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herausgegeben von
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Frühmittelalterliches Hacksilber im nördlichen westslawischen Raum

Archäologie und Archäometallurgie

Beiträge der internationalen Konferenz im Kulturhistorischen Museum Görlitz, 18./19. Oktober 2019

Ergebnisse des Projektes „Hacksilberschätze im Oder-Neiße-Raum“ 1

herausgegeben von
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VORWORT DER HERAUSGEBER

Die vielen Silberschätze des 9. bis 11./12. Jahrhunderts im nördlichen westslawischen Raum, die sich aus Münzen und deren Fragmenten sowie aus meist zerhackten Schmuck- und Trachtstücken zusammensetzen, beschäftigen die Forschung seit ihren Anfängen im 19. Jahrhundert. Diese Funde ragen mit ihrem wertvollen und oft prächtigen Inhalt aus den sonst meist eher unscheinbaren archäologischen Relikten jener Epoche hervor. Von Anfang an warfen sie kulturgeschichtliche Fragen nach den Gründen für ihre Niederlegung, nach dem sozialen Status ihrer ehemaligen Besitzer und nach der Herkunft des erlesenen Zierrats auf, der – anscheinend ohne Rücksicht auf seine vorzügliche Qualität und Handwerkskunst – zerteilt und vergraben worden war. Die Diskussion über diesen Problemkreis ist kontrovers und bis heute nicht abgeschlossen. Neue Impulse erhalten die Forschung und die akademische Debatte in jüngerer Zeit durch immer aussagekräftigere naturwissenschaftliche Untersuchungsergebnisse, die insbesondere durch die Analyse der Bleiisotopenverhältnisse Rückschlüsse zur Herkunft des für die Herstellung von Münzen, Schmuck und Trachtbestandteilen verwendeten Edelmetalls zulassen.

Insofern freuen wir uns als Herausgeber der „Studien zur Archäologie Europas“, dass in diesem Band die Beiträge der Tagung „Hacksilberschätze im frühmittelalterlichen nordwestslawischen Raum – Archäologie und Isotopenanalyse“ vorgelegt werden können, die am 18. und 19. Oktober 2019 in Görlitz stattgefunden hat. Sie wurde im Rahmen des von der VolkswagenStiftung (Hannover) geförderten Projektes „Hacksilberschätze im Oder-Neiße-Raum – archäologisch-analytische Untersuchungen zur Herkunft des Silbers im frühmittelalterlichen Ostmitteleuropa“ realisiert, das sich dem Hacksilber aus Horten insbesondere des ostdeutschen und westpolnischen Gebietes widmete. Dabei kamen archäologische und archäometallurgische Methoden zum Einsatz. Die Konferenz in Görlitz präsentierte die bei diesem Vorhaben erzielten Ergebnisse, aber auch Fallbeispiele aus vielen weiteren Teilen der großen mittel-, ost- und nordeuropäischen Hacksilberzone sowie übergreifende Untersuchungen mit unterschiedlichen methodischen Ansätzen. Die hier veröffentlichten Aufsätze werfen daher vielfältige Schlaglichter auf das Phänomen des frühgeschichtlichen Hacksilbers und seiner Niederlegung in Horten. Sie bringen die Forschung gewiss in bedeutender Weise voran. Die Vorlage der abschließenden Ergebnisse des Forschungsprojektes ist für einen der kommenden Bände unserer Reihe vorgesehen.

Wir danken Susanne Kubenz M. A. (Halle [Saale]) für Satz und Layout sowie Andreas Kieseler M. A. (Kiel und Breslau [Wrocław]), dem die Mühe der Redaktion hauptsächlich oblag. Wie stets ist die professionelle Betreuung der Drucklegung durch Dr. Susanne Biegert vom Verlag Dr. Rudolf Habelt (Bonn) dankend hervorzuheben. Die VolkswagenStiftung hat mit ihrer großzügigen Förderung die ansprechende Form dieser Veröffentlichung ermöglicht.

