



Purse of medieval silver coins from royal shipwreck revealed by X-ray microscale Computed Tomography (μ CT) scanning

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ABSTRACT

We present the archaeological discovery and microscale X-ray Computed Tomography (μ CT) scanning of a silver coin purse lost in a medieval shipwreck while the king who issued many of the coins was aboard. The find demonstrates that shipwrecks are extraordinary repositories of historical information, in this case providing insight into one of the most important and dramatic events of medieval Scandinavia. In the summer of 1495, *Gribshunden*, the flagship of King Hans, ruler of Denmark and Norway, burned and sank in the Baltic Sea en route to a political summit in Sweden. The identified coins in this purse impart direct evidence of Hans' establishment of new mints to increase the amount of currency in circulation, and his decision not to recall and debase existing coins. These were essential elements of Hans' comprehensive strategy for consolidating a Nordic political union and constructing a new nation. The recovered coins are too fragile for mechanical separation, but μ CT allowed full or partial identification of 82% of the coins in the concreted purse. Our investigations suggest the purse likely was the personal possession of a high-ranking and trusted person in the king's entourage. Further, the composition of the purse illuminates politics and monetary policy in medieval northern Europe.

1. Introduction

Shipwrecks preserve archaeological artifacts that do not survive in any other context, and new scientific methods allow maximum extraction of information from those objects. Recent archaeological excavation of the medieval royal Danish-Norwegian flagship, *Gribshunden*, delivered concreted masses determined by microscale X-ray Computed Tomography (μ CT) to be remains of a purse containing 150+ silver coins. This assemblage of coins is uniquely informative for several reasons. First, unlike other coin hoards, the date and circumstance of its loss are documented. This reverses the usual situation of coins determining the approximate date of an archaeological feature, and allows numismatists and archaeologists to pose novel questions. Second, this was an unintentional loss, so the coins represent "active" money in circulation and intended for common use, as opposed to a hoard offered as a donation or deposited as savings. Because it is a very specific variant of a hoard, we here use the term 'purse' to refer to this coin assemblage. Third, King Hans himself was sailing aboard the ship when it sank in the summer of

1495; these coins were officially sanctioned and therefore offer indications of the king's monetary policy. Fourth, the ship was conveying Hans on a diplomatic mission of the highest importance, imbuing each artifact with particular historical significance. Identification of the coins in this purse was imperative because of the potential for generation of new knowledge about the transition from the medieval period to the modern era in the Nordic region.

Study and identification of the individual coins in the purse was complicated by the fact that the silver coins are badly degraded due to the conditions of the depositional environment. Archaeologists and conservation scientists determined that after more than 500 years on the Baltic Sea floor, the coins would be destroyed and all information lost if mechanical separation of the concretion were attempted. A review of possible non-intrusive methods showed encouraging results from recent CT scanning efforts to identify well-preserved coins from a terrestrial hoard (Miles et al., 2016). A more limited outcome was achieved in the only previous attempt to apply the method to concreted coin masses recovered from underwater archaeological sites, resulting in the

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identification of a single coin (Mearns et al., 2016). These studies highlighted μ CT's potential for archaeology.

The authors determined to conduct numismatic analysis of the *Gribshunden* coin concretions by analyzing μ CT data. This allowed identification of the coins while leaving the artifact undamaged and preserving the information contained within it. Our success employing the method to the *Gribshunden* purse demonstrates the general utility of the technique applied to artifacts from maritime contexts, and its specific value in identifying coins too fragile for mechanical separation and cleaning. μ CT scanning extracts otherwise unobtainable information from the mere ghosts of the original objects, allowing voluminous historical and archaeological interpretation.

Gribshunden burned and sank at anchor in June 1495 while King Hans (Denmark 1481–1513, Norway 1483–1513) was traveling to a political summit in Kalmar, Sweden (Hansson et al., 2021). The ship sank off Ronneby, in Blekinge region. This was Danish territory until 1658, when it was ceded to Sweden. Hans' mission on this 1495 voyage was to claim the Swedish throne by convincing Swedish noblemen to elect him king. This would reconstitute the "Kalmar Union" of Denmark, Norway, and Sweden, originally formed a century earlier but dissolved in 1448 (Gustafsson, 2006). The king's tactics to re-establish the Kalmar Union included diplomacy and persuasion, exhibition of military power with the threat of violence, and material demonstrations of his wealth and authority. An element of the king's strategy possibly included distribution of coinage to certain Swedish nobles. Hans ordered *Gribshunden* loaded with everything that would help obtain his political objective and legitimize his rule: a company of soldiers and foreign mercenaries equipped with full armor; the entire range of late medieval weapons: lances, pikes, swords, crossbows, handguns; royal foodstuffs and prestigious spices for feasting and display (Macheridis et al., 2020). The flagship itself was a personal possession of the king, and it and the accompanying squadron were a striking display of power. *Gribshunden* carried on its decks some of the earliest artillery deployed at sea (Spencer, 2019). The loss of the ship en route to the summit was a terrible blow to the king, but it could have been worse. Written sources attest that the conflagration and explosion that dispatched *Gribshunden* also claimed the lives of noblemen, soldiers, and the royal physician/natural philosopher; but Hans was ashore and escaped personal injury (Etting et al., 2019).

The *Gribshunden* coin purse was recovered during an archaeological excavation in 2019. The primary goal of that effort was to assess the archaeological potential of the site, while minimizing interference with it. This initial limited investigation disturbed approximately 1% of the total volume of the wreck site. The excavators opened a 2×3 m trench on the starboard side of the vessel, slightly aft of amidships (Fig. 1). This

area of the ship included a portion of the sterncastle, hypothesized to be where the king and his highest-ranking companions were stationed with their possessions. The purse lay in an upper stratum of the excavation, in close proximity to several high-value prestige objects. An encapsulating layer of corrosion products masks the size and profile of the purse, which consists of three concretions and a few individual or concreted pairs of coins (Fig. 2). In total, the purse is composed of approximately 150 coins, with the majority contained in the largest concretion. The depositional context was burial for more than 500 years in anaerobic sea floor sediments submerged in brackish water, a suboptimal preservative environment for metals (M. M. Jensen et al., 2003).

2. Materials and methods

The subject of the study described here is the largest of the concretions from the purse, a 7.3×3.0 cm object roughly cylindrical in form. Circular outlines at one end are the only visual indication that the dark grey lump represents a coin hoard. An initial X-ray scan revealed that the structure of the largest concretion is approximately 103 coins arranged in three well-defined stacks (stack 1–3). Three smaller stacks (stack 4–6) within this concretion originally might have been integrated into the three main columns, but separated before or during deposition and subsequent concretion. The arrangement of the coins suggests that at the time of deposition they were tightly wrapped in cloth or leather, contained in a type of purse (Fig. 2). These coins were likely a personal possession of money in active use, not part of the mission coffer.

μ CT is extensively used for study of archaeological artifacts, and the technique is now a mature scientific method. The advance made in this study is utilizing results from the method to generate otherwise unobtainable knowledge for the Humanities and social science. In brief, the method consists of X-rays generated by a source passing through the object of study, which partially absorbs some fraction of the energy. The transmitted energy is then registered on a 2D area detector behind the object, thereby creating a projection image of the internal structure of the artifact. By rotating the object continuously during the scan, projections from different angles are recorded. Using computer algorithms, the 3D internal structure of the object is reconstructed from these projections.

Two decades of development of μ CT as a method for investigation of degraded metallic archaeological objects is exemplified by comparison of the *Gribshunden* purse with another high-profile case study. In 2005, a custom microfocus X-Ray machine was built to image the famous Antikythera Mechanism, a 2nd century BCE copper-alloy geared astronomical prediction device discovered on a shipwreck in the Aegean Sea. That CT system, named "Bladerunner", required a dedicated team of engineers and technical specialists to produce initial data voxel (volume pixel) size of $101.0 \mu\text{m}$, and $54.2 \mu\text{m}$ at highest resolution (Pakzad et al., 2018).

