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Thinking Inside the Box

Tree-Ring Analysis, Archaeobotany and Historical Documents Reveal the Authenticity of a Remarkable 14th Century Chest Made in Antwerp

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Abstract

A heavy and impressive chest — part of the museum collection of the city of Antwerp — served as a strongbox to securely store the city's historical documents, including citizen privileges, public liberties, and responsibilities. A recent dendrochronological survey revealed that the tree-ring pattern of the lid dates to 1005–1294 CE, suggesting a felling date early in the 14th century. The Silver fir wood originated from the Vosges mountains in France, and hence was transported to the city of Antwerp that had already developed as an important trade centre along river Scheldt by the

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13th century. The tree-ring pattern of the bottom plank could not be measured, but the presence of caulking material in some large cracks and metal clamps (*sintels*) revealed that this repurposed timber must have originated from a medieval ship. The archaeobotanical analysis of the mosses used as caulking material and of the pollen trapped in these mosses points toward two different locations where the ship was repaired, with at least one location outside the Low Countries.

During the examination, a collection of wooden boxes stored inside the chest drew the attention. It was unclear whether the collection of boxes had any connection with the original content in the chest. Tree-ring dating on these wooden boxes made of oak and beech revealed their 14th to 16th century dating. Furthermore, inscriptions proved their relationship with historical documents.

The combined dendrochronological, archaeobotanical, and historical examination demonstrates that this medieval chest was a privileged spectator of the city's turbulent history.

Keywords

chest – dendrochronology – Middle Ages – palynology – archaeobotany – caulking material

1 Introduction

Chests have been created and designed to protect, preserve, and transport precious goods, objects, and documents for over 5000 years. Simply describing a chest as a wooden container with a lid (and a lock) for storing or shipping goods will not do justice to the stylistic variety, diversity in woodworking techniques, and the assortment of materials used in the creation process of this timeless piece of furniture. Over time, chests have evolved through different styles, wood joining techniques, and modifications to fit a gamut of purposes (Hall 1987; Pickvance 2020; Reeploeg 2013; Susperregi *et al.* 2021; Thun & Svarva 2016).

In Europe, wooden chests, boxes, and hollowed out tree trunks were common pieces of furniture during the Middle Ages. Although chests are considered portable items, they often remained at the same location for many years. They were found in houses, churches, and public buildings, and often they became a generational inheritance. In the Middle Ages, chests were not only used for storage but also for securing precious goods and objects. Security was amplified with heavy metalwork (iron-bound) covering large parts of chests, making them a protected and secured container.

Although the main body of a chest is shaped by joining wooden elements, few chests have been the subject of wood anatomical and dendrochronological studies or in-depth construction analysis (Dominguez-Delmas *et al.* 2021; Bridge & Miles 2011; Christopoulou *et al.* 2022; Haneca 2010; Miles & Bridge 2008). Rather, the chests that have received such attention have been a part of religious institutes (churches, abbeys, cathedrals, etc.) than a part of private collections or civil institutions.

As a secure storage item, chests and wooden boxes have stored and preserved valuable (historical) documents. One such example is a heavy and impressive chest, part of the museum collection of the city of Antwerp, that is believed to have contained and protected the historical documents on public privileges, liberties, and other mandates. However, research on construction details and the historical context has hitherto been limited, and therefore, it remains unclear how old and authentic this chest actually is. Nevertheless, an opportunity to examine the chest arrived when the chest was under temporary storage in the museum depot, during the restoration of the City Hall (2018–2022).

First, to determine the actual age of the chest, a dendrochronological survey (1) was undertaken. A study on construction details (2) was then performed and compared with the dendrochronological dating results. Furthermore, the possibility of other scientific methods (3) revealing more details regarding the construction and assemblage of the chest were examined. Lastly, items currently stored inside the chest were analysed to reveal any potential connection with the original functioning (4) of the chest. The end goal of this multi-faceted survey was to relate (5) the newly acquired information on the construction, history, functioning, authenticity, and origin of the chest and its contents with the rich and turbulent history of the city of Antwerp.

2 Materials and Methods

2.1 *Stylistic and Technical Features of the Chest*

The chest, known as the Antwerp "Privilegiekom" or "Chest of Privileges," is composed of thick and wide planks that are joined at their edges by wrought iron nails. However, not even a single wood joint (e.g., mortise and tenon, dowels, etc.) was used in the construction of the chest. This boarded chest can be seen as a transition from dug-out chests to frame and panel chests. The many metal reinforcements make the chest a secure storage for valuable items and can therefore be considered as a "strongbox" or archival chest (Fig. 1).

The chest measures 227.5 cm in length and 62 cm in width. The lid itself consists of a 6 cm thick plank that was sawn into two parts. The sides of the chest

FIGURE 1 Overview of the Antwerp 'chest of privileges' (outer dimensions: 227.5 × 62 × 59.5 cm)
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are made of a single 5 cm thick and 59.5 cm wide plank. These parts of the chest are made of coniferous wood. However, the bottom plank is made of oak.

The thick planks are held together by nailed wrought iron bands and brackets at the four angles. Smaller angle brackets are positioned under the wrought iron bands and larger L-shaped angle profiles, implying that these were first installed to build the main body of the chest. The other metal parts and the many wrought iron nails were added in the next stage of construction. Additionally, the lid is suspended via nine hinges (4 + 5 for the separate sections) that allows separate openings to both parts (Remmen Science & Heritage 2021).

The interior of the chest is divided into two large compartments that align with the two parts of the lid. At both the outer sides, a small side compartment can be found, each with its own lid. The lids are 51 cm long (which corresponds to the inner dimension of the chest), 18.5 cm wide, and they have a slightly tapered cross section (1.7–2.5 cm thick). These lids can pivot along their longest side on two wooden pegs. All interior compartments are made with oak boards. The bottom of the chest is also lined with high-quality oak planks.

At the inner side of the lid, several clear traces of woodworking are visible. The planks were levelled with a plane after they were sawn from a large trunk. The latter is still evidenced by the presence of saw marks on some parts of the lid and the side planks. At the outer sides of the lid, traces left by an adze or side axe were observed. Next to these tool marks, other traces in the wood indicate that some iron work — probably clamps or nails — have roughly been removed from the chest at some point. These traces suggest that the two parts of the lid were connected by metal straps at one point in time.

Moreover, four handles with a padlock and seven extra hinges allow the chest to be closed and sealed. At the outer edges of the front and back side, four large, iron carrying handles are fixed to the chest.