Frankfurt am Main, Halle (Saale), Szczecin und Brno, im Oktober 2022

Joachim Henning
Felix Biermann
Jiří Macháček

WISSENSCHAFTLICHER BEIRAT

Inhalt

Sources of Silver in the late Ninth-Century Bullion Hoard from Saint-Pierre-des-Fleurs, Normandy: Results of Lead Isotope and Trace Element Analysis

Jane Kershaw, Stephen Merkel, Guillaume Sarah and Jani Oravisjärvi

Introduction

In 2007, a small silver bullion hoard was discovered in Saint-Pierre-des-Fleurs, around 5 km south-west of Elbeuf in Normandy, France (map 1). The hoard contained two Carolingian deniers, nine Anglo-Scandinavian imitation issues from the Danelaw area of eastern and northern England, one Islamic dirham and nine ingot fragments (table 1; fig. 1)[1]. Despite its deposition in Normandy, the composition of the hoard, together with the test marks (folds, nicks and pecks) applied to both the coins and ingots, suggests that it was drawn mainly from circulating currency in the Scandinavian-ruled Danelaw area of England: a region which operated a dual-currency economy based on both coin and bullion exchange[2]. A terminus post quem for the deposition of the hoard is provided by the latest coin, an Anglo-Scandinavian imitation coin in the name of Beagstan, minted c. 895 (fig. 1, no. 6)[3]. With the possible exception of the two Carolingian deniers, which may have been added to the assemblage following its arrival in Normandy, this small parcel of wealth, weighing around 100 g, most likely travelled from England to northern France in Viking hands. It probably relates to late ninth or early tenth-century Scandinavian trading settlements in the Basse-Seine, indicated by the cluster of toponyms of Scandinavian origin (map 1), prior to the official cessation of Normandy to the Viking leader Rollo, in 911[4].

Archaeometric analysis of the hoard thus presents an opportunity to characterise an array of different coin types, including a previously unrecorded Carolingian GRATIA DEI REX denier in the name of Eudes (888–898), minted in Beauvais (fig. 1.2), and the dirham: a Saffarid issue of Panjhir, Afghanistan, minted c. 874/5 (fig. 1.12). More interestingly from the perspective of Scandinavian wealth resources, it can also shed light on the sources of silver in the late ninth-century Danelaw. Of particular interest are the Anglo-Scandinavian coins and the ingots. The coins, all imitations of the 'Two-Line' type issued by Alfred, King of Wessex, were among the first to be issued by Danelaw rulers and mark the early stages of an extensive and well-managed Anglo-Scandinavian currency. Performing archaeometric analyses can help to reveal whether the Anglo-Scandinavian coins were made from the Anglo-Saxon coins they imitated, or instead utilised an unrelated silver source, perhaps one accumulated from the decades of military activity that preceded Scandinavian settlement and minting. The ingots, meanwhile, reflect a system of bullion exchange rooted in Scandinavian economic practices, to be cut, tested and weighed out using scales and regulated weights. Is the silver in these ingots the same as in the coinage, in which case we would have evidence that the same resources were simultaneously fuelling bullion and coin, or are they different, reflecting silver won locally or imported from Scandinavia? The concurrent use of bullion alongside a substantial coin issue testifies to the substantial silver resources of Danelaw rulers. Here we attempt to identify the origin of this wealth for the first time.

We captured both trace element and lead isotope data via high precision mass spectrometry for all hoard items, with the exception of one Anglo-Scandinavian coin[5] held in a British private collection. We then compared the analytical data against an extensive geochemical database built as part of the ERC project, *Silver and the Origins of the Viking Age* (PI: Kershaw). The interpretation of the data requires an acute awareness of the potential for the mixing or recycling of two or more silver sources and/or silver refining (cupellation), discussed further below. Our comparanda includes data for other Anglo-Scandinavian coinage, alongside contemporary Carolingian, Anglo-Saxon, and Islamic coins; silver artefacts in Viking-Age hoards from Scandinavia; and archaeological lead from Viking-Age settlements in Scandinavia and England. It thus enables us to assess both practices (recycling/cupellation). We find that the Anglo-Scandinavian imitation coins are relatively homogenous, and reflect a mixed silver course combining a majority Western European and minority Islamic contribution. By contrast, the ingots are more variable and, overall, show a greater contribution from Islamic silver. Below, we introduce the hoard contents in more detail and outline our theoretical approach to silver provenancing, before detailing the methods and results.