By comparison, in 2019 the largest concretion of the *Gribshunden* purse was scanned by a single investigator at the Danish Technical University using a commercial system: a Nikon HT 225 ST X-ray μ CT set-up. One overview scan resulted in a voxel size of $85.9 \mu\text{m}$. Not all coins were successfully resolved at this resolution, probably because the original coin blanks are very thin and the coins are tightly stacked, presenting no visual structural changes between them. A second higher resolution scan with voxel size $36.6 \mu\text{m}$ more clearly imaged the coins, with the total width of the concretion fitting in the field of view. Three scans along the entire long axis of the largest concretion were conducted at 200 kV voltage, 30 W power, and an exposure time of 0.7 s. The resulting 1571 projections with 2 frames per projection were stitched together into one data set.

Individual image slices of the CT data are stacked along the horizontal axis, but the surfaces of the coins are not arranged in straight horizontal lines. Obverse and reverse motifs of one or more coins often are merged in a single image. To obtain the clearest images of the obverse and reverse of a single coin, the coin stacks must be arranged in

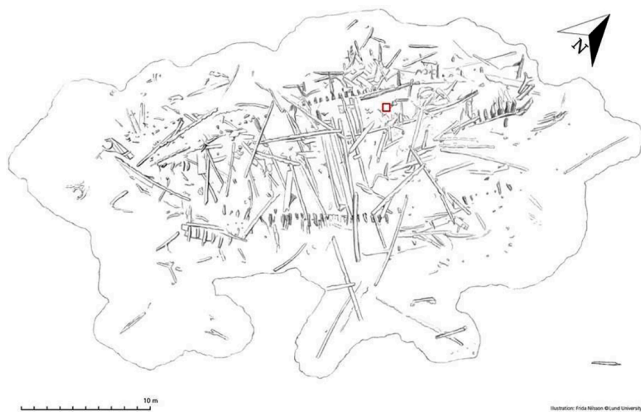


Fig. 1. *Gribshunden* shipwreck site plan. Coin purse locus marked with red square. The ship's bow is to the left and stern is to the right. Illustration: Frida Nilsson, Lund University. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

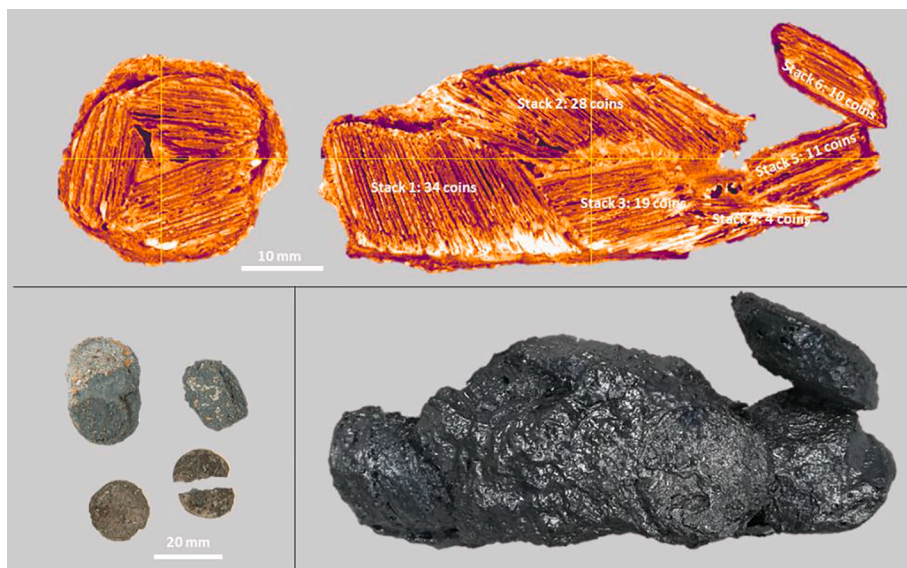


Fig. 2. The *Gribshunden* coin purse. The purse consisted of three concreted masses and concreted pairs or individual coins. The subject of the current study is the largest concretion of 103 coins, pictured on the top, and bottom right. The concretions shown bottom left will be the study of future investigations. The fragility of the coins is demonstrated by the post-recovery fracture of the single coin, bottom left. Top images represent CT profile in horizontal and vertical view of the largest coin concretion, depicting stacks within the mass. Images: top, the authors; lower left, Max Jahrehorn, Oxider; lower right, Anders Henk, Danish National Museum.

horizontal lines. The workflow of singling out obverse and reverse coin motifs revealed that a combination of horizontal and vertical images of the coin stack gave the best results, as the combined information of coin motif and place in stack helped to distinguish one coin from the next (Fig. 3). Some sections of the purse are composed of heavily corroded coins with the motifs obliterated. Coins nearest the ends of the concretions tend to be more degraded than those in the center of the columns.

The scanned images rarely resolve the complete motifs of both obverse and reverse sides of an individual coin, even in the best cases. Numismatic identification therefore depends on an interpretation of motif sections. The accuracy of coin identification depends on which part of the coin is revealed in the data, combined with numismatic knowledge to interpret characteristic details of the coins (Fig. 4). A complete catalog of each coin identified from the *Gribshunden* purse is included in Appendix A. Scan resolution is a limiting factor for identification. The initial 85.9 μm resolution allowed identification of a total of 5 out of 19 coins (26%) in a sample subset selected for methodological

testing. With data from the high-resolution batch scan of the same subset, this increased to 14 of 19 (74%). The positive results from the test cases led the authors to scan the entire concretion at high resolution, and resulted in full or partial identification of 84 of 103 coins (82%). The data were interpreted using an open source image processing software: Fiji ImageJ version 2.1.0/1.53c.

3. Results

High-resolution microscale X-ray computed tomography scanning resulted in full or partial identification of 84 of 103 coins (82%) in the largest concretion of the purse. All identified coins are of the same nominal, *hvid*. 51 coins are dated within a reign, and 58 coins are connected to a specific mint (Table 1).

The *hvid* is a currency of alloyed silver and copper that was minted in large numbers in Denmark c. 1440 – c. 1510 and dominated the coin circulation in Denmark until c. 1530 (Fig. 5). *Hvid* are small coins ~ 17

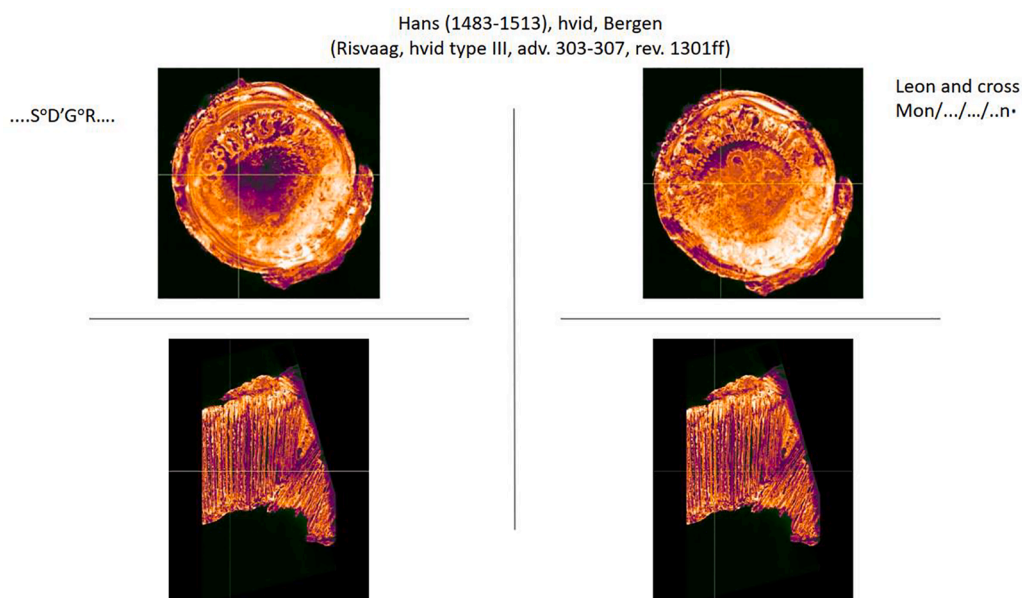


Fig. 3. Representative image of CT data. Illustration of the developed identification method. Top images represent obverse and reverse of the same coin. Bottom images showing relative position of each side of the coin in vertical view. Images: the authors.

