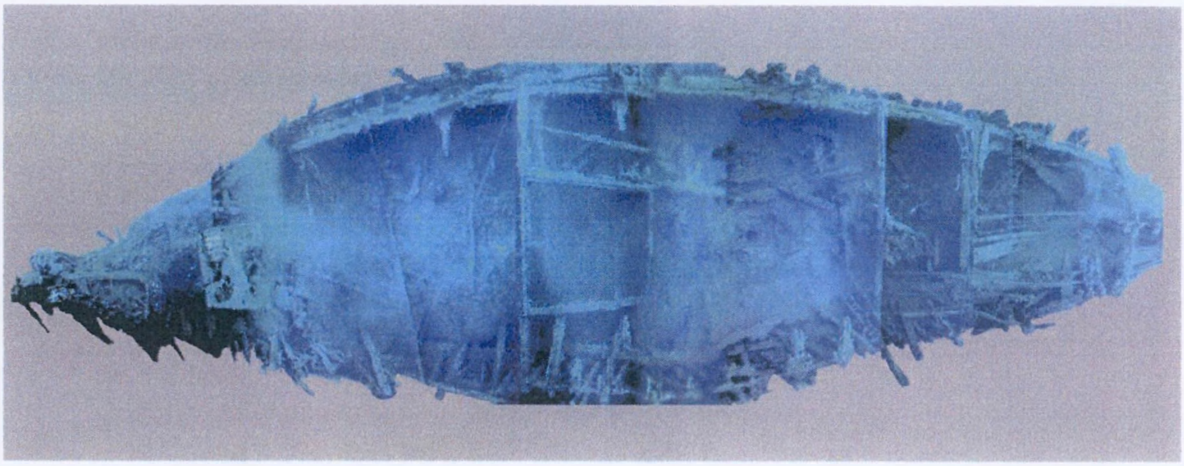
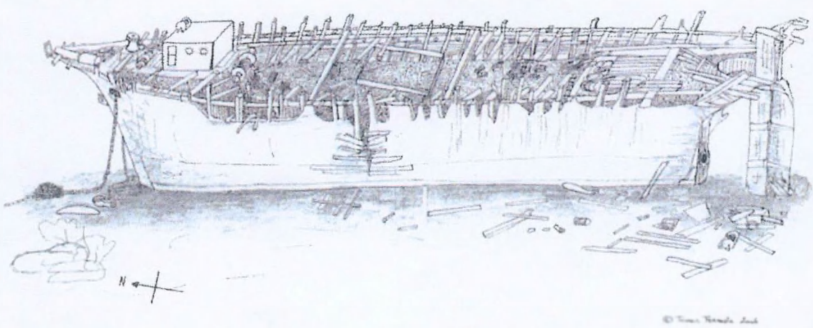
Assessment of the State of Preservation of the Wreck of the Belgica





The National Museum of Denmark
Conservation Department

David Gregory, Poul Jensen & Kristiane Strætkvern

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Aim of the project

The conservation department of the National Museum of Denmark was contacted by Stephen Wickler (14.12.2006), from Tromsø University Museum, concerning assessment of the state of preservation of the wreck of the *Belgica,* prior to its potential raising. The *Belgica* is a Belgian Polar research ship, which sank in Norwegian waters. The National Museum was contacted due to their experience with assessing the degradation of waterlogged archaeological wood in the laboratory and *in situ*.

Subsequently, a dialogue between Marnix Pieters from the Flemish Heritage Insitute (VIOE: Vlaams Instituut voor het Onroerend Erfgoed) was established which resulted in a meeting (7-8.11.2007) in Denmark to discuss the possibilities of collaboration between the institutions and how the state of preservation of the wreck of the *Belgica* could be assessed as part of the *Belgica Project*. As a result of this, Kristiane Strætkvern from The National Museum participated in fieldwork on the wreck (5-8.05.2008), which entailed assessing the state of preservation of selected areas of the wreck in situ and collecting small wood core samples for assessment at the National Museum. Further samples, to assess the presence and activity of large wood boring organisms, were also taken form the wreck site. Costs and logistics for the field work were generously provided by the following people and organisations:

- Belgica Society (http://www.belgica-genootschap.be/?lang=en) for transport and logistics. In particular the support of the Society's members Willy Versluys, Kjell Kjaer, Rudi Caeyers and Ragnar Klevaas.
- Dive vessels were provided by the "Anna Rogde" society and the harbour master of Harstad.
- Diver support by divers of the Harstad Diving Club and Karl Emil Rikardson.

Sampling strategy

Figure 1 shows the locations where in situ (Pilodyn) measurements and oak wood samples for density determination were taken. The selection of these locations was based on knowledge of the wreck from previous diving expeditions and advice from Morten Gøtche from the Viking Ship Museum in Roskilde, who is a specialist in ship construction. Bearing in mind that the Belgica Society would like to raise the ship in one piece, the areas were selected in order to give as much information as possible about the structural strength of the ship within the time limits of the fieldwork.

The port side was considered to be the most poorly preserved and 15 locations were assessed. A further 3 areas on the starboard side and 10 areas on beams and other structural parts inside the wreck were also selected giving a total of 28 areas. Sampling areas were labelled with colour-coded labels denoting port, starboard and structural timbers – it was important that the same areas for in situ measurements and wood core sampling were used in order to compare the results.