Additionally, the bottom plank has many cracks and knots. Some of these cracks are filled with an organic substance and are covered with a thin wooden lath, held in place by wide metal clamps. This way of repairing a crack in timber is identical to the common practice of medieval shipbuilding, used for waterproofing wooden boats and vessels.

2.2 *Small Wooden Boxes*

The opening of the chest revealed that the side compartments contained a set of locks and keys, probably related to the original use of the chest as a secure archive. The main body of the chest was, however, filled with what appeared to be a random collection of 21 wooden boxes of various sizes, shapes, and construction details (Fig. 2).

FIGURE 2 A selection of some of the wooden boxes stored inside the big chest. A single box — made of beech — has an oval shape. All other are rectangular and on some inscriptions (including the dates '1249' and '1261') were observed on the sliding lid. Remains of wax seals were found in two boxes

Their outer dimensions range from compact 18.2 × 13.5 × 6 cm boxes to more stretched containers, measuring 89.5 × 17.8 × 19 cm (length × width × height). Ten boxes were selected for further dendrochronological analysis and wood species identification. One of the selected boxes is oval-shaped and measures 19 × 13 cm. Moreover, some of the rectangular wooden boxes have inscriptions on the lid, and all carry a number drawn with chalk or written on a piece of paper glued to the wood surface. The latter two are probably a part of the old inventory at the museum collection. In one container, fragments of two different wax seals were found; in another box, the highly fragmented grit of wax was present.

2.3 *Tree-ring Analysis*

Tree-ring analysis of the chest was restricted to a limited number of elements upon which a cross-section was accessible, without dismantling or removing paint layers: both parts of the chest's lid and the lids of the inner side compartments. The end grain of all other elements was inaccessible. The small wooden boxes all had one or more elements where the edge grain was exposed and the tree rings were clearly visible. On the oval shaped box, the tree-ring pattern could be observed at the back (tangential plane), as this piece of wood was perfectly split in radial direction.

To conduct the analysis, a narrow strip, *c.* 5 mm wide, was cleaned with a soft brush or pared carefully with a scalpel or razor blade to highlight tree-ring boundaries. Tree-ring patterns were then photographed using a digital camera (Canon EOS 550D) and macro lens (EF-S 60mm f/2.8 Macro) mounted on a focusing rack (Novoflex, castel-XL), which was oriented parallel to the cross-section. Individual images were stitched using *Hugin-Panorama photo stitcher* (http://hugin.sourceforge.net/). After calibrating the high-resolution composite images, ring widths were measured using OSM4 (SCIEM-On Screen Measuring). Subsequently, crossdating between individual ring-width series and absolutely dated European reference chronologies (Hollstein 1980; Eckstein et al. 1986; Hillam & Tyers 1995; Vitas 2020; Daly & Tyers 2022) was performed with TSAPWin Scientific v. 4.81 (http://www.rinntech.de/), relying on *t*-values — after logarithmic standardisation following the Hollstein (1980) algorithm — and the percentage of parallel variation (%PV, *Gleichläufigkeit*) (Eckstein & Bauch 1969; Buras & Wilmking 2015).

Furthermore, felling date intervals or earliest possible felling dates (*terminus post quem*) were calculated based on the sapwood model published by Wazny (1990) for timbers with a southern Baltic provenance. Felling dates of timbers with a more south or westward provenance were established using the Hollstein (1980) sapwood data. These data were digitized and re-analysed by Haneca & Debonne (2012) who fitted a lognormal distribution to the dataset.

FIGURE 3 Detail of the bottom plank showing two cracks that were waterproofed with (1) moss caulking, (2) covered with a wooden lath and fastened with (3) metal sintels

2.4 *Palynological and Macro-botanical Analysis*

To conduct these analyses, four small samples were taken from the caulking material found in the cracks of the bottom plank (Fig. 3). Second, a small subsample (approx. 2 cm^3) was taken from the inner parts of the most compacted fragments of caulking material for pollen analyses. The remaining material was used for macro-botanical analysis. Subsequently, samples for pollen analyses were treated following standard techniques (Moore *et al.* 1991), using HCl (10%) treatment, KOH (10%) digestion, removal of large debris by sieving over a 200 mm sieve, acetolysis, and removal of siliceous material using HF (40%). In each sample, a minimum of 500 pollen grains were identified using Beug (2004) and a reference collection curated by the Royal Belgian Institute of Natural Sciences.

For the macro-botanical analyses, the often highly compacted caulking material was first gently soaked in diluted soap to disintegrate the material. In each sample, the moss species were identified and their relative proportions were determined according to five different classes (i.e., dominant, abundant, frequent, occasional, and sporadic).

2.5 *Historical Sources*

In order to further explore and document the original functioning of the large chest and the individual wooden boxes, the archives of the city of Antwerp were consulted. Inventories were found that described, at several points in time, the documents stored inside the chest or stored in the City Hall room where the chest was located. The recurring opening of the chest by alderman and other dignitaries was documented from the early 15th century onwards.

Furthermore, original charters issued in 1242, 1249, and 1262 CE were consulted. The latter two dates corresponded to *post-factum* inscriptions in Arabic numerals on two of the smaller boxes. In total, 21 historical documents were found in the city's archive, and their outer dimensions were recorded (length × width). Most of these historical documents carried one or multiple wax seals. The smaller charters with only one seal were often folded, as shown by primary and secondary folds running across the document. Through close observation, it was possible to reconstruct the way of folding and, hence, to determine the minimal dimensions of the document when folded. It should be noted however that the seal, in some cases, had a larger diameter than the document in its most compact form.

3 Results

3.1 *Dating Results and Chronology*

The lid and sides of the chest were built with planks cleft and sawn from a large trunk of Silver fir (*Abies alba* Mill.). The bottom plank and bottom interior lining was made from oak timber (*Quercus* spp.). The tree-ring pattern of the lid (measured on both end grains of both parts) confirmed they originate from the same plank and tree, and yielded a series of 298 rings. Furthermore, the outermost ring could be dated to 1294 CE due to the high resemblance (t_{Ho} = 12.5, %PV = 76***, n = 289) of the tree-ring pattern to chronologies built with tree-ring series from living trees and historical construction timbers located north of the Alpine Arc (Büntgen *et al.* 2014). In this area, chronologies were built for three core regions: East, Mid, and West. The highest correlation values of the tree-ring series of the chest's lid were found for the westernmost chronology, decreasing towards the east (Table 1, Fig. 4).