Hoard Content

Dirham

The cut dirham fragment is identified by G. Rispling as a Saffarid issue by the Caliph al-Mu'tamid (870–892) and Emir Ya'qûb bin al-Layth (861–879), struck in al-Banjhîr (Panjhir in the Hindu-Kush, modern-day Afghanistan), in 874–875 (fig. 1.12). Ninth-century Saffarid dirhams struck in Panjhir are rare finds in Viking-Age hoards, with most recorded examples coming from present-day

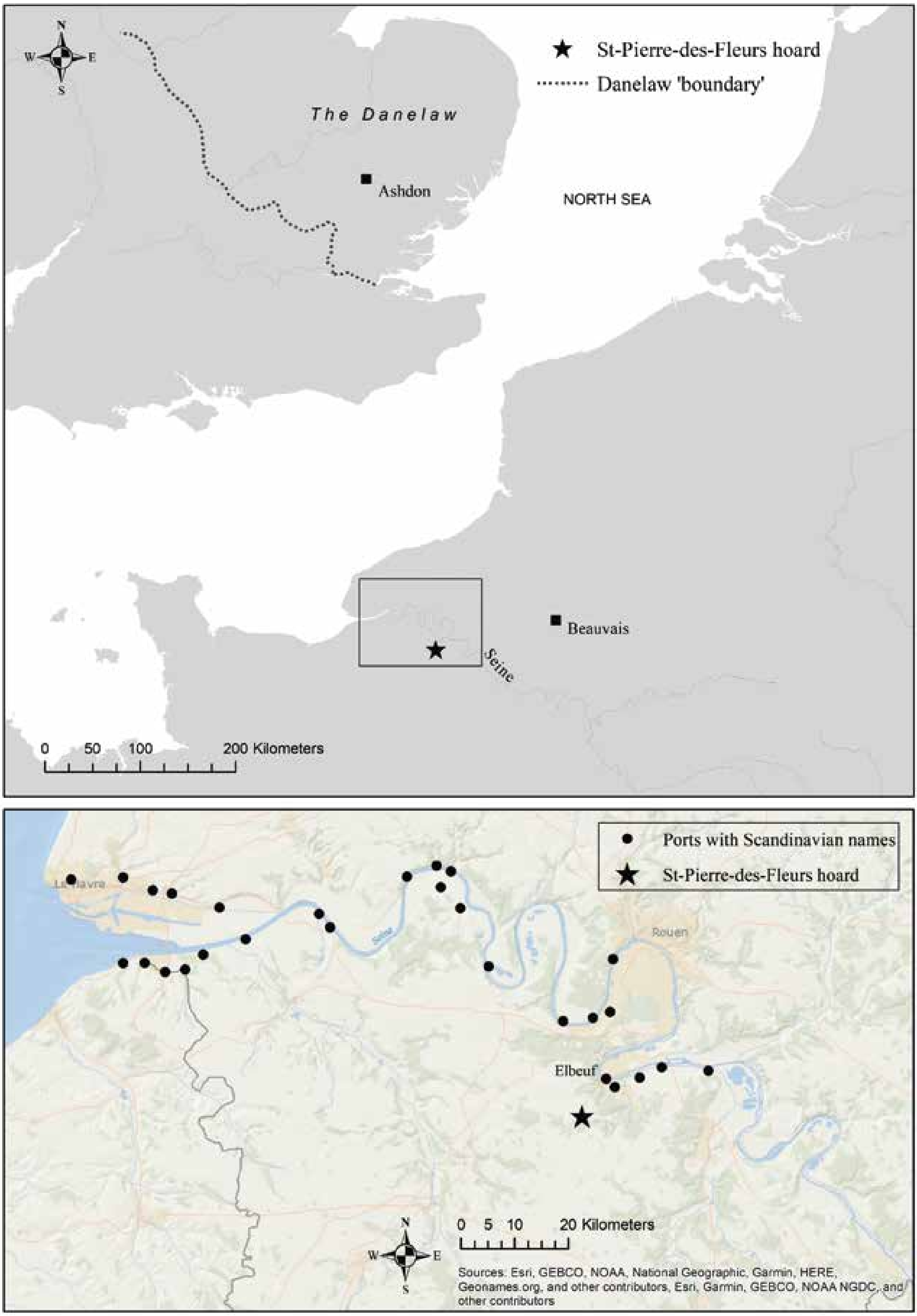
1 Cardon et al. 2008.