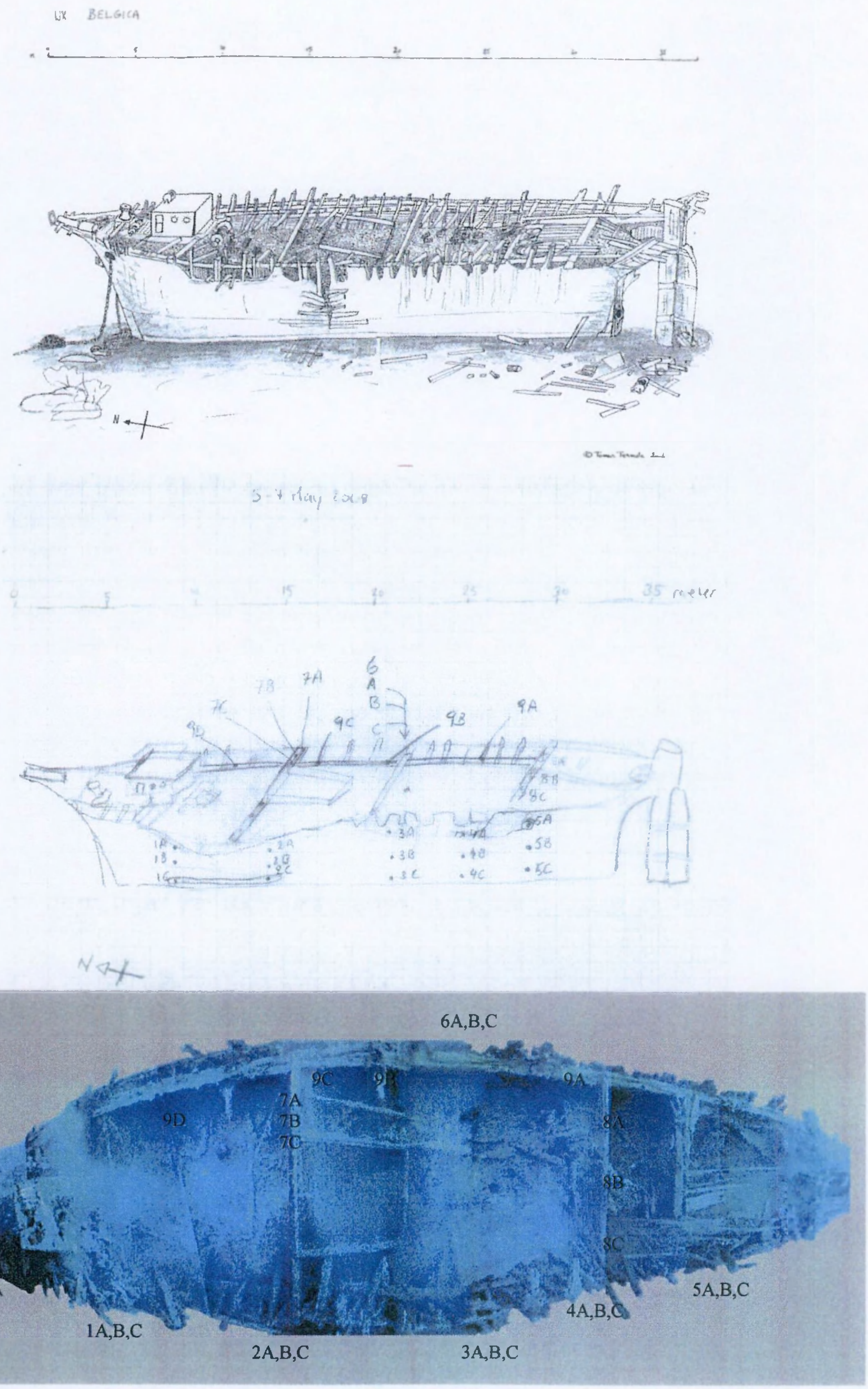


Figure 1: Location of sampling areas. Profiles 1 to 5 on the port side were ca. 6 metres apart. Profile 6 was on the starboard side. Areas 7-9 were on structural timbers.

Methods

Wood in the marine environment can be degraded by a variety of mechanisms. Primarily, these are of a biological nature. Exposed timbers, in saline conditions are often attacked by wood boring organisms such as shipworm and gribble, which can lead to rapid and extensive deterioration of exposed timbers. Furthermore, fungi and bacteria in open seawater and buried environments can degrade the microstructure of the wood leading to a loss of cellulose and hence wood strength.

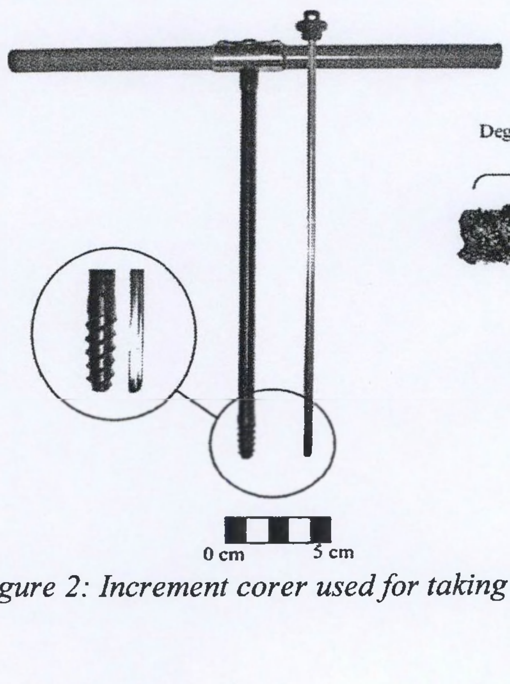
The resulting effects on the strength of the wood can be estimated by assessing the density of the remaining wood. Density is a good parameter for this as it serves as a proxy indicator for many of the structural properties of the wood, such as compression, tensile and bending strength and its modulus of rupture. The density can be determined directly on samples of wood in the laboratory or indirectly using equipment such as the Pilodyn wood tester.

Assessment of wood boring organisms

Two large samples of oak wood were taken from the site and assessed both visually and with X-Ray. It was immediately apparent that the outer surfaces of the wood had been extensively attacked by wood boring crustacea. In order to check that there were living organisms present on the wood, the samples were covered in a damp cloth and left overnight. As the crustaceans responsible for attack require oxygen, the presence of the wet cloth restricts the passage of oxygen to the wood and any living curstacea will come to the surface of the wood to gain more oxygen. To assess the presence of the larger wood boring mollusca, such as the shipworm, X-Ray pictures were taken. The presence of shipworm is very difficult to see on the surface of the wood with the naked eye. However, as they bore into the wood, they secrete a layer of calcium carbonate, which lines the holes of the tunnels they create. Under X-ray this lining is visible due to it being denser than the surrounding wood.

Core sampling

Samples were taken from the locations shown in Figure 1 using an increment corer (Figure 2).



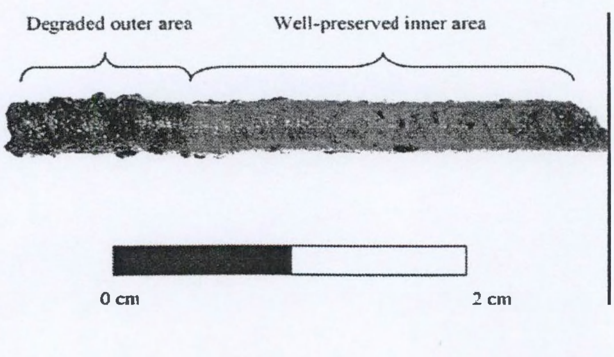


Figure 2: Increment corer used for taking samples and typical sample.

Using the increment corer, samples ca. 5 mm in diameter with lengths up to 100 mm were obtained. Generally, the corer was screwed ca. 7 cm into the wood. The corer with the sample was brought to the boat, taken out, labelled and packed into small plastic vials held in place with wetted paper towels to prevent destruction during transport. All samples and measurements were collected within a radius of 20 cm from the identification label and generally one core sample was taken per area. However, the quality of the wood varied; some samples had to be retaken and a few areas were abandoned after several unsuccessful trials. Density of the samples was determined back at the laboratories of the National Museum.

Density determination

As the core sample in Figure 2 shows, waterlogged archaeological wood often shows a gradient of degradation; from a poorly preserved outer zone to a better preserved inner zone. To account for this gradient, the cores were sectioned in to smaller pieces and their bulk density determined. The distance from the surface of the outer end of the sample (surface of the wood) to the centre of the sectioned sub samples was measured in order to establish a density gradient.

Bulk density (ρ_{wood}) of the wood (dry weight per wet volume) was determined according to the method described by Jensen and Gregory (2006). To summarize the method: the dry weight was determined after drying the samples to constant weight at 105°C and the wet volume was determined by the Archimedes principle.

Pilodyn measurements

The Pilodyn, Figure 3A, works by firing a spring-loaded blunt pin into the wood, to a maximum depth of 40 mm. The depth of penetration of the pin is indicated on a scale on the side of the instrument; the more degraded the wood, the further the pin will penetrate. In this study the average of three measurements were taken. The penetration reflects the shock resistance of wood, that is to say, the resistance of wood to a suddenly applied load. The energy required to overcome this resistance in non-archaeological wood is a complex interaction of the various properties of wood. Research at the National Museum (Gregory, et al., 2007) has shown the correlation between the density of waterlogged archaeological wood and the depth of penetration of the Pilodyn pin, Figure 3B.