The two lids of the inner compartments were made of timber from the same oak tree, as demonstrated by the high mutual correlation between their tree-ring patterns (t_{Ho} = 14.9, %PV = 78, OVL = 144). Crossdating the mean series (n = 173) against European oak chronologies allowed the most recent ring to be

TABLE 1 Crossdating results of the tree-ring series from the lid compared to the Silver fir chronologies presented by Büntgen *et al.* 2014, expressed as t_{Ho}-values and percentage of parallel variation (%PV) with associated significance level (*** $p < 0.001$)

Series	Reference	Overlap	t_{Ho}	%PV
ANPR21_01	West1 (962–1996 CE)	298	12.5	76***
ANPR21_01	Mid1 (1010–1996 CE)	285	9.6	72***
ANPR21_01	East1 (994–2007 CE)	298	9.3	68***

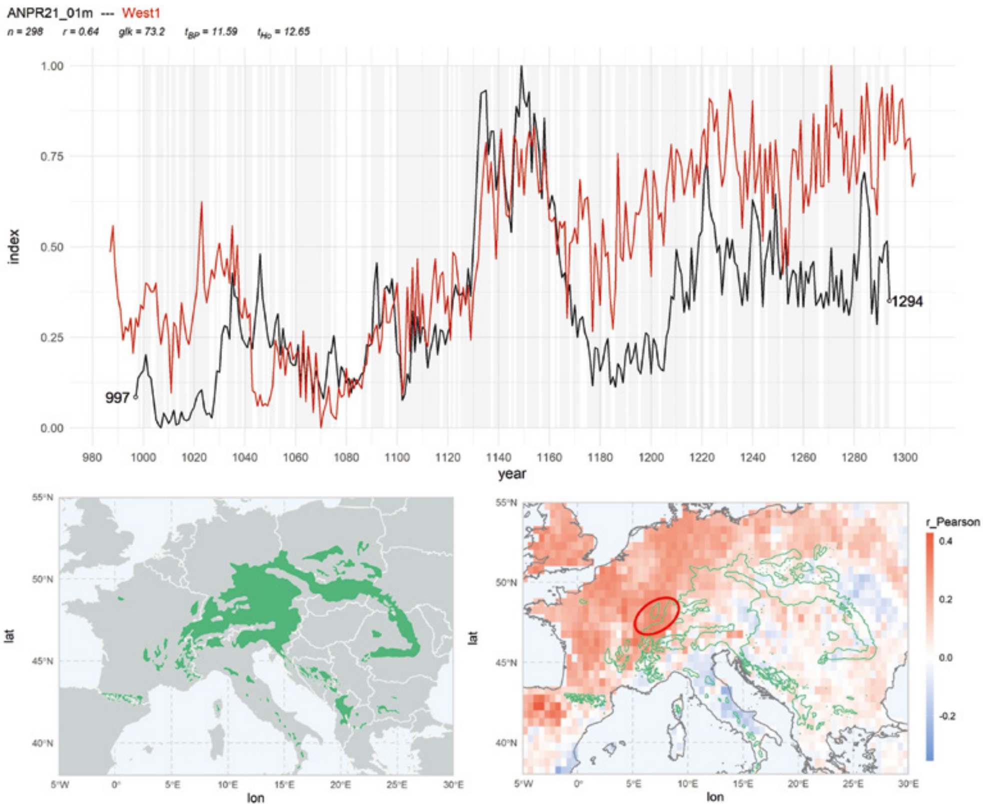

FIGURE 4 Dating and provenance analysis for the tree-ring pattern of lid of the chest made of Silver fir. The top pane shows the excellent match between the measured tree-ring pattern and the Abies-West1 chronology (Büntgen *et al.* 2014). The natural distribution area of *Abies alba* is highlighted in green. Correlation of the tree-ring series with the Old World Drought Atlas (OWDA, Cook *et al.* 2015) slightly points towards the core area of the West1 chronology.

dated to 1301 CE (Table 2). Most significant correlations were found with chronologies from southern Baltic locations. On the left lid, 10 sapwood rings were observed, which allowed a felling date range to be determined. Taking into account the sapwood data published by Wazny (1990), the highest probability density interval (see Haneca *et al.* 2020) indicated that a felling date range was most likely between 1301 and 1317 CE. As such, the dendrochronological dating of the lid and inner (oak) compartments seemed to point toward a common felling date.

On ten selected boxes, the tree-ring pattern of 28 different elements could be accurately measured via calibrated macro-photos. Two of these boxes were made of beech (*Fagus sylvatica*): the box labelled *Cc* and the oval shaped box (Fig. 2). On the first box, the tree-ring pattern of the sliding lid and bottom plank could be measured on the edge grain. The oval shaped box was composed of very thin and bent strips of beech wood and had no exposed end grain. However, as the bottom plank was split perfectly perpendicular to the growth-rings' orientation, the tree-ring pattern was measured upon the radial plane. All analysed elements made of beech contained sufficient rings for further analysis, but only one series could be dated to 1323 CE against a reference chronology covering the area of southern Germany and NE-France (composed by Willy Tegel, 2021, unpublished) (Fig. 5).

All other boxes were completely made of oak and yielded 25 tree-ring series of 92 to up to 294 years (Table 3). For most analysed oak boxes, at least two components were made of wood from the same tree (probably the same plank) as shown by the similarities in their tree-ring pattern. Series originating from a single stem were averaged into a single series, representing an individual tree. For the box labelled *Ca*, the ring-width pattern of the lid had an end date that was only one year apart from the date of the oldest ring measured on the

TABLE 2 Crossdating results of the measured tree-ring series compared to absolutely dated reference chronologies, expressed by t_{BP} and t_{Ho}-values, parallel variation (%PV) and associated significance level (***$p < 0.01$, **$p < 0.01$; *$p < 0.05$)

Series	Series last ring	Reference	Overlap	%PV	t_{BP}	t_{Ho}
ANPR21_02_03	1301	EUBIG7ST	173	65.4***	4.76	5.48
		66STD6	173	62.8***	4.33	5.24
		P671001M	173	65.4***	4.32	5.12
		2021BLT1	159	62.3**	5.17	5.08
		FLmed_raw_1.0	173	62.8***	5.19	4.84