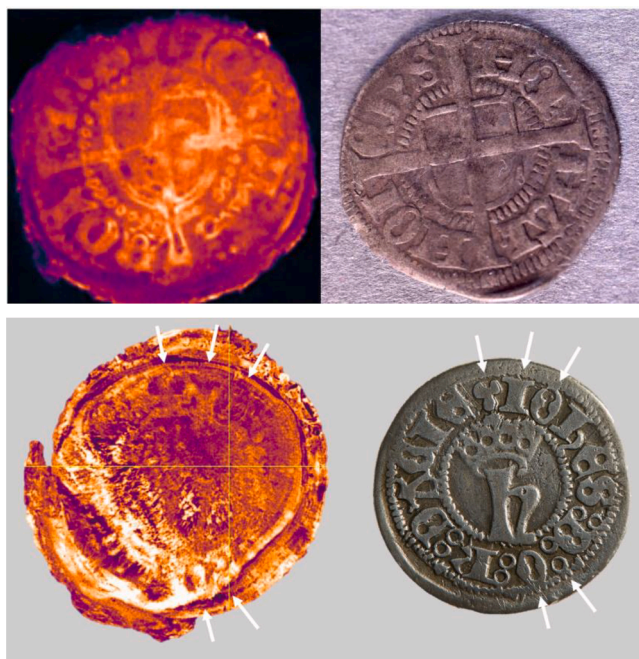


Fig. 4. Coin feature identification from CT data. Top: (L) Mostly legible reverse motif from a Hans *hvid* coin from Malmø in the purse, with (R) comparative photo of the same type of coin from study collection. Bottom: Successful identification can be achieved from scant image details, as with this Hans *hvid* minted in Malmø: (L) CT scan of coin in stack 1. The observable portion of the legend is a trefoil IO... and two small rings followed by an O. The trefoil is the Malmø mint mark. IO are the first two letters of IOHES, an abbreviation of Hans' Latin name, 'Johannes'. The two small rings followed by an 'O' confirm this identification, as these only appear in the legend of this coin type. (R) The same type of coin with the identified features marked. Images: top left and right and bottom left, the authors; bottom right, CC-BY-SA National Museum of Denmark.

mm in diameter, <1.0 mm thick, weight 0.64–1.0 g; they are nearly the same diameter but much thinner and lighter than a modern American dime or European Union one-cent coin. During the reign of Christian I, the silver content of the Danish *hvid* was reduced to as low as 20–30%. Confirmation of the silver content fluctuation in *hvid* awaits a dedicated study, but it is thought that the silver content was probably partly restored under King Hans. However, the Danish *hvid* was still despised abroad due to its low silver content and was even banned in several towns along the southern coast of the Baltic Sea (Galster, 1972; Märcher, 2018a; Poulsen 1986). The *hvid* was the lowest nominal during Hans' reign, complemented by two larger silver coins, *søsling* (=1.5 *hvid*) and *skilling* (=3 *hvid*). However, it is not clear when the *søsling* and *skilling*

were first minted; it may have been as late as 1497, in which case they could not have been carried aboard *Gribshunden* (Eriksson, 2017).

The ship's documented loss date dictates that all of the 84 identified *hvid* could be minted from the introduction of the coin in the 1440s to no later than 1495. μ CT data show that Hans was the issuing authority of 39 coins, while 15 coins predate his reign. The remaining 49 coins cannot be dated more precisely. All stacks within the large concretion include a mix of coins minted before and during the reign of Hans. The purse demonstrates that older coins circulated side by side with new coins in 1495, and from several different mints (Table 1).

Table 1
Issuing authorities and mints of coins within purse.

Authority	Dated	Stack 1	Stack 2	Stack 3	Stack 4	Stack 5	Stack 6	Total
Chritoffer III/ Christian I	1440–1481	1	2					3
Christian I	1448–1481	3		2		2	2	9
Council of State	1481–1481/83	1	1		1			3
Chritoffer III-Hans	1440–1513	5	14	8		2	1	30
Hans	1481/83–1513	16	5	5	2	5	6	39
no id		8	6	4	1			19
Total		34	28	19	4	9	9	103
Mint (city)	Present-day	Stack 1	Stack 2	Stack 3	Stack 4	Stack 5	Stack 6	Total
Malmø	Sweden	15	10	3	2	4	9	43
Malmø/Aalborg	Sweden/Denmark			3				3
Aalborg	Denmark	4		1	1	2		8
Bergen	Norway	3						3
Bergen/Oslo	Norway		1					1
Trondheim	Norway	2						2
Visby	Sweden (Gotland)					1		1
Not identified		12	17	10	1	2		42
Total		36	28	17	4	9	9	103



Fig. 5. Three examples of *hvid* from a study collection. The *hvid* motifs stayed unchanged for almost a century through issuances by various authorities. The obverse motif was a crowned 'K' for either Kristoffer or Kristian, or a crowned 'h' for Hans. *Hvid* minted by the interregnum Council of State carried a lion (not pictured). The reverse motif was a simple shield and cross dividing the legend in four sections. The legends are in Latin and state on the obverse the king's name and title, for example CHRISTOFER REX DACIA. The reverse legend reads MONETA or MON and the mint name for example MONETA MALMOIENS. Abbreviations are common. Images: CC-BY-SA National Museum of Denmark.

4. Discussion

4.1. Numismatic perspectives

The *Gribshunden* purse offers an unusual numismatic and archaeological research object. For archaeologists, coins encountered in an excavation may provide a *terminus post quem* to help date the earliest possible date for the site. For numismatists, normally one of the important tasks is to establish the time of a hoard's deposition; this is done by identifying coin types and analyzing the overall composition of the hoard. In contrast to these typical cases, the deposition of the *Gribshunden* purse is securely and accurately dated, so the composition of the purse gives precise information about coin circulation in 1495.

In the archaeological record of late medieval Denmark, the *hvid* is the most common coin found in hoards and as single finds, indicating it functioned as a vehicle for savings as well as everyday currency. During the reign of Hans' father, Christian I, the *hvid* was the only nominal and was minted Visby on Gotland and in Malmø in southern present-day Sweden (Märcher, 2018a).

From the early days of Hans' reign, repeated conflicts with Sweden forced the young king to recruit a professional army. The common soldier was probably paid in victuals, supplemented by *hvid*. Expanded military payrolls led to an increased need for currency. To meet this demand, Hans founded additional *hvid*-production mints in Denmark at his capital, Copenhagen, and his place of birth, Aalborg. Hans also produced *hvid* at the existing mint at Visby on the island of Gotland. During Hans' reign, Norway and Denmark instituted a monetary union, and Hans established mints in Bergen, Oslo, and Trondheim (Nidaros). The establishment of a Norwegian coinage was among the terms for the union between the King Hans and Norway, and mints in Bergen, Oslo and Trondheim are mentioned in Hans's *håndfæstning* (literally: "handbinding", meaning royal charter) from 1483 (Risvaag, 2006). The document states that the Norwegian coinage should copy its Danish counterparts. As with the *Gribshunden* purse, the inclusion of a few Norwegian coins is common in hoards deposited in the 1490s, while Visby coins occur more rarely (Jensen et al., 1992) (Table 1). To pay the foreign mercenaries augmenting Danish ranks, denominations larger than *hvid* were necessary. Beginning perhaps in 1496, Hans minted the first Danish gold coins (*nobel*). Written documents testify to the production of 150,000 gold coins (*gylden*) financing the participation of German mercenaries in a conflict with Sweden in 1497, with their monthly salary rising quickly from 2 to 5 *gylden* by 1501; but Hans' gold coins have not yet appeared in any archaeological context (Kreem, 2001; Märcher, 2018a). It is possible future excavations on *Gribshunden* could deliver examples of new coin types minted by Hans; the purse of silver

coins already has adjusted the accepted date of production in new Danish mints.

The *Gribshunden* purse provides new information about the start of production at the mints established by Hans in Copenhagen, Aalborg, and Trondheim. The Copenhagen moneyer Herman van Nassau is mentioned in a document from 1495, but no coins from that city are identified in the recovered purse; perhaps coin production started somewhat later at that mint. Conversely, the Aalborg moneyer Hans Mitzener is first documented in 1497 (Märcher, 2018a). Numismatic practice has been to date hoards with Aalborg coins no earlier than 1498. However, the *Gribshunden* purse demonstrates that coins were minted in Aalborg before the historic documentation of that mint. Similarly, the start of coin production at Trondheim can be shifted earlier than previously known. Dendrochronology of wood from the earliest archaeological excavation stratum of the Trondheim mint suggests a founding date around 1500, but the coins from the wreck representing that mint demonstrate coin production at least as early as 1495 (Lohne et al., 2010; Nordeide et al., 2000).