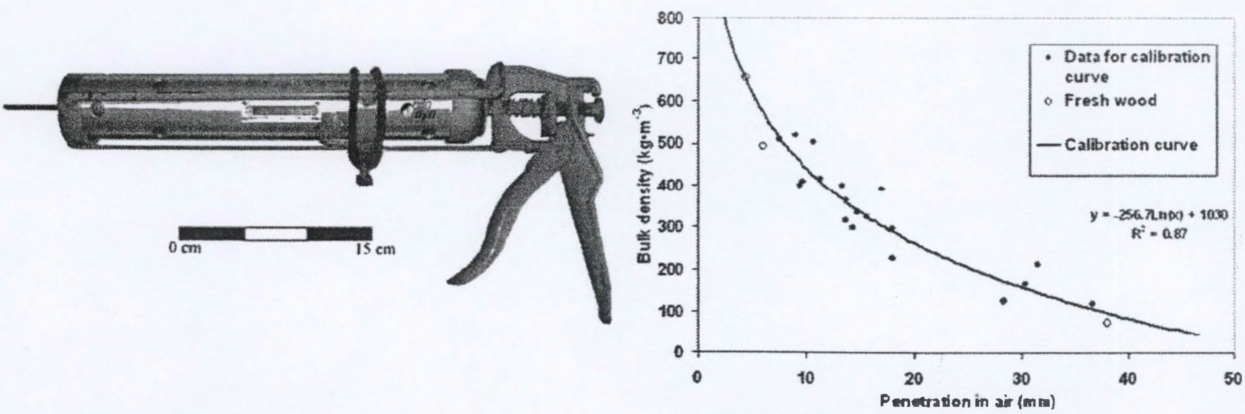


Figure 3: A: The Pilodyn B: Correlation between depth of pin penetration and bulk density of waterlogged archaeological wood.

Pilodyn measurements taken on archaeological wood will never give a true picture of the density gradient, as the depth of penetration recorded is only a summation of the properties of the wood that the pin has penetrated. Therefore, half the depth of the needle penetration (if the wood is homogeneous) corresponded to the average density of the wood. This assumption makes it possible to compare the pilodyn results with the densities determined from the core samples.

Inorganic content of wood samples
After determination of the density of the wood core samples, it was noticed that the dried wood was very red in colour, Figure 4.

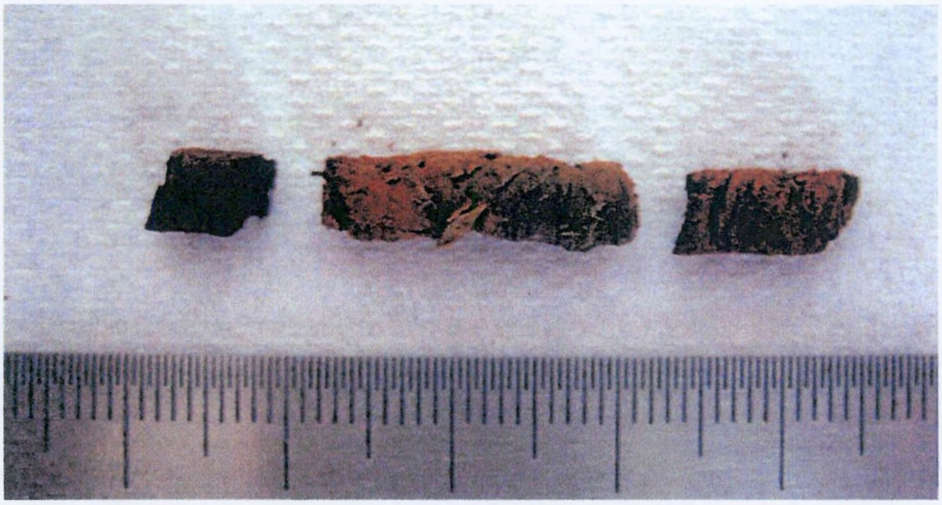


Figure 4: Section of wood core after determination of density. The outer surface of the wood (i.e. exposed to seawater) is to the left of the picture.

The change to red indicates an oxidation of the iron in the sample during the oven-drying at 105°C. Therefore it was suspected that there were considerable amounts of iron corrosion products and other inorganic matter in the samples. An XRF-analysis of one sample with a high inorganic content showed an iron content of more than 90% of the analyzable atoms. The oxidation of the iron has probably resulted in the formation of Fe_3O_4 or Fe_2O_3. The formation of oxidized iron also indicates that there have probably been anoxic conditions inside the wood.
The dried samples were placed in a muffle oven at 600°C for 12 hours and the %w/w[1] inorganic content (ash, iron oxides) calculated. The amount of iron oxides can be calculated from the dry weight of the wood in order to obtain a corrected density for the wood with out any inorganic material. The method of subtracting the ash content from the dry weight is subject to some errors as the oxidation at 105°C might not be complete and because more anions are lost during the heating to 600°C in the muffle oven than by just drying at 105°C.

[1] this is the weight of the resulting ash divided by the dry sample weight multiplied by 100.

Results

Presence and activity of wood boring organisms
Figure 5 shows the two samples of oak wood taken to assess the activity of wood boring organisms.