2 Kershaw 2017.

3 Cardon et al. 2008, cat. no. 6.

4 Cardon et al. 2008; Le Maho 2005.

5 Cardon et al. 2008, cat. no. 4.



Map 1. Location and context of the Saint-Pierre-des-Fleurs hoard (drawn by J. Kershaw, after Le Maho 2005, 175).

Sample No.	Museum Ref.	Object Type	Description	Mint	Mass (g)
RN2007_01	**SPDF_02**	Denier, Carolingian	Charles the Bald GDR	*vallée de la Loire*	-
RN2007_02	**PS_SPDF_01**	Denier, Carolingian	Eudes	Beauvais	1.56
RN2007_03	**SPDF_03**	Coin, AS Imitation	Imitation Alfred of Wessex, moneyer Ludig	-	-
RN2007_05	**SPDF_07**	Coin, AS Imitation	Imitation Alfred of Wessex, moneyer Ludig?	-	-
RN2007_10	**PS_SPDF_03**	Coin, AS Imitation	Imitation Alfred of Wessex, moneyer Aeldei	-	1.14
RN2007_06	**SPDF_05**	Coin, AS Imitation	Imitation Alfred of Wessex, moneyer Beagstan	-	-
RN2007_08	**SPDF_08**	Coin, AS Imitation	Imitation Alfred of Wessex, moneyer unknown	-	-
RN2007_09	**PS_SPDF_02**	Coin, AS Imitation	Imitation Alfred of Wessex, moneyer Ceneferth	-	0.91
RN2007_11	**SPDF_04**	Coin, AS Imitation	Imitation Alfred of Wessex, moneyer unknown	-	-
RN2007_07	**SPDF_06**	Coin, AS Imitation	Imitation Alfred of Wessex, moneyer Goda	-	-
RN2007_12	**SPDF_01**	Dirham, Islamic	Yaqub ibn al-Layth and al-Mutamid	Panjhir	-
RN2007_18	**SPDF_13**	Ingot	-	-	7.08
RN2007_14	**SPDF_09**	Ingot	-	-	33.14
RN2007_16	**SPDF_11**	Ingot	-	-	2.95
RN2007_21	**SPDF_16**	Ingot	-	-	1.31
RN2007_15	**SPDF_10**	Ingot	-	-	8.52
RN2007_17	**SPDF_12**	Ingot	-	-	10.01
RN2007_13	**PS_SPDF_04**	Ingot	-	-	19.6
RN2007_19	**SPDF_14**	Ingot	-	-	1.73
RN2007_20	**SPDF_15**	Ingot	-	-	2.06

Table 1. Object list (for the coins, only the weights of intact specimens are provided).

Sweden. However, one certain and one possible example minted 873–4 are known from the Giekau hoard, Plön, Schleswig-Holstein (part of Viking-Age Denmark), deposited after 921/2[6]. A dirham struck in Panjhir between 873 and 892 was also found in the Cuerdale, Lancashire, hoard, deposited c. 905–10[7]. The presence of such a coin in the Cuerdale hoard makes it plausible that the dirham fragment from the Saint-Pierre-des-Fleurs hoard circulated in the Danelaw, and was assembled there with the Anglo-Scandinavian coinage and ingot fragments before travelling to Normandy.

Carolingian Deniers

The corpus of Carolingian coins in the Saint-Pierre-des-Fleurs hoard constitutes one complete denier and one fragment (fig. 1.1, 2). Neither are from Rouen, the closest mint to the find-spot. The complete coin is a denier of Eudes (888–898) from Beauvais, c. 70 km north of Paris in Picardy (map 1). On the fragment, one can identify on one side a *Karolus* monogram and a Gratia Dei Rex legend, which dates it to between 864 and 877. The other side bears the letters IVITAS (for the ending of a legend [*name of the mint* C]IVITAS). The style of the lettering suggests that this coin was issued in a mint located in the Loire valley[8], roughly in the opposite direction from the find-place as Beauvais. The breaks on the fragment appear to be recent