There are no extant records of the minting numbers during the reign of Hans, but the quantity of variants within the different coin types indicates the ratio among the different mints. The high proportion of Malmø *hvid* in the *Gribshunden* purse and in other contemporary hoards demonstrates that Malmø was the most productive Danish mint. It produced 74 variants of *skilling* and 44 variants of *hvid*. In comparison, the Aalborg mint produced four variants of *skilling* and 17 variants of *hvid*, while the Copenhagen mint stamped only seven variants of *skilling* and five variants of *hvid* (Märcher, 2018a). The modest production of *hvid* in Copenhagen is underlined by the absence in the *Gribshunden* purse of *hvid* minted there. The lack of the higher-denomination *skilling* and *søsling* may indicate that these nominals were not minted before June 1495, but the sample size of this one securely dated hoard is too small to draw definitive conclusions.

4.2. The owner and purpose of the purse

Several factors influence the Composition of historic coin hoards. Key internal considerations include the status of the owner, the purpose of collecting, and the reason for deposition. External concerns include the number of coins in circulation, the variety of available coins, and microeconomic motivations for saving. Hoards deposited in societies with bullion economies may contain a wide range of precious metal objects, while hoards in fully monetised societies may consist only of coins. Hoards representing family savings contain specially selected objects saved during a long period of time, while a purse lost on the way to the market displays the active coin stock at the time of loss (Burström,

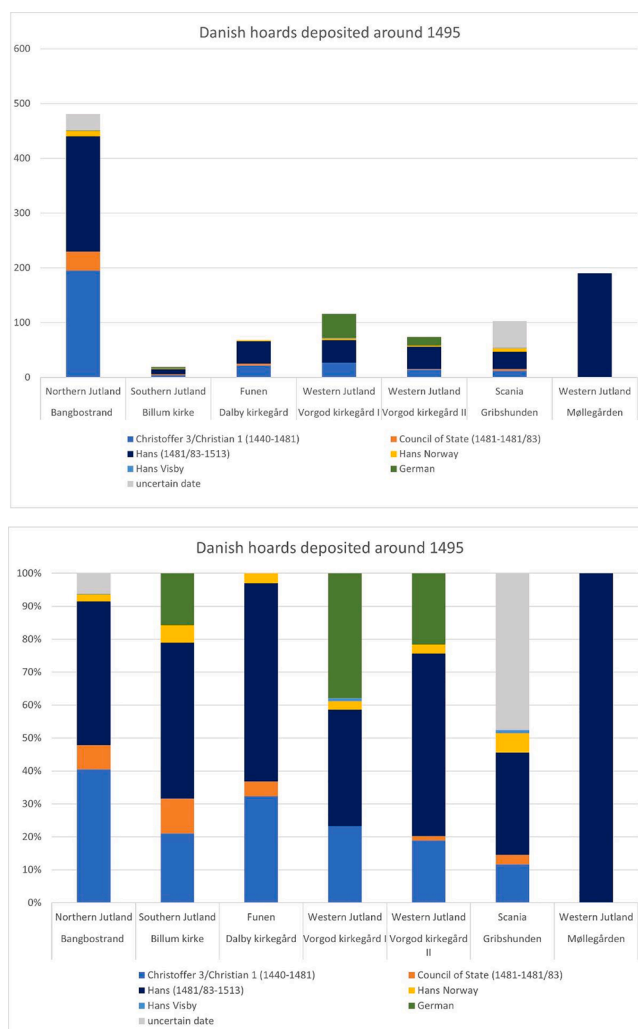


Fig. 6. Contemporary Danish hoards. The composition of known Danish hoards deposited in the 1490s, with total numbers of coins in each hoard and identification. Graphs: the authors. Data for other hoards from Jensen et al 1992.

2018; Ingvarsson, 2018).

In some respects the *Gribshunden* purse resembles other contemporary Danish hoards. Six other Danish hoards probably deposited in 1490s are known (Fig. 6). In five of these hoards the Danish coins consist of exclusively *hvid*. Hans' coins predominate, but coins from previous issuing authorities are present. The monetary union between Denmark and Norway is reflected as a small influx of Norwegian coins in all *hvid*-dominated hoards. The sixth hoard, discovered at Møllegården, is an outlier because it consists exclusively of Hans' *skilling* (Märcher, 2018b). Møllegården's divergent composition may indicate that the hoard was deposited late in the 1490s, and that *skilling* also was issued late in the 1490s. However, functional difference cannot be ruled out.

The *Gribshunden* purse differs from several of the contemporary Danish hoards because of the absence of foreign coins; Brangbostrand (1 Rostock *sechsling*), Billum Kirke (3 *bracteats*) Vorgod Kirkegård I (44 *bracteats*) and Vorgod Kirkegård II (1 *witten* and 15 *bracteats*). This may be because foreign coins were not acceptable in a royal Danish context, or because the *Gribshunden* hoard represents a purse with active currency, while other hoards represent savings. However, we must also

consider methodological limitations. With two exceptions all foreign coins in the other comparable hoards are German *bracteats*, which is a coin type minted on paper-thin silver foil. It is possible that these coins would not survive in the shipwreck's depositional environment, and therefore could not be detected. If they did survive in some degraded condition, it is unknown if they would be identifiable through the μ CT scanning method. Despite these reservations the overall interpretation must be that the *Gribshunden* purse was not composed of specially selected coins. Instead, the coins probably represent a purse of everyday money drawn from the available coin stock.

The *Gribshunden* purse diverges from all other coin hoards because of its historical context: aboard ship with the king, with his royal entourage in close proximity, and lost in a catastrophic event. It is unlikely that the monarch would directly handle money himself; he had people for that. An assemblage consisting of 150+ low denomination coins is unlikely to represent the total mission coffer; future excavations on the wreck site may deliver additional finds of coins. Surviving written documents and the archaeological record testify that the ship was loaded with items and persons carefully selected to signify power and prestige. One would

expect the mission coffer to contain larger nominals with Hans as the issuing authority, demonstrating the king's hegemony over the available coin stock. Instead, the purse contains old and new coins of the least valuable (but possibly only) type of Danish coin.

The archaeological context provides insight into the owner of the purse. It was found among personal items of a martial nature including the handle of a dagger and high-quality mail armor made in Bavaria. Hans increased *hvid* production partly to meet the demand for salary payments to mercenaries, many of whom came from the German states. However, a purse of more than 150 *hvid* is unlikely to be in the possession of a common soldier. It is nearly impossible to ascertain the actual purchasing power represented by this purse; the exchange rates among the coins minted in various regions, and the value of precious metals and commodities used as money in the medieval period have been described “positively mind-boggling” (Naismith, 2018b). There exist very few records of prices from late 15th century Scandinavia, but the monthly salary of a skilled worker is estimated to have been perhaps 50–60 *hvid* (Lagerqvist, 2011). The *Gribshunden* purse could represent some months of wages for a mid-level mercenary.

A more likely possibility is that the purse belonged to one of the ship's senior officers. A document in the Danish royal archives records the names and monthly wages of 32 men assigned to *Gribshunden* for a 1487 mission to Gotland. Three men, presumably the senior officers, received four *mark danske*; the others received three marks or less (Etting et al., 2019; Wegen et al., 1864). One mark equalled 48 *hvid* (Edvinsson, 2009), so the ~150 *hvid* in the total concreted coin assemblage matches a wage payment for one of these officers. During the 2019 archaeological excavation, the concreted coins' recovery locus was within one meter of another noteworthy find: a rare milled wooden tankard colored with the red pigment of the king's household, and bearing a possible royal crest. The most recent excavation on the wreck, conducted in May–June 2021, provided more archaeological context. The find spot of the dagger handle, armor elements, tankard, and coins is directly adjacent to concentration of imported spices, containing expensive imported extravagances such as saffron, safflower, cloves, ginger, and peppercorns. Presumably, these exotic prestige goods would have been closely guarded aboard ship, with their care detailed to a reliable authority. Numismatic analysis combined with the archaeological context indicates that the *Gribshunden* purse was among the personal belongings of a high-ranking person close to and trusted by the king, perhaps a senior foreign mercenary or one of the ranking Danish military officers.