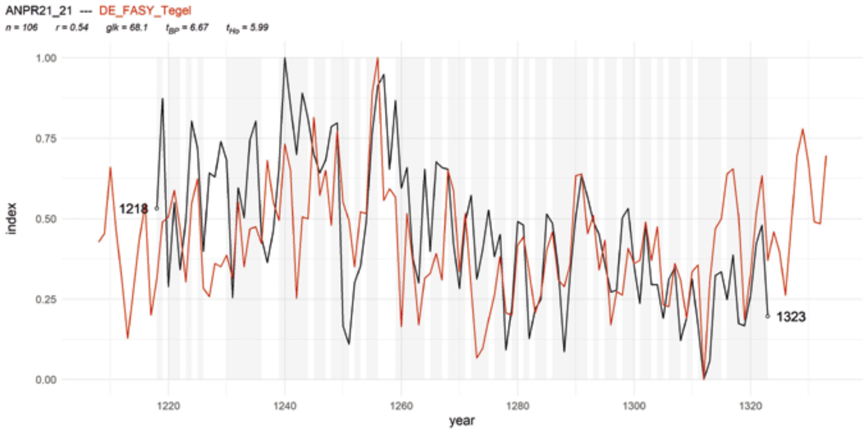

FIGURE 5 The strong match between the tree-ring series from the small wooden box made of beech compared to a reference chronology composed of historical tree-ring series from NE-France and southern Germany dates the most recent ring to 1323 CE.

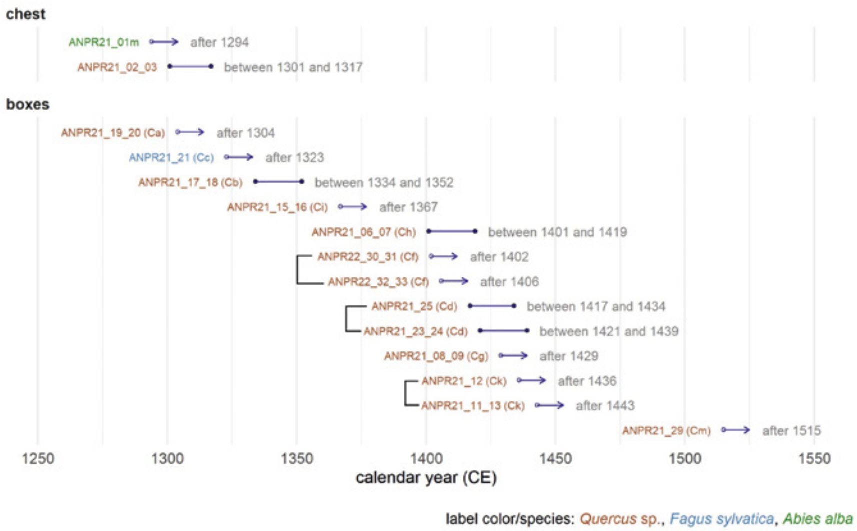

FIGURE 6 Overview of all dendrochronologically dated items and the interpretation of the felling date

bottom plank, which might indicate that these elements were shaped from the same timber. However, no significant correlations were observed between ring-width series of individual boxes. Furthermore, crossdating against absolutely dated reference chronologies allowed the secure dating of 13 series. Even more so, the dates of the most recent growth-rings were distributed along the 14th and 15th centuries (Fig. 6). In the same spirit, one element of the box labelled *Cm* dated to the early 16th century.

The highest correlation values were found with chronologies representing tree-growth in the southern Baltic region (Table A1 in the Appendix); an exception was the small box labelled *Ca* and one element from the box labelled *Cm* where the affinity with historical chronologies covering more western European regions was more pronounced (e.g., the river Meuse catchment area).

3.2 *Analysis of Caulking Material*

3.2.1 Macro-botanical Analysis

For this analysis, we identified that cracks in the bottom plank of the big chest were intentionally filled with organic material. The caulking material that was used to fill the cracks in the bottom plank consisted exclusively of mosses. Two samples, taken from two parallel and adjacent cracks located near the front of the chest, were uniquely composed of *Drepanocladus aduncus* (Knieff's Hook-moss), or they were at least dominated by this moss species as only a fraction of the moss fragments had preserved diagnostic features that allowed taxonomic identification (Table A2 in the Appendix: samples #2 and #3).

One other sample of organic material was taken from a crack on the other side of the bottom plank (Table A2 in the Appendix: Sample #4). This sample also consisted exclusively of mosses, but it had a more diverse species composition. It was dominated by *Neckera crispa* (Crisped Neckera), while the two other moss species and a liverwort occurred occasionally (*Drepanocladus aduncus*) or only sporadically (*Plagiochila porelloides* — Lesser Featherwort, *Plagiomnium cuspidatum* — Woodsy Thyme-moss).

3.2.2 Palynological Analysis

Mosses function as a natural pollen trap as they capture the pollen rain at the site where they grow (Boyd 1986; Cundill 1985, 1991). Therefore, the pollen content recovered from mosses used for caulking material reflects the vegetation of the area where these mosses have been collected and the observed pollen spectra could potentially be used for provenancing these areas of moss collection and, probably, the region the ship was built or repaired at, provided the mosses were not transported over large distances prior to their use as caulking material (Deforce *et al.* 2014).

Three samples (Sample #1, #2, and #3) of the caulking material from the bottom plank of the chest show a very similar pollen assemblage and are dominated by Poaceae (86.8%–93.1%) and associated grassland weeds (e.g., *Plantago lanceolata*, *Rumex acetosa* type, *Trifolium repens* type, etc.) (Table A2

TABLE 3 Overview of all examined wooden boxes, listing their outer dimensions, labels, the elements that were examined, wood species identification and details on their dendrochronological date (start/end, date of the oldest/most recent tree-ring measured for each individual element)

Object	Outer dimensions (cm)	Element
Chest	227.5×62×65.5	Lid
		Lids inner compartments
Box labelled Ch	42.8×24.2×10.3	Bottom plank and sliding lid
Box labelled Cg	54.3×18.7×15.5	Two side planks
		Sliding lid
Box labelled Ck	50×27.5×25.5	Two side planks
		Bottom plank
		Sliding lid with metal handle
Box labelled Ci	57.5×22.3×11.5	Bottom plank and sliding lid
Box labelled Cb	23.3×14.1×6	Bottom plank and sliding lid
Box labelled Ca	18.2×13.5×6.5	Bottom plank and sliding lid
Box labelled Cc	21×12.2×7	Sliding lid
		Bottom plank
Box labelled Cd	42.7×20×13.8	Bottom plank and sliding lid
		side plank
Oval shaped box	19×13	Backpanel
Box labelled Cm	47.7×26.7×21	Side plank (left)
		Side plank (right)
		Sliding lid
Box labelled Cf	89.5×17.8×19	Bottom plank and sliding lid
		side plank

Observed but unmeasured rings are mentioned as well.

in the Appendix). These samples are further characterized by a very low total of arboreal tree pollen (1.9–3.8%), indicating an almost treeless landscape.