6 Wiechmann 1996, cat. no. 9, coin nos. 113, 114.

7 Lowick 1976, 26, cat. no. 15.

8 Cardon et al. 2008, 31.

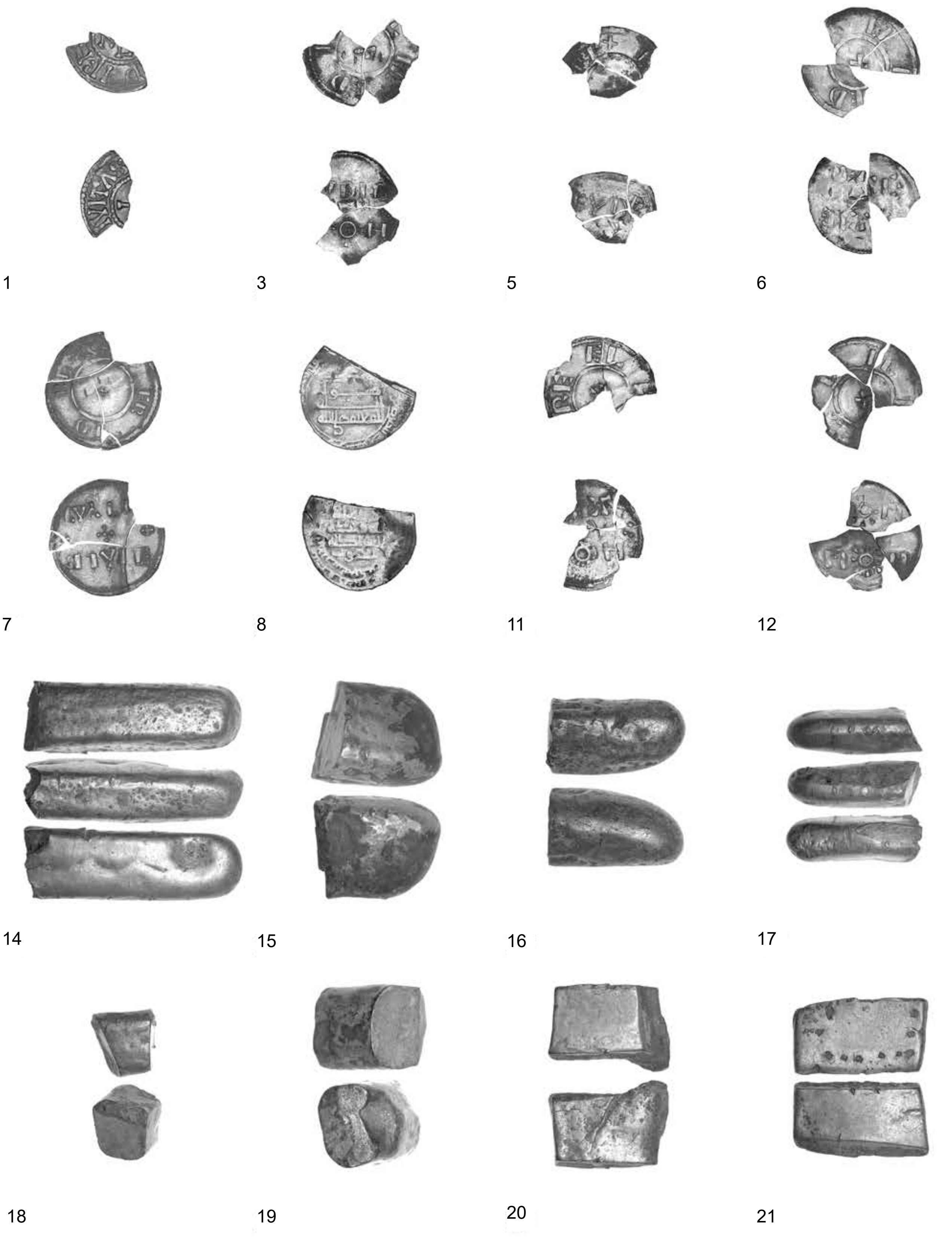


Fig. 1. Analysed coins and ingots in the Saint-Pierre-des-Fleurs hoard. The catalogue numbers are the same as those produced in Cardon et al. 2008 – see Table 1 for a description of the items. Catalogue numbers 2, 9, 10 and 13 are from a private collection and were not photographed (1–14, 17, 18: scale 1:1; 15, 16, 19–21: scale 2:1) (photos by G. Sarah).