5. Conclusion

The discovery of a purse of travel money in the possession of a high-ranking military officer in the Danish royal entourage delivers a bounty of new knowledge. The purse contains many coins minted during the reigns of Hans' predecessors. The coins were in the closest proximity to the king, directly demonstrating that older coins constituted accepted currency and commonly remained in circulation. Further, because the purse contained travel money, it is direct evidence of coin circulation at the time of deposition, in opposition to previous known hoards potentially representing savings. The presence of older *hvids* indicates that maintaining a sufficient supply of coins in circulation was among Hans' political and economic considerations. A critical lack of coin stock in the realm is reflected by the fact that one of the terms in the Danish-Norwegian *Håndfæstning* from 1483 was the establishment of a Norwegian coinage (Risvaag, 2006). From the earliest days of Hans' ascent to the throne, a goal of his monetary policy was to provide an ample

supply of circulating coins. The king achieved this by allowing circulation of the older *hvids*, and also by increasing *hvid* production. This need was driven in part to meet the demand for salary payments to his mercenaries.

The production of the *hvid* began around 1440 during the reign of Christoffer III and continued for more than a century through four kings and an interregnum. The motifs of successive *hvid* issuances were nearly identical, illustrating that there was no political will to distinguish newly minted coins from their predecessors (refer Fig. 3). The multiple mints represented in the *Gribshunden* purse demonstrate the expansion of *hvid* production even earlier in Hans' reign than previously known. The lack of high-denomination coins in this purse may reflect a small sample size, or it may be an indication that production of *skilling* and *søsling* commenced only after June 1495. Renewal and debasement of coins was an economic instrument often used throughout medieval Europe in times of war or unrest to secure a sufficient supply of coins, often to finance military expenditures. Replacing high silver content coins with debased substitutes would increase the amount of money in circulation without requiring fresh inputs of silver (Deng 2011; Naismith, 2018a; Spufford, 1988). In contrast, the *Gribshunden* purse reveals that older coins were common and fully accepted for general circulation even in the highest echelons of Danish society. The motif similarities among coins minted by Hans and his predecessors demonstrates a deliberate continuity in Danish coinage policy - the need to maintain in circulation an ample coin supply without disruption outweighed the potential benefits of re-minting debased coinage.

CRedit authorship contribution statement

Gitte T. Ingvarsson: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Dirk Müter:** Methodology, Writing – original draft. **Brendan P. Foley:** Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing, Project administration, Funding acquisition.

Declaration of Competing Interest

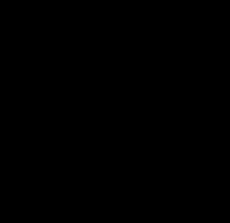
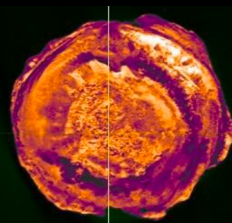
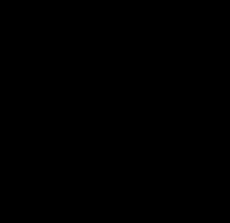
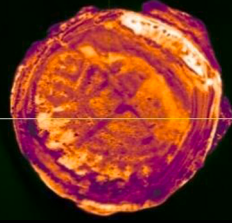
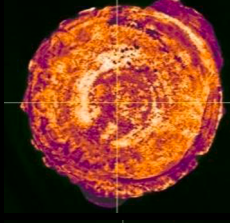
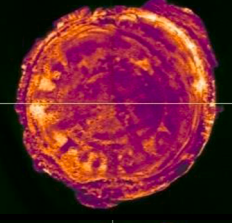
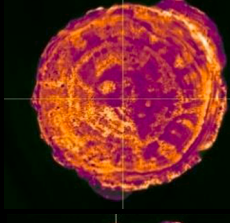
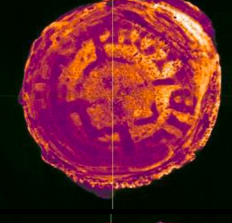
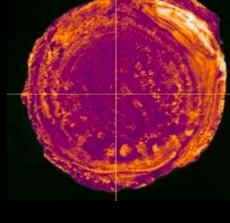
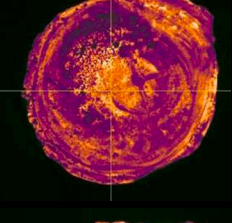
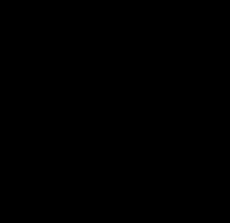
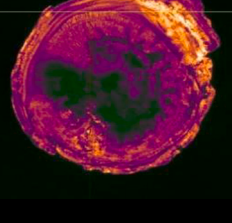
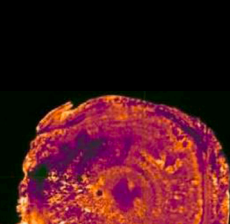

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Catalog of microscale Computed Tomography (μ CT) data slices of *Gribshunden* coin purse with identified motif characteristics.

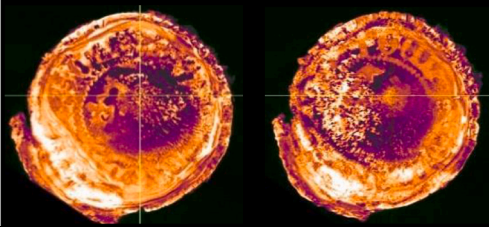
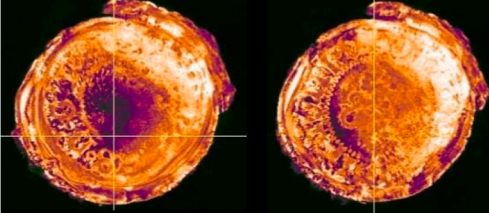
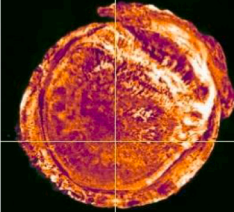
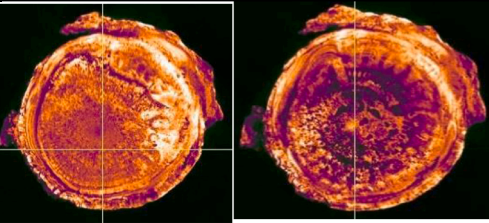
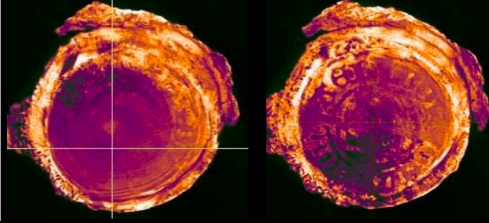
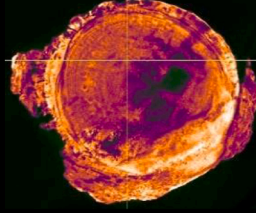
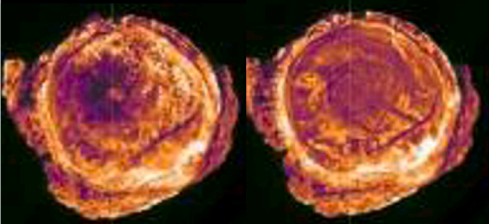
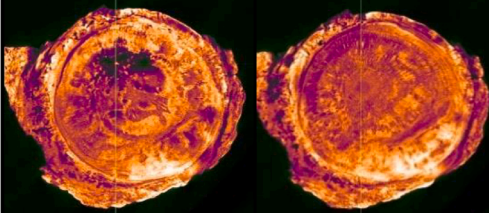
Stack.no	Authority	Type	Mint	Id markers	Adverse	Reverse
1.1	Christoffer 3-Hans	hvid	Malmø	Adv:		
	1440-1513			Rev: part of shield and cross [.../.../M or mol/...]		
1.2	Christoffer 3-Hans	hvid	Malmø?	Adv:		
	1440-1513			Rev: part of shield and cross [Mon/M(?)A./.../...]		
1.3	Hans	hvid	Aalborg	Adv: (crowned) h		
	1481-1513			Rev: part of shield and cross [.../.../.../BOR/...]		
1.4	Christian I	hvid	Malmø	Adv: crowned K [...R...D'..]		
	1448-1481			Rev: shield and cross [.../mA./mOI/en.]		
1.5	Hans	hvid	Malmø	Adv: (crowned) h [...SDOR...]		
	1481-1513			Rev: shield and cross [.../.../M(?)OI/...]		
1.6	Hans	hvid	Trondheim	Adv:		
	1481-1513			Rev: o (sidemark) [... /.../.../OR /WDI]		
1.7	no id			Adv: Rev:		
1.8	no id			Adv: Rev:		
1.9	Hans	hvid		Adv: (crowned)h [...O....OR.]		
	1481-1513			Rev: shield and cross		