Sample #4 shows a much higher arboreal pollen percentage (65.4%), reflecting a far more wooded landscape, with mostly *Quercus*, *Alnus*, *Corylus avellana*, *Carpinus betulus* and *Betula*. Also, some pollen grains from *Abies* and *Picea* have been found in this sample, which are absent in the first three samples, except for one pollen grain of *Abies* found in Sample #3.

TR series	Species	No. rings	Start	End	Sapwood rings	Unmeasured rings
ANPR21_01m	ABAL	298	997	1294		
ANPR21_02_03	QUSP	173	1129	1301	10	
ANPR21_06_07	QUSP	142	1259	1400	7	+1 (earlywood)
ANPR21_08_09	QUSP	100	1322	1421		
ANPR21_10	QUSP	117				
ANPR21_11_13	QUSP	231	1205	1435		
ANPR21_12	QUSP	294	1135	1428		
ANPR21_14	QUSP	266				
ANPR21_15_16	QUSP	160	1200	1359		
ANPR21_17_18	QUSP	157	1178	1334	8	
ANPR21_19_20	QUSP	184	1113	1296		
ANPR21_21	FASY	106	1218	1323		
ANPR21_22	FASY	80				
ANPR21_23_24	QUSP	259	1162	1420	7	+1
ANPR21_25	QUSP	150	1267	1416	8	+1
ANPR21_26	FASY	122				
ANPR21_27	QUSP	92				
ANPR21_28	QUSP	185				
ANPR21_29	QUSP	114	1396	1509		
ANPR22_30_31	QUSP	147	1250	1396		
ANPR22_32_33	QUSP	119	1282	1400		

4 Discussion

Construction details of the large chest imply that all wooden elements, outer planking, and inner compartmentalization were assembled simultaneously. Replacement of one or more elements required dismantling the whole chest, which would have damaged most of the other elements. All side planks were nailed at the corners, after which the metal bands and L-shaped reinforcements were nailed on the planks to make the chest a secure container for valuable items. The only element that could have been replaced was the lid, but tree-ring dating now shows that this piece of timber had its earliest possible felling date close to the dating of two elements of the inner compartments, which have a felling date of most likely falling between 1301 CE and 1317 CE. Although the lid and side planks are made of *c.* 5 cm wide boards of Silver fir, the bottom plank and interior compartments have been designed with oak planks. Owing to this, the bottom plank seems clearly of inferior quality (with cracks, knots, and a coarse grain) compared to the timber used for the interior of the chest. Moreover, provenance analysis demonstrates that the chest was constructed using timbers originating from different locations: the Silver fir planking originated from the Vosges mountains and the oak planking of the interior compartments originated from forests in the southern Baltic region. The use of imported timbers for the construction of chests is not an uncommon observation, as many medieval chests made of pine have been documented in England, a region where pine doesn't occur naturally (Simpson 2008). In the lid, some large cracks can be observed in the wood, which might be related to the drying of the timber. This could suggest that relatively fresh-cut Silver fir was used, and that the felling date is closely related to the construction date of the chest.

It is striking to see that no wood-joints have been used in the construction of the chest. All major elements of the chest are connected by metal nails at the corners. The absence of wood joinery is probably related to the guild regulations at that time, when the application of wood joints was an exclusive right of the members of the Saint Luke's guild of carpenters. This particular type of chest was probably made by "*fortsiermakers*" — members of a small guild, specialising in producing reinforced chests (Van Damme 1985) — who only used wrought iron nails to join the timbers. Furthermore, no specific carpenter or enigmatic marks are observed on any of the chests' timbers.

The bottom plank of the chest — whose tree-ring pattern could not be measured and thus no felling date and region of origin could be established — shares some characteristics with the archaeological ship timbers dated to the Middle Ages, especially the way cracks were waterproofed with caulking material (in this case mosses), covered by a thin wooden lath and secured with sintels (wide metal clamps), which is typical of lapstrake-built vessels. However, the bottom plank is more likely to be a carvel-built bottom plank of a (late) medieval ship, as these are straight and can be as wide (more than 50 cm) as the chest is. The Doel ships (Haneca & Daly 2014; Vermeersch & Haneca 2015; Vermeersch *et al.* 2015), for instance, two 14th century cog vessels found near the town of Antwerp, have bottom planks that measure up to 55 cm. The caulking material further underpins their interpretation as repurposed ship timber. The botanical identification of the mosses and pollen trapped in these mosses indicate that the cracks were filled with material originating from at least two different locations. This observation makes it unlikely that the bottom plank of the chest originated from a water-bound timber construction such as a sluice or a dam. Therefore, this should rather be interpreted as the result of the regular and essential maintenance of a medieval ship in order to guarantee its waterproofing. It must be noted that re-use of ship timbers was a common practice in medieval times. It is unlikely that elements were replaced or renewed after the initial construction of the chest. Therefore, the dendrochronological date of the chest can serve as the *terminus ante quem* date for the re-used ship timber.

At first sight, the species composition of the caulking material seems contradictory: *Drepanocladus aduncus* typically grows in lowland fens and bogs, while the two other moss species (*Neckera crispa, Plagiomnium cuspidatum*) and the liverwort (*Plagiochila porelloides*) grow on solid substrates, often on limestone or on other base-rich rocks, usually in shaded sites or on (old) trees with a mineral and alkalic outer bark (e.g., old beech trees) (Fritz *et al.* 2009). On locations with abundant growth of *Neckera crispa*, the two other species can grow as well. *D. aduncus,* on the other hand, is not expected to occur in these types of environments.

Until the 13th century, most mosses used for caulking were collected from woodland environments (Cappers *et al.* 1998; Saatkamp *et al.* 2011). However, from the 14th century, mosses from wetter environments (fens and bogs) become dominant, especially *Sphagnum* and *Drepanocladus* species (Cappers *et al.* 1998; Gos & Ossowski 2009). The chest is dated in the early 14th century when this transition in caulking material is also noted. The mixture of multiple moss species that do not share a common habitat type indicates that this crack was caulked several times — that too with caulking material originating from different locations — over the life span of the vessel.