and may be due to modern cultivation activities, rather than intentional cuts made in the Viking Age.
Coin circulation in Upper Normandy at the time of the deposition of the Saint-Pierre-des-Fleurs hoard can be deduced from two earlier and two later hoards[9]. Two hoards found in Upper Normandy can be dated c. 869–877: Imbleville (Seine-Maritime) and Pont-Saint-Pierre (Eure)[10]. Although Pont-Saint-Pierre is only partially recorded, both hoards indicate that Upper Normandy was, at this time, part of an area of coin circulation geographically oriented north-eastwards, including a wide region north of Paris. Coin circulation in Upper Normandy is also known from two later hoards, dated after the Duchy of Normandy was created, both from the Eure département: Coudres (c. 920) and Evreux (942–945). According to J. Chr. Moesgaard, their composition suggests that Normandy was included in a wide Neustrian area of coin circulation, which also incorporated the Loire valley and the Maine. Thus, between these two periods, c. 869–877 and c. 920–945, there appears to be a geographic shift in coin circulation which, we hypothesize, may have been connected with the 911 Treaty of Saint-Clair-sur-Epte giving the territory of Normandy to the Viking chief Rollo. Whatever the case, the two Carolingian coins from the Saint-Pierre-des-Fleurs hoard, one from Picardy and the other possibly from the Loire Valley, represent each of the two periods of coin circulation described. Their presence together in the Saint-Pierre-des-Fleurs hoard is consistent with the coins available in Upper Normandy at the very end of the ninth century.

Anglo-Scandinavian Coins

The Saint-Pierre-des-Fleurs hoard contains nine Anglo-Scandinavian imitations of Alfred's Horizontal/Two-Line type, the majority of which imitate coins from the London mint (fig. 1.5–11). Several are bent and/or pecked. They are all 'anonymous' in that they copy the name of King Alfred, rather than carry the name of Scandinavian rulers. This imitative coin series, struck to a lighter weight and, sometimes, with an anomalous style and/ or poor literacy relative to Alfred's official issues, was produced from c. 885 to c. 895 at mints in East Anglia and the East Midlands[11]. While many of the coins carry the name of the moneyer Ludig, who produced coins early on at the London mint, one coin bears the name Beagstan: a moneyer working towards the end of the imitative series in c. 895 (fig. 1.6)[12]. In the total corpus of Anglo-Scandinavian imitative coins scholars have identified the names of over 30 Danelaw moneyers, suggesting that the scale of production was large[13]. In the southern Danelaw region, this coinage appears to have circulated to the exclusion of other issues, for it is the only imitative coin variety contained within the Ashdon hoard, deposited in north Essex c. 895 (map 1)[14]. Nonetheless, even in the Ashdon hoard, the coins were pecked and bent: a reminder than even 'official' issues could be treated as bullion, as the Anglo-Scandinavian coins in the Saint-Pierre-des-Fleurs hoard seem to have been. The homogenous character of this coin parcel in the Saint-Pierre-des-Fleurs hoard may point to a similar origin in the southern Danelaw.

Ingots

The nine fragments of silver ingots from the hoard together weigh 86.4 g. Seven items have finger-like forms and deliberately, chisel-cut ends that are typical of ingots found in Viking-Age hoards in Britain, as well as single finds from the Danelaw (fig. 1.14–19)[15]. Two further items are described in the original publication as chisel-cut plate ('plaque coupée au ciseau') (fig. 1.20, 21)[16]. They have a less regular shape, and broader, flat surfaces, which, on one item, carries decorative irregular, squarish stamp impressions (fig. 1.21)[17]. Stamping is occasionally seen on Danelaw ingots (for instance: PAS 'Find-ID' NMS-730A92) and it is clear from the deliberately cut form of one item, and from the edge nicking exhibited on both pieces, that they functioned as stores of metal. Overall, the rate of nicking among the ingots is high: of nine items, seven are nicked, with the number of nicks per ingot ranging from three to 18+. Their heavily tested condition, coupled to their highly fragmentary form, suggests an extended period of circulation within the Danelaw, and, perhaps, an earlier 'life' within Scandinavia or other overseas territories in which the Scandinavians were active. It is perhaps likely that the ingots are older than the coin element in the hoard, something that may be revealed through archaeometric analysis.