(continued on next page)

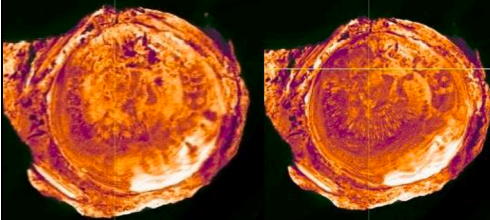
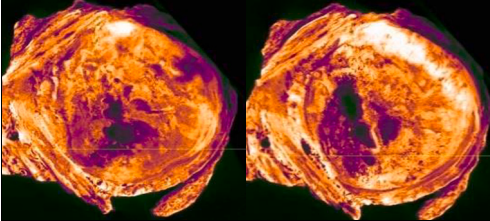
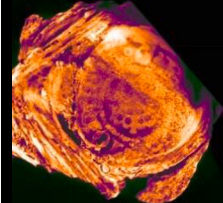
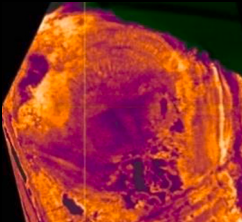
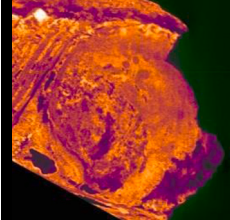
(continued)

1.10	Christoffer 3-Hans	hvid		Adv: crown(ed letter)	
	1440-1513			Rev: shield	
1.11	Hans	hvid	Bergen	Adv: crowned n [...OR....]	
	1481-1513			Rev: part of cross [Mon/.../.../...]	
1.12	Council of State	hvid	Malmø	Adv: lion's tail [...nloD...]	
	1481-1483			Rev: part of shield and cross [.on/MA./Mo./...]	
1.13	Christian I	hvid	Malmø	Adv: crowned K [...STI...]	
	1448-1481			Rev: shield and cross [Mon/.../MØI/ens]	
1.14	Hans	hvid		Adv: crowned h	
	1481-1513			Rev: shield and cross	
1.15	Christian I	hvid	Malmø	Adv: crowned K [...STI...]	
	1448-1481			Rev: shield and cross [.../.../MØI/...]	
1.16	Hans	hvid	Trondheim	Adv: n	
	1481-1513			Rev: part of cross [.../.../OR(?)WDI]	
1.17	Christoffer 3-Hans	hvid	Malmø	Adv:	
	1440-1513			Rev: shield and cross [.On/MA./.../...]	

(continued)

1.18	Hans	hvid	Bergen	Adv: crown(ed h) [trefoil .On...]	
	1481-1513			Rev: part of lion [.../.../.../Gen]	
1.19	Hans	hvid	Bergen	Adv: [...SoD'GoR...]	
	1481-1513			Rev: lion and cross [Mon/.../.../...n dot]	
1.20	Hans	hvid	Malmø	Adv: [trefoil IOI.....]	
	1481-1513			Rev: cross	
1.21	Hans	hvid	Malmø	Adv: [... two small rings O...]	
	1481-1513			Rev: shield and cross [.../.../MOI/en.]	
1.22	Hans	hvid	Aalborg	Adv: [... two small rings G two small rings...]	
	1481-1513			Rev: shield and cross [Mon/AeL/BOR/Gen]	
1.23	Christoffer 3- Hans	hvid		Adv:	
	1440-1513			Rev: shield and cross	
1.24	Hans	hvid	Aalborg	Adv: crowned h [flower a....]	
	1481-1513			Rev: shield and cross [on/Ae./.../...]	
1.25	Hans	hvid	Malmø	Adv: crowned h [trefoil IO]	
	1481-1513			Rev: shield and cross	

(continued)

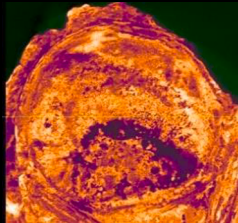
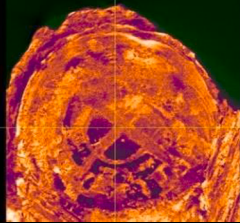
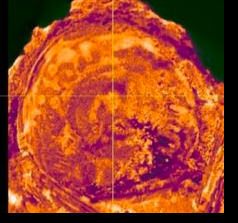
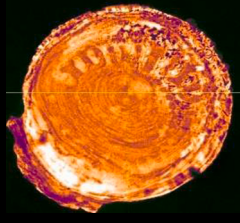
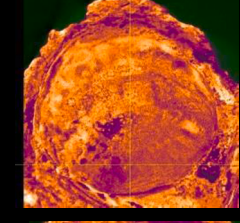
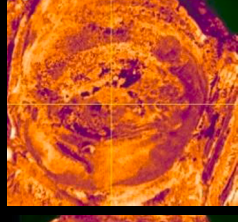
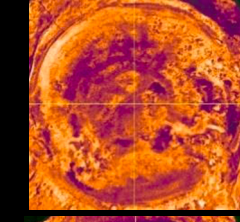
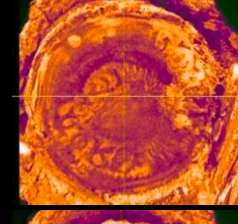
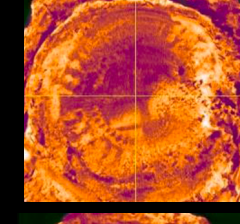
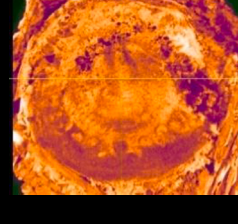
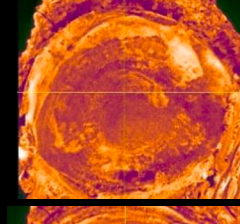
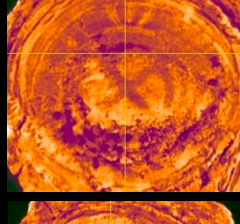
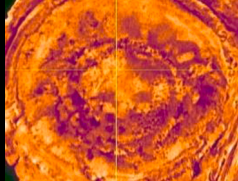
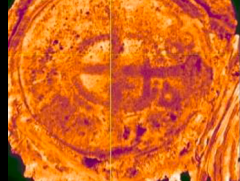
1.26	Hans	hvid	Malmø	Adv: crowned h [...a s D...]		
	1481-1513			Rev: shield and cross [.../.../MOI/.nS]		
1.27	no id			Adv: Rev:		
1.28	no id			Adv: Rev:		
1.29	Christoffer 3/ Christian I	hvid	Malmø?	Adv: crowned K		
	1440-1481			Rev: part of shield and cross		
1.30	Hans	hvid	Aalborg	Adv: crown(ed h) [loh.....ring G.]		
	1481-1513			Rev: part of shield and cross [.../.../.O./Ga.]		
1.31	no id			Adv: Rev:		
1.32	no id			Adv: Rev:		
1.33	no id			Adv: Rev:		
1.34	no id			Adv: Rev:		
2.1	no id			Adv: Rev:		
2.2	Christoffer 3- Hans	hvid?		Adv:		
	1440-1513			Rev: part of shield and cross		
2.3	no id			Adv: Rev:		
2.4	no id			Adv: Rev:		
2.5	no id			Adv: Rev:		
2.6	Christoffer 3- Hans	hvid?		Adv: part of crown?		
	1440-1513			Rev:		

(continued on next page)

(continued)

2.7	Christoffer 3-Hans	hvid		Adv:	
	1440-1513			Rev: part of shield and cross	
2.8	Christoffer 3-Hans	hvid		Adv:	
	1440-1513			Rev: part of shield and cross	
2.9	Christoffer 3-Hans	hvid		Adv:	
	1440-1513			Rev: part of shield and cross	
2.10	Hans	hvid	Bergen/ Oslo	Adv: crown(ed h)	
	1481-1513			Rev: lion's tail	
2.11	Christoffer 3-Hans	hvid		Adv:	
	1440-1513			Rev: part of shield and cross	
2.12	Christoffer 3-Hans	hvid		Adv:	
	1440-1513			Rev: part of shield and cross	
2.13	Christoffer 3-Hans	hvid	Malmø	Adv:	
	1440-1513			Rev: part of shield and cross [.O./.../.../..S]	
2.14	Christoffer 3-Hans	hvid	Malmø	Adv:	
	1440-1513			Rev: part of shield and cross [.../.../MO./...]	