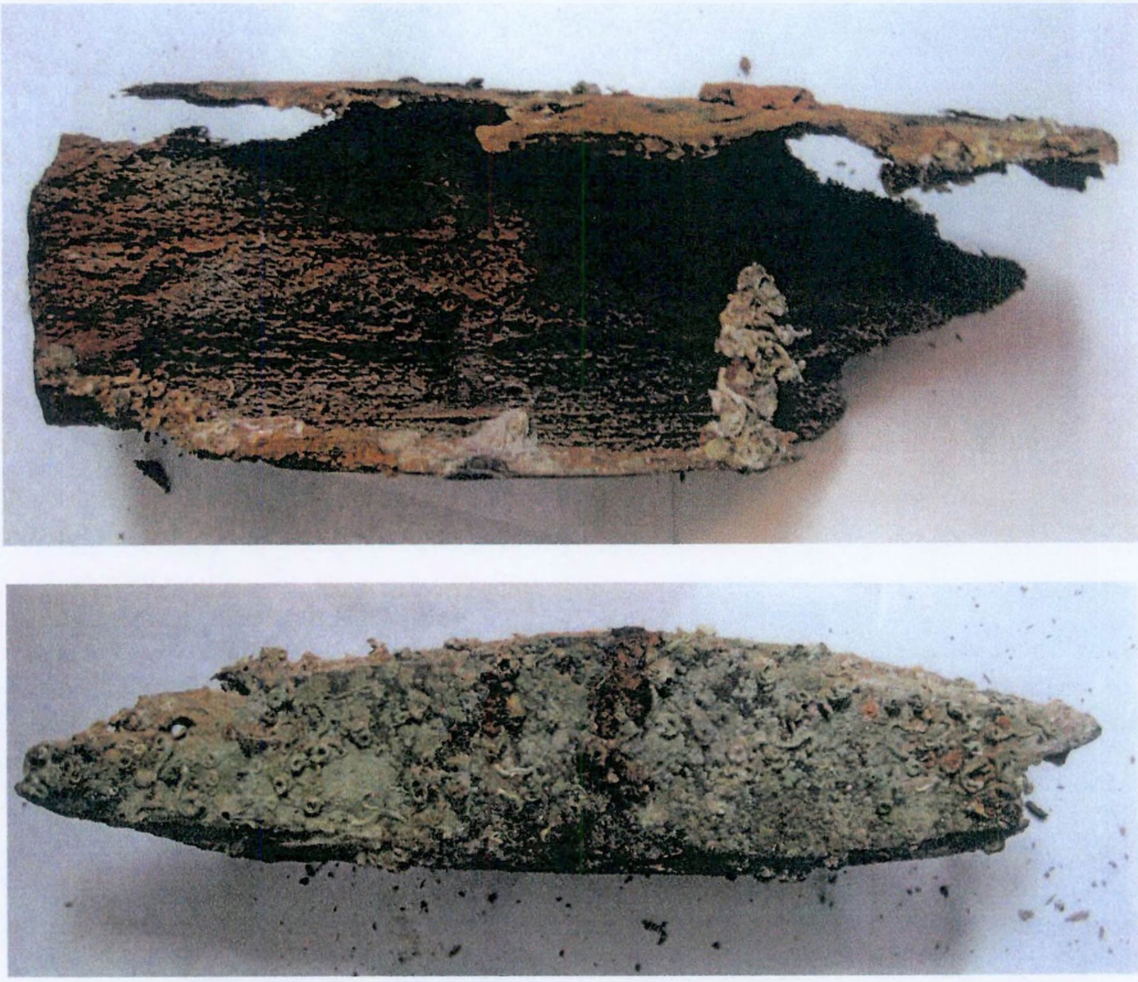


Figure 5: Two samples of wood from the wreck.

There were definite signs of colonisation by fouling organisms. These organisms tend to live on the surface of the wood rather than bore in to the wood, Figure 6.

Figure 6: Biofouling organisms on the surface including calcareous tubeworms and barnacles.

Wood boring crustacea (Gribble)

The surfaces of both wood samples were heavily degraded by the activity of wood boring crustacea, Figure 7. Although there were no signs of living organisms on the wood, it should not necessarily be concluded that they are not present and active on other parts of the wreck.

Figure 7: Surface of wood sample extensively degraded by wood boring crustacea.

Wood boring mollusca (Shipworm)

The wood boring mollusca are far more important than the crustacea in terms of the total degradation of waterlogged archaeological wood. Even through their presence is often not clear from the surface of the wood, they create a network of tunnels, which drastically reduce the overall strength of the wood. Use of X-Ray can highlight the calcareous lining of these tunnels, as previously discussed, and is a non-destructive way of assessing their presence. Figure 8 shows X-ray pictures of the two samples in Figure 5. No shipworm tunnels were visible in the samples, yet as with the boring crustaceans, it does not mean that shipworm are not present on other parts of the wreck.

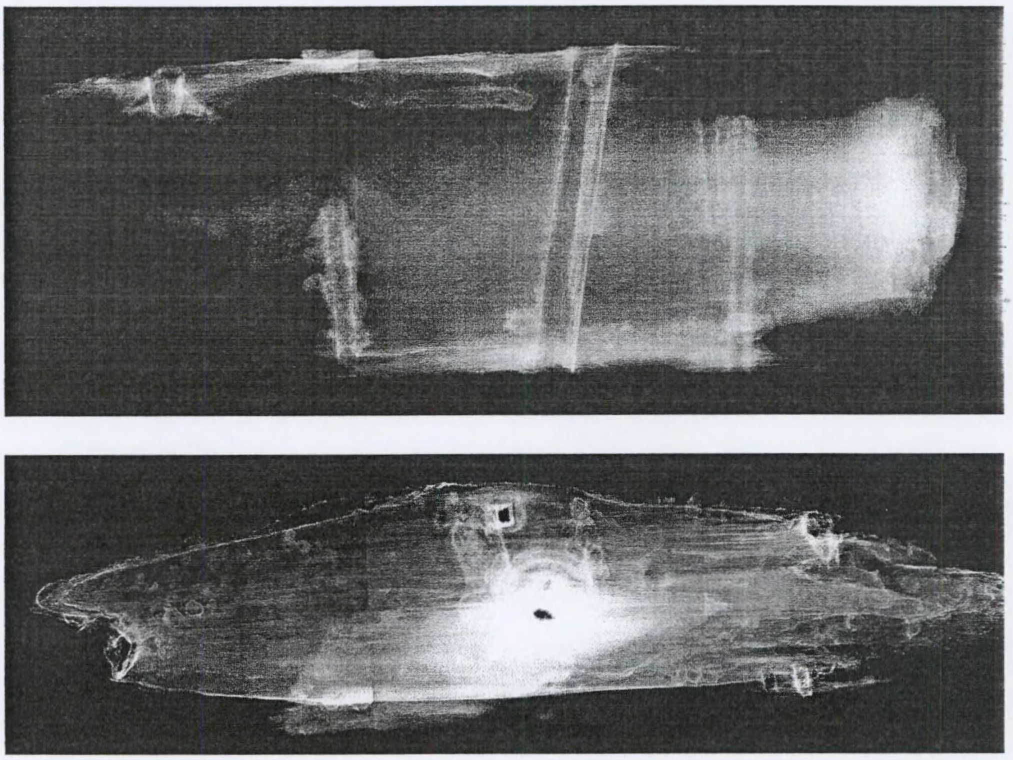


Figure 8. X-ray pictures of samples from the wreck site. No characteristic shipworm tunnels are present. The calcareous tubeworms on the surface of the wood samples in the lower picture are clearly visible (see Figure 6) (Pictures: Birthe Gottlieb, The National Museum of Denmark).

Density and inorganic content (ash) of core samples

The samples were treated in two discrete populations. Table 1 shows a summary of all results from the planking (Samples 1-6) and Table 2 shows a summary of results from structural timbers (Samples 7-9).

Table 1: Summary of results from planking. Samples 1–6.

Sample	Comments	Depth in core	Density	Average Pilodyn penetration	Density from Pilodyn	Ash Content	Density corrected for Ash content
		(mm)	(kg / m^3)	(mm)	(kg / m^3)	(%)	(kg / m^3)
1A	Good sample	Total length 62 mm					
		18	309	3	646	16.8	257
		47	341			18.8	277
1B		Total length 56 mm					
		2	643	9	382	46.2	346
		25	489			30.3	341
		47	469			25.7	349
1C		Total length 60 mm					
		5	425	3	703	6.2	398
		17	426			7.5	394
		35	466			6.0	438
2A	Very poor	Total length 50 mm					
		10 or 40	350	6	510	18.8	284
2B	Good sample	Total length 77 mm					
		9	353	7	455	9.4	320
		39	419			5.2	398
		62	469			11.2	417
2C	Good sample	Total length 63 mm					
		11	543	3	673	31.1	374
		30	667			37.4	418
		51	[illegible]			45.5	450
3A	Good sample	Total length 86 mm					
		8	417	8	416	16.3	349
		24	400			11.0	356
		45	494			9.0	449
		67	486			9.9	437
		80	532			12.3	466
3B	Poor sample	Total length 74 mm					
		13	325	8	434	13.4	281
		37	388			11.5	343
		52	408			9.0	372
		69	450			7.9	414
3C	Good sample	Total length 81 mm					
		2	636	3	646	43.9	357
		16	574			19.1	465
		37	505			4.6	482
		59	454			5.5	429
		80	494			4.7	470
4A	Good sample	Total length 70 mm					
		2	450	9	382	27.0	328
		9	392			8.0	361
		23	416			6.4	389
		39	376			6.6	351
		58	367			8.4	336
4B	Good sample	Total length 73 mm					
		8	403	7	455	5.9	380
		26	350			6.3	328
		46	515			28.0	371
		69	390			5.9	367
4C	Good sample	Total length 88 mm					
		17	453	9	391	20.8	359
		36	385			11.8	339
		56	476			22.9	367
		85	533			25.0	400
5A		Total length 59 mm					
		3	591	6	481	30.4	412
		26	450			17.0	374
		51	490			15.6	414
5B	Good sample	Total length 43 mm					
		2	447	5	525	15.1	380
		18	455			7.7	420
		33	421			5.3	399
6A	Good sample	Total length 73 mm					
		5	438	9	401	11.0	389
		21	467			7.3	433
		43	468			11.4	414
		60	474			7.8	437
6B	Good sample but surface missing	Total length 63 mm					
		15	342	18	213	7.0	318
		36	321			9.3	291
		54	362			6.2	340
6C	Good sample but surface missing	Total length 32 mm					
		8	356	10	364	3.3	344
		24	492			3.7	473
6D	Good sample surface missing	Total length 98 mm					
		6	352			6.6	329
		24	394			7.7	364
		40	378			7.8	349
		55	349			8.0	321
		74	295			8.2	271
		90	366			6.5	342