This is further supported by the analysis of pollen trapped in the mosses. The pollen spectra in the samples, dominated by *Drepanocladus aduncus*, show that most of this moss-caulking material was collected from an almost treeless, heavily deforested environment, as indicated by the low percentage of arboreal pollen (ΣAP) grains in these samples (ΣAP = 1.9%–3.8%). Contrastingly, the one sample with a mixed composition of different moss species originates from a far more wooded area (ΣAP = 65.4%), dominated by pollen from *Quercus* and *Alnus*. Moreover, the presence of pollen from fir (*Abies*) and spruce (*Picea*) — although in low quantities — excludes the Low Countries as a possible origin of this last sample (Maes *et al.* 2006). As such, the archaeobotanical and palynological examinations of the caulking material indicate at least two different locations of reparations for the ship timber.

Further, *Neckera crispa* could have been harvested close to the city of Antwerp, but this would require the presence of large, old-growth forest patches where this moss species could have been harvested in large quantities to serve as caulking material. This is questionable as it is known that by the end of the 13th century, the current area of Flanders was already heavily deforested due to conversion to arable land and a high demand for fuel and construction timber (Tack *et al.* 1993; Deforce 2017). Therefore, for the high- and late-medieval periods, further north locations — probably along the Baltic Sea coastlines — seem to be more plausible regions for origin of this material. On the other hand, the pollen spectra indicate a more central European origin, with the presence of *Abies* pollen and low percentages of *Pinus*.

Moreover, *Drepanocladus aduncus* is a common moss species and can grow abundantly in wet, open environments. Therefore, this caulking material could have originated from a wide area along the North Sea coastline and lowlands, including the region of Antwerp. It is known to be used as caulking material. For example, this species was abundant in some of the analysed caulking samples from the 14th century cog Doel 1 (Deforce *et al.* 2014).

After the tree-ring analysis revealed the early 14th century origin of the chest, the construction dates of the wooden boxes inside the chest can be interpreted with relation to the construction date of the chest. The first observation is that multiple elements in several boxes originate from the same log or tree, indicating that they were assembled in an economical way by using a limited number of timbers. Generally, the lids and bottoms, or both sides, are usually made of the same plank. Additionally, the oldest wooden box found inside the chest has a felling date after 1304 CE, and it is the only analysed box that could have been made at the same time as the large chest. All other boxes are certainly younger as their earliest possible construction date is situated after 1317 CE. Despite the fact that an interval for the felling date of the used timbers could be established only for three boxes, it becomes clear that these boxes were not created simultaneously but were fashioned in the 14th and 15th centuries. Even the most recent box dates back to only the early 16th century.

The chronology of the selected wooden boxes shows that the content of the chest changed over time. More documents and custom-made wooden boxes were added and might have replaced others. Today, the chest is known as the "Privilegiekom," i.e., the chest that holds the city's privileges and liberties. In fact, the city of Antwerp first received its city rights and liberties in 1221 CE by the Duke of Brabant, Hendrik I. This event clearly predates the items stored in the chest that survive today. However, on the lid of two of the smallest boxes, inscriptions are visible that depict a date. On the box labelled "*Cb*" the *post factum* inscription of "1261" is written on the lid in Arabic numerals. Considering the late-medieval writing style, another inscription on the lid referring to the

Duchy of Brabant ("… *van Brabant*") might coincide with the making of the box. Both inscriptions most likely refer to a series of charters with peace settlements between Antwerp and other Brabantine cities issued in 1262 CE (new style, 1261 CE in old style). As this box has a most likely dendrochronological felling date range situated between 1334 and 1352 CE, it was clearly made many years after the original documents. Another small box (labelled "*Cc*") — with a felling date situated after 1321 CE — has the date "1249" inscribed on the lid, once again a *post factum* inscription in Arabic numerals. More — but hard to decipher — text is present on the lid. In late-medieval writing style, possibly contemporary with the making of the box, the text refers to "letters" (plural) ratified in Antwerp ("*Item vanden brieve*(*n*) (…) *ende w*(…)*ere … Die tantwerpen gebannen* (…)"). The city's archives indeed preserve a series of charters dating back to 1249 CE, all of similar dimensions and containing legal agreements between Antwerp and other cities in Brabant and the prince-bishopric of Liège.

When comparing the inner dimensions of the oldest wooden boxes with the sizes of the (folded) charters issued in 1249 and 1262 CE, it becomes clear that multiple documents like these could fit in the small boxes with corresponding dates (Fig. 7). When folded, the documents and their seals measure no more than 9.8 cm (for charters issued in 1249 CE) or 11 cm (issued in 1262 CE). Both wooden boxes have inner dimensions of 19.5 × 10.8 × 6 cm (for the box with "1249" inscribed on the lid) and 21.5 × 12.3 × 5.8 cm (for the box labelled "1261"). Furthermore, the text mentioned on the lid of the "1249" labelled box explicitly refers to the plural "letters," and not to the singular "letter," which further supports the hypothesis that multiple folded documents were stored in this tailor-made storage box.

Another interesting inscription, present on one of the larger boxes (labelled *Ci*, measuring 57.5 × 23 × 11.5 cm), refers to "imperial privileges" ("*hier in siin alle keyserlike prevelegen*"). The specificity of the documents issued by the emperor points toward the first half of the 16th century, when the Holy Roman Emperors Maximilian I and Charles V were lords of Antwerp and the Duchy of Brabant. However, this does not agree with the felling date that is situated after 1367 CE, long before the reign of Maximilian I and Charles V.

The largest box (*Cf*) has a dendrochronological *post-quem* date of 1406 CE and inner dimensions of 86.3 × 14.7 × 16.1 cm (Fig. 2, top-left panel). On the lid, a "Brabantine charter" is mentioned, without specifying any data. This particular tailor-made box probably served as the storage unit for a larger document, which often had numerous seals and could therefore not be folded and was rolled up, benefiting from a protective cover to shield the seals. An example of such is the Charter of Kortenberg,[1] a 70 cm wide document issued in 1312 CE.

1 https://commons.wikimedia.org/wiki/File:Charter_van_Kortenberg_in_het_FelixArchief.jpg.

FIGURE 7 Two representative historical documents issued in 1249 CE (left, https://felixarchief.antwerpen.be/archievenoverzicht/333616) and 1261 CE (right, https://felixarchief.antwerpen.be/archievenoverzicht/333627) and the wooden boxes that have those dates inscribed on the lid. The folded documents and their seal easily fit in the wooden boxes.