Approaches to Silver Provenancing

To explore the question of silver provenance through archaeometric methods, it is important to build an interpretational framework founded on the latest understanding of metallurgical processes and the archaeology of silver, as well as on the use of a combined analytical approach using high resolution mass spectrometry[18]. The first objective is to identify whether the silver is the result of 1. new primary production, 2. recycling via re-melting or 3. secondary refining/cupellation. Cupellation, namely the metallurgical process of refining silver with lead through the high temperature oxidation of impurities, is thought to have been ubiquitous in the Middle Ages, and there-

9 Moesgaard 2007, 114–117.
10 Coupland 2011 (hoards no. 144 and 146).
11 Blackburn 2011, 5, 152.
12 Blackburn 2011, 169.
13 Blackburn 2011, 152.
14 Naismith 2017, 288; Blackburn 2011, 5.
15 Kershaw 2017.
16 Cardon et al. 2008, cat. nos. 20, 21.
17 Cardon et al. 2008, cat no. 21.
18 For a fuller discussion see Merkel 2019; Sarah 2019.

	206/204	2SD	207/204	2SD	208/204	2SD	207/206	2SD	208/206	2SD
SRM981	16.932	0.002	15.485	0.002	36.683	0.005	0.91453	0.00003	2.1664	0.0001
SRM982	36.735	0.004	17.154	0.002	36.733	0.005	0.46697	0.00002	0.99995	0.00005

Table 2. Oxford Earth Sciences lead isotope analyses of NIST SRM981 and NIST SRM982 lead isotope standards. These are the average values during the measurement session. SRM981 are the measured values and the SRM982 are adjusted values after normalizing SRM981 to the values of Todt et al. 1996.

fore understanding this process, and its outcome, is the cornerstone for silver studies of this period. Experiments have shown that many elements (for instance, tin, zinc) are reduced to very minimal levels through cupellation. However, gold, platinum and bismuth survive cupellation intact (in the case of bismuth, until the very end of the process). These elements thus ought to relate to their original ore source, although we note that the behaviour of trace elements in silver during cupellation depends on the scale, characteristics and point of cessation of the process[19]. The purity and trace element characteristics of the silver allows freshly refined silver to be distinguished from silver that has contamination indicative of alloying and mixing, while the levels of source-indicator elements are useful for discriminating between potential sources.

The composition of the alloy is also crucial in interpreting lead isotope data. Two major hurdles that stand in the way of sourcing archaeological silver using lead isotope analysis are cupellation and mixing. Silver may contain impurities of lead connected to the original production of the silver, but secondary refining silver by cupellation requires the addition of exogenous lead to sequester silver from impurities and can therefore entail foreign lead contamination. The mixing of multiple silver stocks together can homogenise lead isotope ratios, which would then fall on a 'mixing line' for two sources, or within a polygon for three or more sources, plotting graphically between them[20]. However, for Viking-period silver, these risks are minimised by the fact that Viking silver artefacts were cast from two, and only two, main sources: silver from western Europe (Carolingian Empire and Britain) obtained primarily during late eighth- and ninth-century raids in Britain and on the Continent, and Islamic silver dirhams, imported into Scandinavia via the Russian riverine trade route in large quantities from the ninth century. Significantly, ninth-century western European silver is distinct from, and unrelated to, contemporary Islamic dirham silver, both isotopically and elementally[21]. For instance, the gold content of Abbasid Islamic dirhams is, on average 0.2 wt.%, and ninth-century Anglo-Saxon and Carolingian coins commonly have three to four times higher gold contents than this[22]. This fact allows the two sources to be identified, either as discrete sources or when mixed. Moreover, archaeological lead found in Viking-Age contexts in England and Scandinavia – the lead available for use in cupellation – is consistent with Western European lead sources. Thus, when silver artefacts yield lead isotope ratios that are inconsistent with Melle or other European silver/lead, but have parallels in Islamic dirham stocks, it is likely that the silver derives, either wholly or in part, from the re-melting of dirham silver. This, in combination with elemental characteristics, allows Islamic silver to be traced despite recycling.

Methods

Two sets of analyses were carried out. Elemental analysis was performed at the IRAMAT–Centre Ernest Babelon, CNRS–Université d'Orléans using a well-established laser ablation inductively coupled plasma mass spectrometry technique[23]. Lead isotope analysis was performed at the University of Oxford, Department of Earth Sciences. Micro-samples of 1–10 mg were taken by scalpel and prepared for solution-based lead isotope analysis by multi-collector ICP-MS. Samples were purified using anion exchange chromatography to remove the matrix and details of the analytical procedure can be found in Standish et al. 2021. Blanks were 0.05 % relative. Average analyses of NIST SRM 981 (measured) and 982 (normalised) on measurement days are found in table 2. Lead isotope ratios were normalised to the ratios of Todt et al. 1996: $^{208}Pb/^{206}Pb = 2.16701$, $^{207}Pb/^{206}Pb = 0.91459$, and $^{206}Pb/^{204}Pb = 16.9356$. Standard deviations (2SD) were calculated from three repeat analyses of the same sample solution. The elemental results are presented in table 3 and the lead isotope ratios in table 4.