Table 2: Summary of results from structural timbers. Samples 7-9.

Sample	Comments	Depth in core (mm)	Density (kg / m3)	Average Pilodyn penetration (mm)	Density from Pilodyn (kg / m3)	Ash Content (%)	Density corrected for Ash content (kg / m3)
7A	Only Pilodyn measurement			5	525		
7B	Good sample	Total length 82 mm					
		9	397	7	443	6.2	372
		28	402			5.9	379
		50	386			6.0	363
		68	418			5.1	397
7C	Good sample	Total length 83 mm					
		14	407	9	386	6.5	381
		34	397			6.7	371
		54	427			8.0	393
		74	658			3.3	636
8A	Good sample	Total length 65 mm					
		10	527	5	525	3.1	511
		34	585			2.2	572
		53	516			2.5	503
8B	Only Pilodyn measurement			7	468		
8C	Good sample	Total length 107 mm					
		3	406	8	421	10.0	366
		22	502			6.0	472
		42	490			4.6	467
		63	397			5.4	376
		80	355			6.0	333
		98	397			5.8	374
9A	Poor sample	Total 51 mm					
		3	453	8	411	14.9	385
		22	648			34.9	422
		45	648			26.7	475
9B	Good sample	Total length 68 mm					
		15	449	7	443	4.6	428
		37	438			6.4	410
		58	530			11.4	470
9C	Good sample	Total length 63 mm					
		8	366	9	391	5.7	345
		27	382			5.5	361
		46	408			5.2	387
9D	Only Pilodyn Measurement			11	347		

Discussion of results

Wood boring organisms

From the two oak samples taken from the wreck site, it could be seen that the wreck has been exposed to predominantly oxic conditions since sinking. This is attested by the presence of wood boring organisms, which require dissolved oxygen from the surrounding seawater for their respiration. Even though there was no apparent sign of deterioration by large wood boring shipworm, the outer surfaces of the samples were heavily degraded by wood boring crustaceans. There was no sign of living organisms on the samples, but this does not mean they do not survive and are currently active on other parts of the wreck site.

Density measurements on samples and with Pilodyn

According to diver reports many of the timbers on the wreck have been attacked by wood boring organisms, which have implications for the accuracy of the methods to assess the density of the remaining wood. When positioning the Pilodyn instrument on highly degraded surfaces, it is very easy to remove the outer degraded surface layer of wood. This leads to a low penetration of the needle, as the needle is penetrating well-preserved wood, resulting in an artificially high density (see Table 1, samples 1A, 1C, 2C and 3C). If we consider the use of the increment corer, a similar problem can be encountered as underwater it is very easy to lose the outer degraded surface of the wood (see Figure 2) during collection. This leads to an incorrect determination of the depth of the core in the wood and will give artificially high densities nearer the surface of the wood (See Table 1, samples 1B and 6B).

Correlation between density and depth in wood

The average density of fresh waterlogged oak wood (*Quercus robur L.*) is between 500 and 600 kg/m^3 (dry weight / wet volume). The densities of all samples taken from the wreck were plotted against the corresponding depths of the sample cores. As Figure 9 shows there is a poor correlation between these parameters, indicating that the deterioration of the wreck is heterogeneous and that the local environment and various properties of the different pieces of timber have all affected the rates and extent of deterioration.

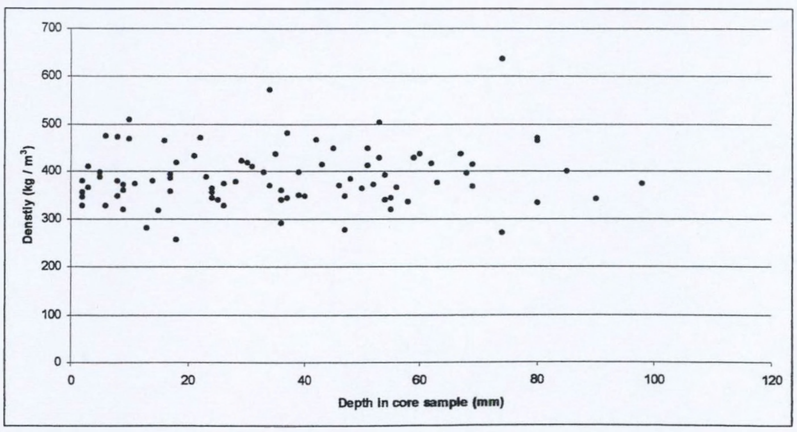


Figure 9: Depth in core sample vs. density of sample taken with increment corer.

Based on this, it was decided to split the wood samples into two discrete populations – those samples relating to the planking of the ship (Samples 1-6) and the structural timbers, such as the beams (Samples 7, 8 and 9).

Planking

The planking, Samples 1-5 on the port side and sample 6 on the starboard side, were from locations on the wreck, which appear to have been continually above the seabed and therefore exposed predominantly to oxic conditions. The densities of the samples reflect the long-term deterioration caused by micro organisms (fungi and bacteria). Tables 3 and 4 show summaries of the average density measurements, as determined on the core samples, in relation to their locations on the wreck site.

Table 3: Density of samples as a function of height on the wreck: A: Top, B: Middle, C: Bottom.

	Sample Position		
	A	B	C
Average Density (kg / m³)	381	359	409

Table 4: Density of samples as a function of location on the port side of the wreck site: See Figure 1 for locations of the sample positions 1-6.

	Sample Position					
	1	2	3	4	5	6
Average Density (kg / m³)	350	396	405	360	400	361

As Tables 3 and 4 show that there is no significant correlation between height on the wreck or location on the sides of the ship and average density, indicating that all planks are randomly degraded.

Figure 10 shows summaries of average density measurements on core samples corrected for ash content, in their relation to depth in the core sample, arranged in depth groups.

