60a	NOP P 33	WS	16B/17A	10	Z1958/IV 1
60b	NOP P 33	WS	16B/17A	1	Z1958/IV 2
60c	NOP P 33	WS	16B/17A	1	Z1958/III 100
61	NOP R 13	WS	16B/17A	8	Z1960/II 176
62	O.Fl. U 86	WS	16B/17A	8	No number
63	NOP N 14/15	VS	17A	1	Z1960/II 173
64	Kreupel	CV	17	10	YKR/104
65a	NOP E 81	CV (>)	17	8	NE81-213
65b	NOP E 81	CV (>)	17	10	B.b. forward part of vessel, no number
66	NOP O 79	CV (<)	17	1	Z1950/III 140A

67	O.Fl. G 34	WS	17	4	Z1965/I 298
68	O.Fl. T 23	WS	17	1	T23/26
69	NOP E 42/43	CV ? (<)	17 ?	10	Z1950/XII 372,
70	O.Fl. J 68	?	17 (?)	1	Z1965/II 219
71	NOP E 160	FB (<)	17B	1	Z1954/II 143
72a	O.Fl. H 41	FB	17B	8	Seam 3rd and 4th strake b.b. bow side, no number
72b	O.Fl. H 41	FB	17B	8	Seam 1st and 2nd strake b.b. behind, no number
73a	O.Fl. F 34	CV	17B	8	FO34/72
73b	O.Fl. F 34	CV	17B	8	FO34/73
74	O.Fl. M 65	CV	17B	4	Z1965/V 27
75	Z.Fl. AZ 71	CV	17B	1	ZA 71-31
76a	Z.Fl. OZ 71	CV	17B	1	ZO71/179
76b	Z.Fl. OZ 71	CV	17B	1	ZO71/180
76c	Z.Fl. OZ 71	CV	17B	1	ZO71/181
76d	Z.Fl. OZ 71	CV	17B	1	ZO71/182
77	O.Fl. B 55 II	CV	18A	1	From seam side
78a	Oostvoornse Meer	CV	18A	10	OVM2/5 (southern shore)
78b	Oostvoornse Meer	CV	18A	10	OVM2/39.1 (southern shore)
78c	Oostvoornse Meer	CV	18A	10	OVM2/117 (southern shore)
78d	Oostvoornse Meer	CV	18A	10	OVM2/39.2 (southern shore)
78e	Oostvoornse Meer	CV	18A	10	OVM2/122 (southern shore)
79a	Waddenzee: Buitenzorg	CV (>;VOC)	18A	10	ZWA 1958-III 90
79b	Waddenzee: Buitenzorg	CV (>;VOC)	18A	3	ZWA 1958-III 91
80a	NOP E 161	CV	18	1	Z1954/V 90
80b	NOP E 161	CV	18	1	No number
81	NOP B 6	CV	18B	8	NB6/175
82a	NOP E 165	CV	18B	8	Z1954/XII 75
82b	NOP E 165	CV	18B	8	Z1954/XII 76
82c	NOP E 165	CV	18B	1	Z1954/XII 77
83	NOP L 61	CV	18B	9	Z1952/XII 124
84	Z.Fl. LZ 8	PU	18B ?	4	ZL8/9
85	O.Fl. T 21	CV	18B/19A	1	ZO1966/V 91
86	NOP M 20	CV	19A	5	Z1946/VII 180
87	NOP H 49	CV	19	12	Z1956/XII 436
88	NOP P 15	CV (<)	19	5	Z1960/II 175
89	O.Fl. E 46	CV	19A/B	4	No number
90	O.Fl. H 92	CV	19	8	ZO1965/X 68
91	Hondsb. Zeew.	CV (>)	19 ?	10	Z1965/VII 154
92	O.Fl. ('t Spijk)	?	19/20	1	Z1965/VII 58
93	Hindeloopen	?	?	10	II, no number
94	Kornwerderzand	?	?	9	ZY1957/IV 232
95	NOP K 47	?	?	10	Z1955/X 44
96	O.Fl. G 64	?	?	1	No number
97	Stavoren	?	?	10	Z1965/I 76
98	Terschelling	SF	?	10	Beach pole 19/20, Ter.19/20-2