Furthermore, two of the larger boxes (*Cg* and *Gk*) contain fragments of wax seals. Both boxes have an earliest possible felling date after 1429 CE and 1443 CE, respectively. The most complete fragments of the wax seals display decorations that could be dated stylistically to the 15th century and, therefore, the dating of the fragments concur with the dendrochronological dates of the boxes.

5 Conclusion

The combined dendrochronological, archaeobotanical, and stylistic research on the impressive chest not only reveals its early 14th century construction date but informs nuances on its assemblage, design, choice of material, and builders. It is striking to note that the whole chest was originally assembled with imported and/or recycled timbers — imported Silver fir for the lid and sides and repurposed ship timber for the bottom. The archaeobotanical analysis of the caulking material originating from the bottom plank corroborates the hypothesis that its origin was indeed a ship's timber, despite the impossibility of performing tree-ring and provenance analyses on this particular timber.

Furthermore, the current content of the chest — at first sight, not necessarily a coherent assemblage — proved to be related to the archival chest. The wooden boxes probably served as protective packaging for historical documents related to liberties, privileges, and other legalities acquired by the medieval town of Antwerp. At the time of the chest's construction, the items already stored inside could be interpreted as "historical documents." Some of the wooden boxes inside the chest bore inscriptions which referred to the original documents they were preserving, although the containers themselves were conceived much later, as revealed by their dendrochronological dates. Moreover, the city of Antwerp had already developed as an important trade centre along the river Scheldt in the 13th century. It first received its city rights and liberties in 1221 CE, by the decree of the Duke of Brabant. Subsequently, an archive of documents began building and would have at some point required a safe and secure storage facility. Thus, from the 14th century onwards, this chest served the required function and hence can be seen as the oldest preserved archive of the city of Antwerp. Some of the original 13th century charters are still preserved in the city of Antwerp's archives, and based on the dendrochronological dates and the inscriptions on the boxes, a substantiated hypothesis can now be formulated that allows to bring back together the documents with their original, tailor-made storage boxes and secure strongbox.

Data Availability

Detailed macro-photographs of the wood structure and tree-ring pattern observed on the examined elements of the "Privilegiekom" chest and individual wooden boxes, along with the measured ring-width series, are available in the Zenodo repository: https://doi.org/10.5281/zenodo.7064215.

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Appendix

TABLE A1 Crossdating results of all measured and dated elements of the wooden boxes and lids of the inner compartments of the chest, made of oak

Series	Series_end	Reference	Overlap	%PV	%PV_sig	t_{BP}	t_{Ho}
ANPR21_02_03	1301	EUBIG7ST	173	65,4	###	4,82	5,48
ANPR21_02_03	1301	66STD6	173	62,8	###	4,32	5,24
ANPR21_02_03	1301	2021BLT1	159	62,3	##	5,14	5,08
ANPR21_02_03	1301	FLmed_raw_1.0	173	62,8	###	5,26	4,84
ANPR21_06_07	1400	2021BLT2	142	66,3	###	7,27	8,41
ANPR21_06_07	1400	EUBIG7ST	142	65,6	###	5,58	6,23
ANPR21_06_07	1400	66STD6	142	62,4	##	5,34	5,58
ANPR21_06_07	1400	E-Pomerania	142	58,9	#	5,21	5,47
ANPR21_08_09	1421	2021BLT1B	100	71,2	###	5,58	5,64
ANPR21_08_09	1421	Fletcher1	100	66,2	##	5,9	5,21
ANPR21_08_09	1421	EUBIG8ST	100	69,7	###	5,23	5,14
ANPR21_08_09	1421	Retabels_BE	100	72,2	###	5,3	5,07
ANPR21_08_09	1421	2021BLT1	100	66,7	###	5,41	4,93
ANPR21_08_09	1421	Klaipéda	100	66,2	##	4,73	4,89
ANPR21_10	–						
ANPR21_11_13	1435	2021BLT2	231	65,4	###	6,33	7,01
ANPR21_11_13	1435	Fletcher4	199	63,1	###	6,1	5,87
ANPR21_11_13	1435	EUBIG7ST	231	61,3	###	4,78	5,37
ANPR21_11_13	1435	Torun3	231	62,4	###	4,64	5,21
ANPR21_11_13	1435	Retabels_BE	231	63,7	###	5,55	5,13
ANPR21_11_13	1435	2021BLT1	231	61,3	###	5,64	4,96
ANPR21_11_13	1435	E-Pomerania	231	58,7	##	4,17	4,65
ANPR21_12	1428	Fletcher4	269	62,5	###	7,01	7,44
ANPR21_12	1428	2021BLT1	286	60	###	7,13	7,35
ANPR21_12	1428	2021BLT2	243	63,8	###	5,97	7,01
ANPR21_12	1428	EUBIG8ST	294	57,2	#	5,81	6,33
ANPR21_12	1428	EUBIG7ST	294	59,9	###	5,45	5,01
ANPR21_14	–						
ANPR21_15_16	1359	Fletcher4	160	65,4	###	5,73	4,7
ANPR21_15_16	1359	2021BLT2	160	63,5	###	4,53	4,55
ANPR21_15_16	1359	EUBIG8ST	160	61,6	##	5,06	3,98
ANPR21_15_16	1359	Fletcher2	76	66	##	4,02	3,87
ANPR21_15_16	1359	2021BLT1	160	61,9	##	4,51	3,71

TABLE A1 Crossdating results of all measured and dated elements of the wooden boxes (*cont.*)