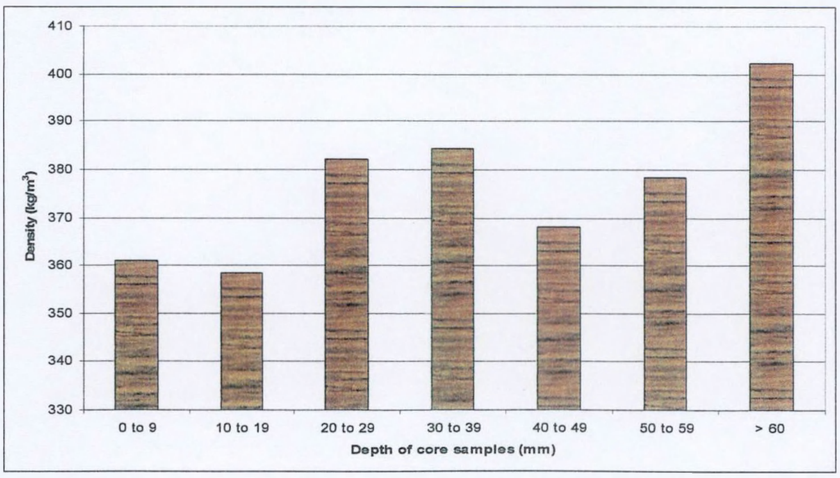


Figure 10: Depth in core samples vs. average corrected densities of depth groups.

Figure 10 does not show a high correlation between depth of sample and corresponding density, but it demonstrates that the outer zone of the wood is the most degraded with average densities increasing towards the centre of the planks. The innermost part of the cores from the planks, i.e. at depths deeper than 60 mm, have an average density, corrected for ash content, of 392 kg/m^3, giving a loss of mass of more than 28% (density of fresh oak taken as 550 kg/m^3). One must expect that the samples have had a loss in strength of more than 28%, due to cleavage of the wood polymers during the degradation processes in the wood.

Structural timbers

The structural timbers (Samples 7, 8 and 9) were all exposed and located on the upper part of the wreck. Considering the densities determined on the core samples (Table 2), it is apparent that all timbers have been homogeneously degraded throughout the length of the cores. Densities from the Pilodyn give a good correlation with the densities determined from the core samples (data not shown). Table 5 shows average, minimum and maximum values for the densities of the core samples plus the average density determined by Pilodyn and the ash content.

Table 5: Density and ash content of structural timbers Samples 7, 8 and 9.

Sample	Density (kg/m^3)				Ash (%w/w)
	Average	Minimum	Maximum	Pilodyn	
7	437	386	658	452	6
8	464	355	585	471	5
9	480	366	648	398	13

Table 5 shows that there is no significant correlation between location of the structural timbers and their average density, measured on core samples corrected for ash content.

Figure 11 shows summaries of average density measurements on core samples corrected for ash content, in their relation to depth in the core sample, arranged in depth groups.

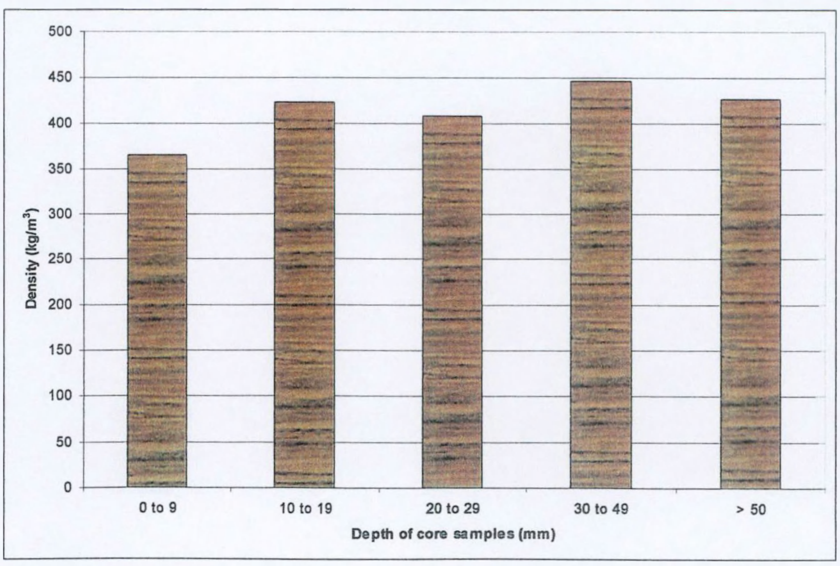


Figure 11: Depth in core samples vs. average corrected densities of depth groups.

Figure 11 shows the correlation between depth in the core and the average density corrected for ash content for structural timbers. As with the planks, there is not a high correlation between depth of sample and the corresponding density, but it demonstrates that the outer zone of the wood is more degraded than the centre of the timbers.

The innermost parts of the cores from the timbers, i.e. depths below 50 mm, have an average density corrected for ash content of 427 kg/m^3, giving a loss of mass of more than 22% (density of fresh oak taken as 550 kg/m^3). Again one must expect that the samples have had a loss in strength of more than 22%, due to cleavage of the wood polymers during the degradation processes in the wood.

Ash content measured on samples

The ash content, determined as %w/w, was measured on all sub samples. This made it possible to see if there was a correlation between ash content and spatial position of the sub core samples (in the ship, depth of the sub sample in the sample). Figure 12 shows the poor correlation between these parameters, indicating that the ash content is dependent on local parameters, although there is a tendency for higher concentrations at the surface of samples.

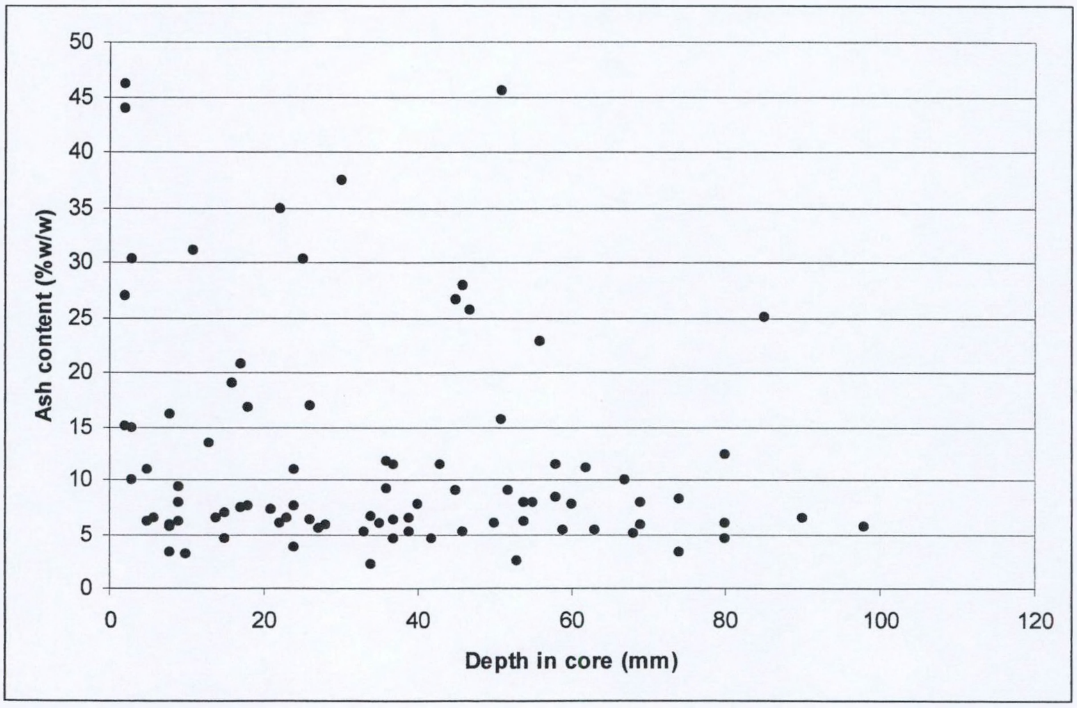


Figure 12: Depth in core samples vs. ash content.