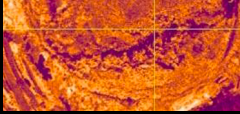
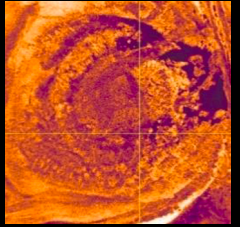
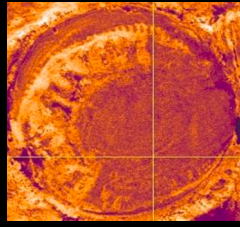
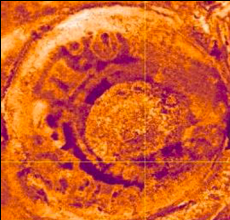
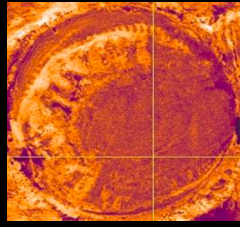
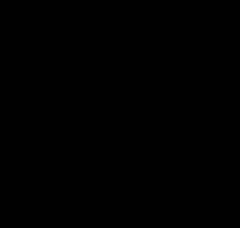
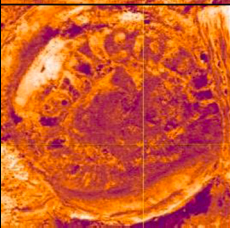
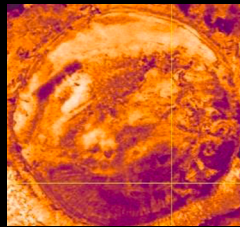
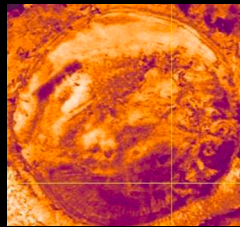
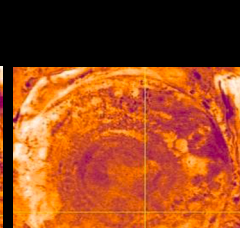
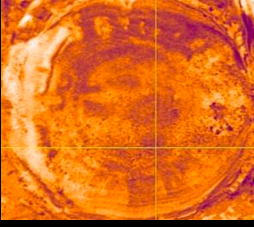
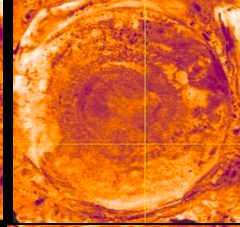
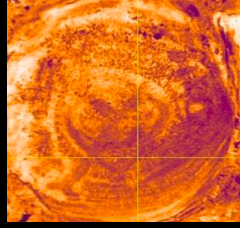
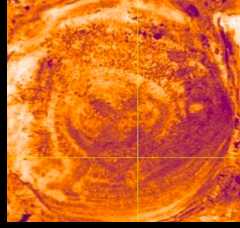
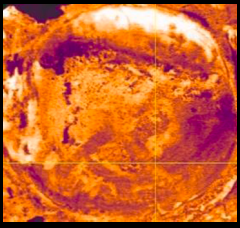
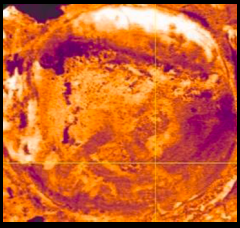
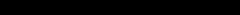
(continued)

2.15	Christoffer 3-Hans	hvid	Malmø	Adv: Crown [trefoil.....S]		
	1440-1513			Rev: part of shield and cross [.../.../..O!/...]		
2.16	Hans	hvid	Malmø	Adv: [...aSD...Q..]		
	1481-1513			Rev: shield and cross [.../.../..!/...]		
2.17	Christoffer 3-Hans	hvid		Adv:		
	1440-1513			Rev: part of shield and cross		
2.18	Hans	hvid		Adv: crowned h or n		
	1481-1513			Rev: part of shield and cross		
2.19	Council of State	hvid	Malmø	Adv: lion's leg and tail [...AoR..]		
	1481-1483			Rev: part of shield and cross [.../MA./..Ø./...]		
2.20	Hans	hvid	Malmø	Adv: crowned h [trefoil]		
	1481-1513			Rev: part of cross [.../MA./.../...]		
2.21	Christoffer 3-Hans	hvid		Adv:		
	1440-1513			Rev: part of shield and cross		
2.22	Christoffer 3-Hans	hvid	Malmø	Adv: crown(ed letter) [...D...]		
	1440-1513			Rev: shield and cross [Mon/M./.../..nS]		

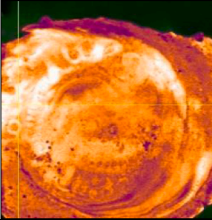
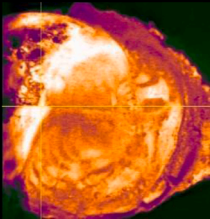
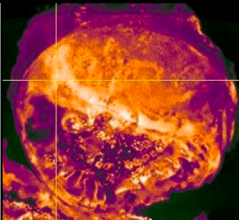
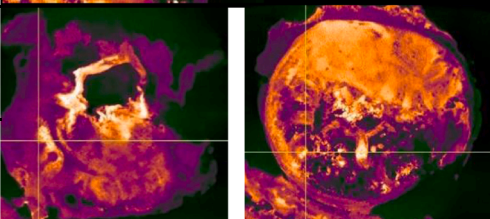
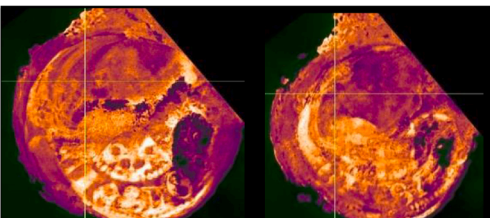
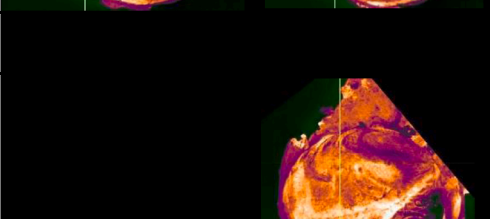
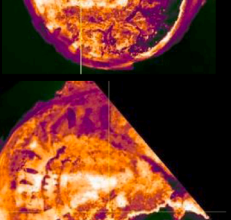
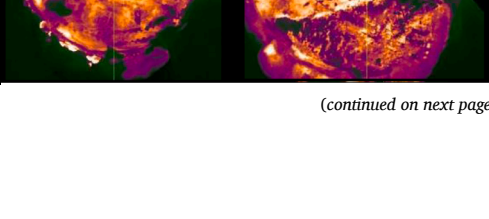
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2.23	Hans	hvid	Malmø	Adv: [trefoil IO...]	
	1481-1513			Rev: shield and cross	
2.24	Christoffer 3/ Christian I	hvid	Malmø	Adv: (crowned) K	
	1440-1481			Rev: part of shield and cross	
2.25	Christoffer 3/ Christian I	hvid	Malmø	Adv:	
	1440-1481			Rev: shield and cross [.../m./.../...]	
2.26	Christoffer 3-Hans	hvid		Adv:	
	1440-1513			Rev: part of shield and cross [MOn/.../.../...]	
2.27	no id			Adv: Rev:	
2.28	no id			Adv: Rev:	
3.1	Christoffer 3-Hans	hvid		Adv: central h or K	
	1440-1513			Rev: shield and cross	
3.2	Christoffer 3-Hans	hvid		Adv:	
	1440-1513			Rev: shield and cross [H(?).../.../...nS]	
3.3	Christian I	hvid	Malmø	Adv: [..RI. ...RD..]	
	1448-1481			Rev: part of cross [..on/m./.../...]	
3.4	Christoffer 3- Hans	hvid	Malmø	Adv:	

(continued)