Series	Series_end	Reference	Overlap	%PV	%PV_sig	t_{BP}	t_{Ho}
ANPR21_15_16	1359	EUBIG7ST	160	65,7	###	5,41	3,51
ANPR21_17_18	1334	EUBIG7ST	157	69,9	###	8,66	7,49
ANPR21_17_18	1334	66STD6	157	66,3	###	7,56	6,38
ANPR21_17_18	1334	E-Pomerania	157	65,7	###	7,35	6,16
ANPR21_17_18	1334	2021BLT1	157	66	###	6,01	5,64
ANPR21_19_20	1296	S-Engl	184	61,2	##	4,65	5,03
ANPR21_19_20	1296	Arden4	151	63	##	4,75	4,82
ANPR21_19_20	1296	FR.Meuse	184	65,6	###	3,92	4,71
ANPR21_19_20	1296	Meuse5	184	63,4	###	4,18	4,04
ANPR21_23_24	1420	Fletcher4	242	66,2	###	8,47	8,83
ANPR21_23_24	1420	2021BLT1	259	64,5	###	7,05	7,72
ANPR21_23_24	1420	Retabels_BE	259	64,9	###	6,71	7,49
ANPR21_23_24	1420	EUBIG8ST	259	62,2	###	5,61	6,59
ANPR21_23_24	1420	EUBIG7ST	259	60,7	###	6,12	6,09
ANPR21_25	1416	P671001M	81	73,8	###	5,36	5,97
ANPR21_25	1416	Retabels_BE	150	63,1	##	3,23	5,08
ANPR21_25	1416	2021BLT1	150	58,7	#	2,78	4,55
ANPR21_25	1416	EUBIG8ST	150	63,4	##	3,09	4,47
ANPR21_25	1416	Klaipéda	150	63,8	###	2,55	4,02
ANPR21_27	–						
ANPR21_28	–						
ANPR21_29	1509	NL.DenBosch	114	59,3	#	5,54	5,89
ANPR21_29	1509	NL.zuid	114	65	##	5,19	5,75
ANPR21_29	1509	EUBIG2LA	114	66,4	###	4,53	5,02
ANPR21_29	1509	FR.Meuse	114	66,4	###	5,01	5,01
ANPR21_29	1509	Wallonie_WT2017	114	63,3	##	4,75	4,79
ANPR21_29	1509	EUBIG1ST	114	65,5	###	4,11	4,6
ANPR21_29	1509	DE.Westfalen.2	114	59,3	#	4,12	4,55
ANPR21_29	1509	NL.Westfalen	114	65,5	###	4,23	4,54
ANPR21_29	1509	DE.Westfalen.1	114	58,8	n.s	4,42	4,48
ANPR21_29	1509	DE.Holl80	114	61,1	#	4,1	4,47
ANPR22_30_31	1396	Fletcher4	147	62,3	##	5,37	5,77
ANPR22_30_31	1396	2021BLT2	147	68,5	###	5,91	5,58
ANPR22_30_31	1396	Baltic2	140	67,6	###	5,75	5,39
ANPR22_30_31	1396	EUBIG7ST	147	68,2	###	5,22	4,53
ANPR22_32_33	1400	Fletcher2	117	68,1	###	5,82	5,86

TABLE A1 Crossdating results of all measured and dated elements of the wooden boxes (*cont.*)

Series	Series_end	Reference	Overlap	%PV	%PV_sig	t_{BP}	t_{Ho}
ANPR22_32_33	1400	Baltic2	119	69,1	###	5,5	5,73
ANPR22_32_33	1400	2021BLT2	119	66,9	###	5,67	5,3
ANPR22_32_33	1400	Torun3	119	65,3	###	4,03	4,41
ANPR22_32_33	1400	Fletcher2	117	68,1	###	5,82	5,86

TABLE A2 Archaeobotanical analysis results of the caulking material

Sample	#1		#2		#3		#4	
MARCROBOTANICAL ANALYSIS								
Drepanocladus aduncus			dom		dom		oc	
Neckera crispa							dom	
Plagiochilla porelloides							sp	
Plagomnium cuspidatum							sp	
POLLEN ANALYSIS	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**
Trees and shrubs								
Abies	–	–	–	–	1	0,2	3	0,5
Alnus	7	1,4	4	0,7	3	0,6	58	10,4
Betula	1	0,2	3	0,5	–	–	21	3,8
Carpinus betulus	–	–	–	–	1	0,2	21	3,8
Corylus avellana	1	0,2	2	0,4	1	0,2	22	3,9
Fagus sylvatica	1	0,2	–	–	–	–	11	2,0
Fraxinus excelsior	–	–	–	–	–	–	2	0,4
Picea	–	–	–	–	–	–	1	0,2
Pinus	1	0,2	–	0,0	–	0,0	6	1,1
Populus	–	–	–	–	1	0,2	1	0,2
Quercus	3	0,6	8	1,4	2	0,4	209	37,5
Salix	1	0,2	4	0,7	1	0,2	9	1,6
ΣAP	*15*	*3,0*	*21*	*3,8*	*10*	*1,9*	*364*	*65,4*
Herbs								
Apiaceae	3	0,6	2	0,4	2	0,4	3	0,5
Asteraceae-Liguliflorae	–	–	1	0,2	1	0,2	–	–

TABLE A2 Archaeobotanical analysis results of the caulking material (*cont.*)

POLLEN ANALYSIS	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**
Artemisia	–	–	5	0,9	3	0,6	1	0,2
Brassicaceae	–	–	–	–	–	–	1	0,2
Calluna vulgaris	3	0,6	1	0,2	1	0,2	2	0,4
Cannabaceae	9	1,8	–	–	3	0,6	3	0,5
Cerealia	4	0,8	13	2,3	6	1,1	10	1,8
Chenopodiaceae	2	0,4	1	0,2	–	–	2	0,4
Cyperaceae	2	0,4	4	0,7	3	0,6	1	0,2
Lythrum	–	–	–	–	–	–	1	0,2
Filipendula	1	0,2	3	0,5	2	0,4	11	2,0
Matricaria type	2	0,4	3	0,5	–	–	4	0,7
Papaver rhoeas type	–	–	–	–	–	–	1	0,2
Plantago lanceolata	8	1,6	10	1,8	1	0,2	6	1,1
Poaceae undiff.	439	87,3	485	86,8	499	93,1	139	25,0
Ranunculus acris type	1	0,2	2	0,4	–	–	3	0,5
Rubiaceae	2	0,4	–	–	–	–	–	–
Rumex acetosa type	6	1,2	7	1,3	3	0,6	3	0,5
Senecio type	1	0,2	–	–	–	–	1	0,2
Trifolium repens type	2	0,4	1	0,2	1	0,2	–	–
Urtica dioica type	–	–	–	–	–	–	1	0,2
Valeriana officinalis type	–	–	–	–	1	0,2	–	–
ΣNAP	*488*	*97,0*	*538*	*96,2*	*526*	*98,1*	*193*	*34,6*
ΣP	*503*	*100,0*	*559*	*100,0*	*536*	*100,0*	*557*	*100,0*
Spore plants								
Equisetum	2	0,4	–	–	–	–	–	–
Filicales	4	0,8	4	0,7	1	0,2	5	0,9
Polypodium vulgare	–	–	–	–	–	–	1	0,2
Indeterminata	5	1,0	–	–	2	0,4	9	1,6