Profiles of density and ash content

Figures 13A, 13B and 13C show the local gradients of the ash content, the density and the density corrected for ash content of three full core samples in planks, Sample no. 3A, 3B and 3C.

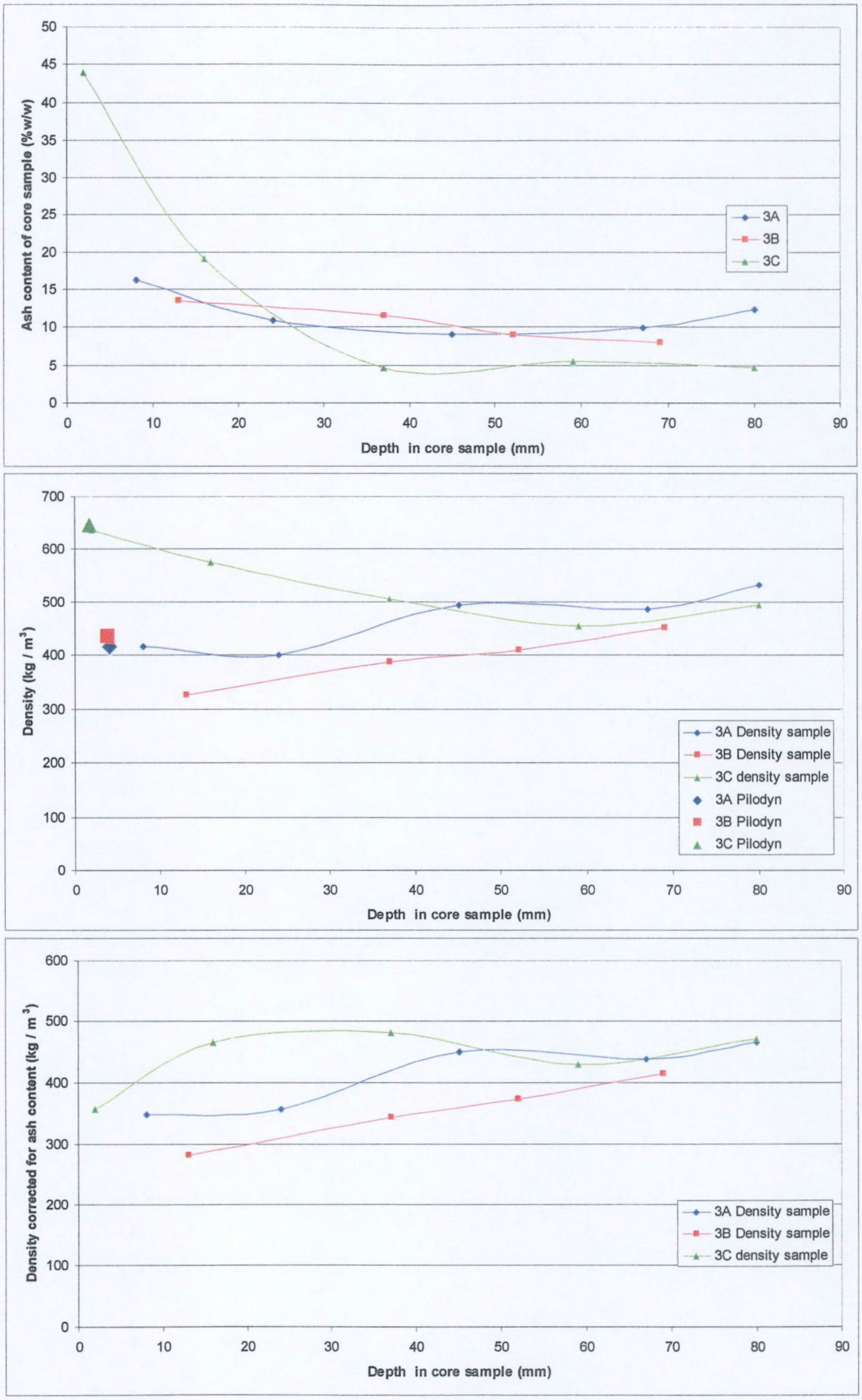


Figure 13: Depth in core (plank) vs. ash content, density measured in core and density corrected for ash content. Plus density calculated from Pilodyn measurement.

Figure 13A shows the ash content of the plank. The ash content is between 5 and 45% with the highest ash content near the surface of the core (plank).
Figure 13B shows the poor correlation between depth and density of the core uncorrected for the ash content. A high agreement between the density of the core and density determined from the Pilodyn measurements is apparent.
Figure 13C shows densities corrected for ash content versus depth. All three profiles show that the density is increasing with the depth.

Figure 14 shows the gradients of the ash content, the density and the density corrected for ash content of a full core sample in a structural timber, Sample no. 8C.

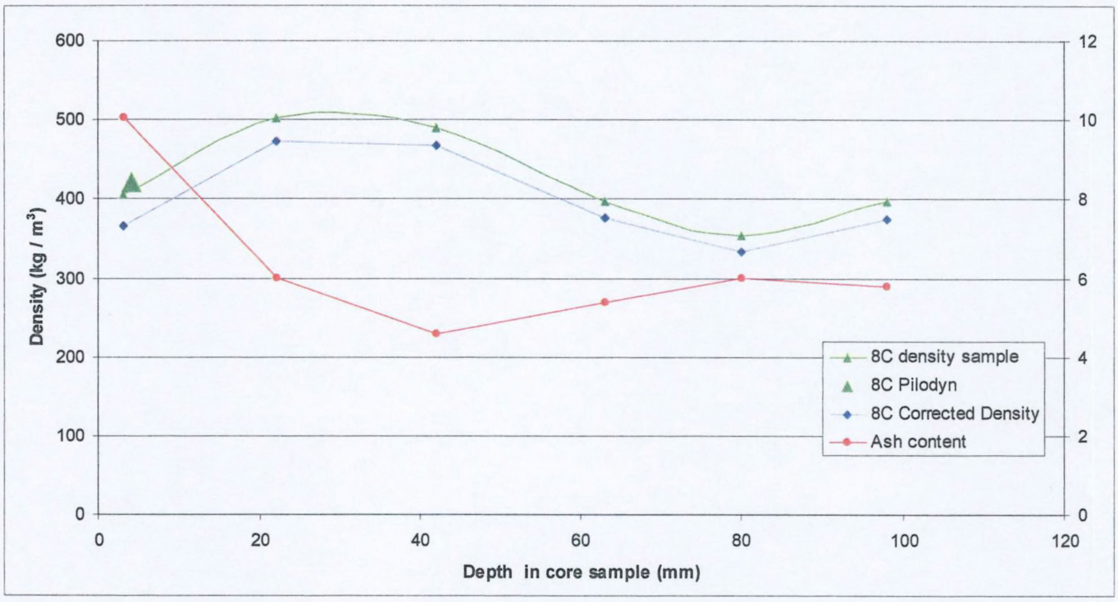


Figure 14: Depth in core (timber) vs. ash content, density measured in core and density corrected for ash content.