	1440-1513			Rev: [.../.../MOI/...]		
3.5	Christoffer 3-Hans	hvid ?		Adv:		
	1440-1513			Rev: part of shield and cross		
3.6	Hans	hvid	Malmø/ Aalborg	Adv: [...O two small rings R...]		
	1481-1513			Rev: part of shield and cross		
3.7	Christian I	hvid	Malmø	Adv: (crowned) K [+ ...STIe...]		
	1448-1481			Rev: shield and cross [mO./.../.../en.]		
3.8	Hans	hvid	Malmø/ Aalborg	Adv:		
	1481-1513			Rev: [...two rings BA...]		
3.9	no id			Adv: Rev:		
3.10	Hans	hvid	Malmø	Adv: part of (crowned) h [trefoil]		
	1481-1513			Rev: part of shield and cross		
3.11	Christoffer 3-Hans	hvid	Malmø	Adv:		
	1440-1513			Rev: part of shield and cross [.../M./.../...]		
3.12	Christoffer 3-Hans	hvid		Adv:		
	1440-1513			Rev: part of shield and cross		
3.13	no id			Adv: Rev:		

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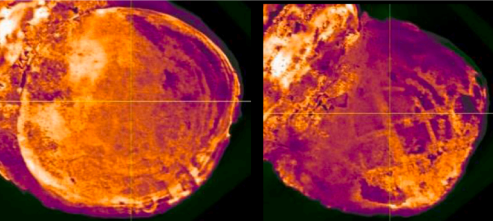
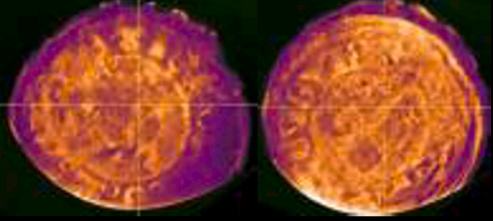
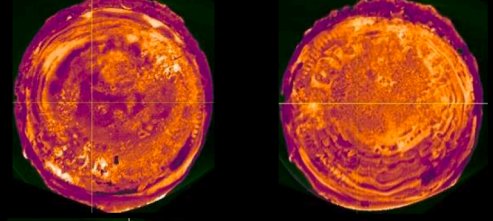
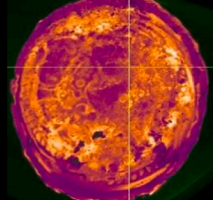
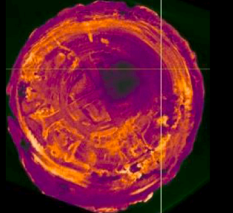
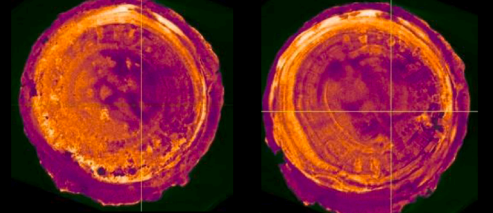
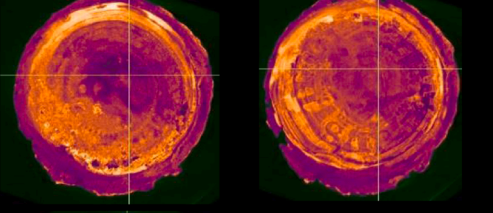
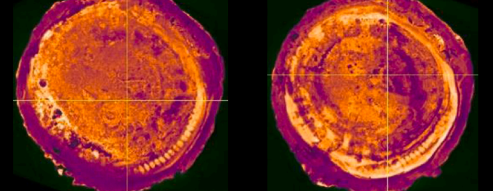
3.14	no id			Adv: Rev:	
3.15	no id			Adv: [...IO...] Rev:	
3.16	Hans	hvid	Malmø/ Aalborg	Adv: [... two small rings R] Rev:	
	1481-1513				
3.17	Christoffer 3- Hans	hvid		Adv: Rev: part of cross [.IO...]	
	1440-1513				
3.18	Hans	hvid	Aalborg	Adv: (crowned) h Rev: [.../Aa./.../...]	
	1481-1513				
3.19	Christoffer 3- Hans	hvid		Adv: [...O...] Rev: shield and cross	
	1440-1513				
4.1	Hans	hvid	Malmø	Adv: crown [trefoil IO....le] Rev: part of shield [MO./.../.../ns]	
	1481-1513				
4.2	no id			Adv: [...On...] Rev: [...Sl...]	
4.3	Hans ?	hvid?	Aalborg?	Adv: Rev: crossarm [.../.../ga./...]	
	1481-1513				
4.4	Council of State	hvid	Malmø	Adv: lion's head [DAel...] Rev: part of shield and cross [.../MAL/M.../...]	

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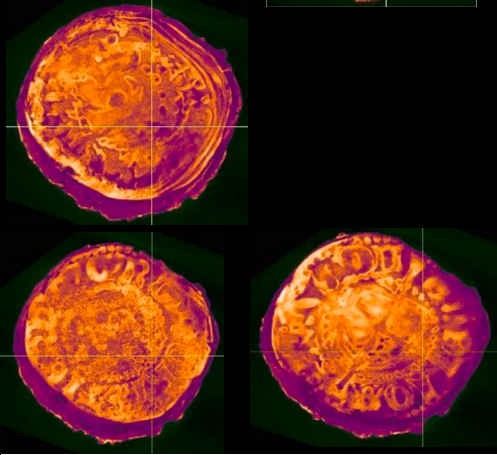
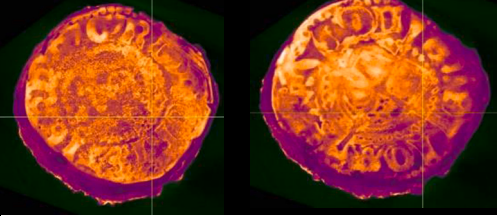
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5.1	Christian I	hvid	Malmø	Adv: crowned K [trefoil CRIS ..R'D']	
	1448-1481			Rev: [.../.../mA/...]	
5.2	Hans	hvid	Aalborg?	Adv: crowned h	
	1481-1513			Rev: [.../.../n/HO]	
5.3	Hans	hvid	Malmø	Adv: [trefoil IOha....]	
	1481-1513			Rev: [.on/.AL/.../...]	
5.4	Christoffer 3- Hans	hvid		Adv: crown(ed letter)	
	1440-1513			Rev: [.../.../.../ens]	
5.5	Hans ?	hvid ?	Visby	Adv: lily bush	
	1481-1513			Rev:	
5.6	Hans	hvid	Aalborg	Adv:	
	1481-1513			Rev: shield and cross [Mon/.../.../aR]	
5.7	Christian I	hvid	Malmø	Adv: crowned K [...laR ..]	
	1448-1481			Rev: shield and cross	
5.8	Christoffer 3- Hans	hvid		Adv:	
	1440-1513			Rev: shield and cross [Mon/.../.../...]	

(continued)

5.9	Hans	hvid	Malmø	Adv: [..two small circles l...]	
	1481-1513			Rev: shield and cross	
6.1	Hans	hvid	Malmø	Adv: crowned h [trefoil]	
	1481-1513			Rev: shield [Mon/.../ØI/ens]	
6.2	Hans	hvid	Malmø	Adv: crowned h [IO...]	
	1481-1513			Rev: [Mon/MA./.../...]	
6.3	Hans	hvid	Malmø	Adv: crown(ed h) [loh...]	
	1481-1513			Rev: part of shield [.../.../.../ns]	
6.4	Christoffer 3- Hans	hvid	Malmø	Adv:	
	1440-1513			Rev: part of shield [.../...L/M./...]	
6.5	Hans	hvid	Malmø	Adv: (crowned) h [IO....]	
	1481-1513			Rev: shield and cross [MO./MAL/MOI/ens]	
6.6	Hans	hvid	Malmø	Adv: crowned h [..two small rings...]	
	1481-1513			Rev: cross [M./.../OI/ens.]	
6.7	Hans	hvid	Malmø	Adv: crown(ed h) [trefoil]	
	1481-1513			Rev: cross [M./...L/M./ens]	

(continued)

6.8	Christian I	hvid	Malmø	Adv: crowned K [...RnR..]	
	1448-1481			Rev: shield and cross [M./.../.../ns]	
6.9	Christian I	hvid	Malmø	Adv: (crowned) K [.RI.TlaRn.G'RD]	
	1448-1481			Rev: shield and cross [mon/mA./mOl/en.]	

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