As for the planks, the structural timbers show the highest ash content at the surface of the sample (timber) and a good agreement between density measured in the core and density determined by the Pilodyn.

Conclusion

From these analyses the following can be concluded about the current state of preservation of the *Belgica:*

- The surface of the timbers is heavily degraded by wood boring crustacea but there is no apparent sign of wood boring mollusca. This was based on two samples taken from the site and wood borers may be active on other areas of the wreck.

- On a micro-structural level all wood has been homogeneously degraded by micro organisms. This degradation has resulted in a removal of wood cell material (primarily cellulose) lowering the density and hence strength of the wood.

  Structural timbers, such as the beams, the density at depths deeper than 50 mm in the timbers has decreased from ca. 550 kg/m^3 (fresh oak) to 427 kg/m^3. This gives a 22% loss of mass but the inherent strength of the wood will have been reduced by significantly more than 22%.

  Planking, the density at depths deeper than 60 mm, has decreased from 550 kg/m^3 to 392 kg/m^3. This gives a 28% loss of mass but the inherent strength of the wood will have been reduced by significantly more than 28%.

  To put this into context, the wrecks of the *Mary Rose* and *Vasa* had average densities, which were higher than those measured here and they required complex lifting systems to raise them as complete units. In Denmark the wreck of the Kolding cog had average densities of 450 kg/m^3 and it was still deemed too degraded to raise the hull as one complete unit.

- All timbers contain inorganic matter, as determined by ashing of the samples. The results range from 5 – 45%, with highest contents being seen at the surface of the wood. A preliminary analysis of the composition of the ash indicates that it is predominantly iron which should be taken into consideration if there are plans to raise and conserve the *Belgica.*

Recommendations

Even though this assessment has given an overview of the current state of preservation of the *Belgica*, it is based on relatively few samples from the site. Further research to supplement this could be:

- Marine biological survey of the wreck focusing on the presence of living / active wood boring organisms.

- Assessment of the strength properties of timbers – in particular those timbers which would be subjected to the most stress and strain – should the wreck be raised either as a complete unit or as separate sections. This could be achieved by measuring the compression and tensile strength, modulus of elasticity and rupture on selected timbers.

- When considering the potential raising and subsequent conservation the wreck the iron content (and sulphur) content of the wood must be taken into consideration. Although this may not be relevant to the actual raising of the wreck, it has a significant bearing on the future conservation and curation of the find. In the archaeological conservation world there is an ongoing debate about the need to remove iron and sulphur compounds, as they are believed to produce acid within the wood leading to its chemical degradation.

References

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Appendix

The fieldwork in Harstad, May 2008
The fieldwork took place over a period of three days, Monday 5th to Wednesday 8th of May 2008. The Belgica wreck is situated at 20 meters depth in Brurvika, 2 km north of the city of Harstad, Norway.

The team, shown in Figure 14, consisted of:
Project leader: Marnix Pieters (also diving) and Tom Lenaerts from the Flemish Heritage Insitute.
Divers: Tomas Termote, Cris Beerens, Wim Vermeire and Mayke Van Hecke
Conservator: Kristiane Strætkvern (The Conservation Department, The National Museum of Denmark)

Figure 14: The project team on board "Astrid". From the left: Wim Vermeire, Cris Beerens; Mayke Van Hecke, Marnix Pieters, Tom Lenaerts.

Project plan:
At the National Museum, the Conservation Department, three tasks were planned to be undertaken during the mission: core sampling, Pilodyn measurements and conductivity measurements. Based upon a sketch of the wreck, 28 areas had been pointed out as interesting locations for taking measurements. According to the sketch, the port side was considered to be the least preserved one. In order to map this side of the wreck, 15 locations were distributed in 5 rows with 6 meters between the rows, each row with 3 spots (top-bottom-middle spots). Another row of 3 locations was placed in the middle of the starboard side and further 10 areas were located on beams and other structural parts at the inside of the wreck.

Monday morning
Camp: the beach
Task: labelling of measurement spots

An initial briefing in Harstad introduced the work. The various tasks were described, discussed and given priorities.

The first task was to put out a system of wires to enable the correct distribution of locations on the wreck. After the first dive at the wreck, the wire system was in place; however the divers reported that the port side was in a very bad condition and that the wreck was in a worse condition than in August 2006 (Termote and Cattrijsse 2006).

As it could be dangerous to carry out sampling near the bottom of the ship in a few places, it was decided to put a couple of locations a bit further up than originally planned.

Monday afternoon
Camp: the port authorities' boat, "Astrid"
Task: start core sampling

Taking core samples from each spot was given first priority. A corer was screwed approximately 7 cm into the wood; the sample in the corer fixed on a needle and the corer unscrewed. The corer with the sample was brought to the boat, taken out, labelled and packed by the conservator's team in the field laboratory (Figures 15 and 16). Three corers had been purchased for this purpose. All samples and measurements were collected within a radius of 20 cm from the identification label and in principle; one core sample was taken per spot. In order to carry out analyses, the collected samples with a diameter of 5 mm had to be in a condition that enabled a minimum of handling. The core sampling technique was easily adapted by the divers; however the quality of the wood varied, some samples had to be retaken and a few spots were given up after several unsuccessful trials. Still, 5 samples were successfully collected the first day.

Tuesday
Camp: the schooner "Anna Rogde"
Tasks: continue core sampling, Pilodyn and conductivity measurements

One team continued core sampling; the second team started the Pilodyn measurements. Three measurements were taken per location and the values recorded at a silicone coated note pad. In order to avoid diving teams disturbing each others tasks, the teams' working areas were defined in advance.

A conductivity meter designed for underwater purposes had been brought to the site. Values indicating the relative conductivity through the outer layers of the wood could supply the analyses of the core samples and the Pilodyn measurements. Although tested at -5 meters in Danish waters, the conductivity meter could not withstand the pressure during the diving at the Belgica wreck, and this part of the measurement programme was given up.

Other tasks during Tuesday, was to move a few of the measurement areas to other spots. The initial dives revealed that parts of the interior of the wreck were easier to access than thought from the start. Thus, a series of measurement spots were established on a beam along the interior of the port side. Moreover, the divers started taking photographs of the measurement spots on the wreck.

Wednesday
Camp: the port authorities' boat, "Astrid"
Tasks: collect remaining core samples and Pilodyn measurements, photo documentation
Although most of the samples were in an acceptable condition, a few had to be retaken. Moreover, some of the Pilodyn values needed confirmation and extra measurements from some of the spots were required. In addition, the divers had reported heavy shipworm attack of the timbers. In order to investigate the attack of the bio degraders, two samples were taken home for further analyses. The schedule also allowed more photographs to be taken of the wreck. By the end of Wednesday, the team had successfully collected altogether 26 core samples and 85 Pilodyn values and they had all been prepared for transport and further analyses at the National Museum in Denmark.

Figure 15. The field laboratory at "Astrid". On the black table are the Pilodyn (to the left) and the three corers. The aluminium suitcase holds the rest of the laboratory.

Figure 16. The field laboratory at "Anna Rogde". Needles have been prepared for the next core sampling, the labels indicating that the next samples are to be collected from spot 3B and 3C. The plastic vials are prepared to hold core samples from the spots 4B and 3A.