Results

Elemental Results

The elemental analyses indicate that all objects are above sterling silver quality and typically have copper contents

19 See Flament et al. 2017, 278 f.; L'Héritier et al. 2015; McKerrell/Stevenson 1972; Pernicka/Bachmann 1983.

20 Pernicka 2014, 256–258.

21 Merkel 2019; Sarah 2008; 2019.

22 Sarah 2010; Kershaw/Merkel 2019b.

23 For details on the methods refer to Sarah et al. 2007; Sarah/Gratuze 2016.

Sample No.	Museum Ref.	Object Type	Ag	Cu	Pb	Au	Bi	Zn	Sn	Ni	As	Sb	Pt	Zn/ (Zn+Cu)	Sn/ (Sn+Cu)
RN2007_01	**SPDF_02**	Denier, Carolingian	93.7%	4.1%	9016	9461	124	2519	1289	2.3	27	34	0.65	5.8%	3.1%
RN2007_02	**PS_SPDF_01**	Denier, Carolingian	93.6%	4.3%	8795	11617	76	608	580	2.0	39	25	1.00	1.4%	1.3%
RN2007_03	**SPDF_03**	Coin, AS Imitation	93.1%	4.2%	9016	9382	362	3143	5221	4.3	70	157	0.85	7.0%	11.1%
RN2007_05	**SPDF_07**	Coin, AS Imitation	92.9%	3.3%	10809	11800	249	5772	9051	4.2	67	180	0.87	15.1%	21.7%
RN2007_10	**PS_SPDF_03**	Coin, AS Imitation	93.5%	4.3%	7859	9717	197	1710	2233	3.7	57	101	0.94	3.8%	4.9%
RN2007_06	**SPDF_05**	Coin, AS Imitation	93.7%	3.7%	8801	10728	352	2532	3557	3.4	52	65	1.0	6.4%	8.7%
RN2007_08	**SPDF_08**	Coin, AS Imitation	93.1%	4.2%	7947	8460	650	5007	4097	4.4	57	133	0.69	10.6%	8.8%
RN2007_09	**PS_SPDF_02**	Coin, AS Imitation	94.4%	3.1%	7830	8791	429	2599	5051	4.3	49	72	0.8	7.8%	14.1%
RN2007_11	**SPDF_04**	Coin, AS Imitation	93.1%	4.2%	10151	9445	356	3262	4426	2.6	58	103	0.74	7.3%	9.6%
RN2007_07	**SPDF_06**	Coin, AS Imitation	93.0%	4.1%	8134	8159	495	7552	4085	4.6	73	70	0.62	15.5%	9.0%
RN2007_12	**SPDF_01**	Dirham, Islamic	99.0%	0.1%	3499	31	5647	19	1.0	0.62	7.8	0.52	0.10	-	-
RN2007_18	**SPDF_13**	Ingot	93.0%	5.5%	7504	3218	1041	1438	741	6.5	58	19	0.54	2.5%	1.3%
RN2007_14	**SPDF_09**	Ingot	93.0%	4.8%	10111	8575	465	806	1582	5	39	26	1.05	1.6%	3.2%
RN2007_16	**SPDF_11**	Ingot	91.3%	6.3%	15942	2950	3484	972	729	11	307	26	0.55	1.5%	1.2%
RN2007_21	**SPDF_16**	Ingot	94.4%	4.0%	6649	4884	883	1142	2168	6.1	29	12	0.73	2.8%	5.1%
RN2007_15	**SPDF_10**	Ingot	93.6%	4.3%	5918	13308	328	901	785	4.1	48	18	1.8	2.1%	1.8%
RN2007_17	**SPDF_12**	Ingot	92.6%	5.7%	4031	11010	188	802	788	2.9	30	25	1.2	1.4%	1.4%
RN2007_13	**PS_SPDF_04**	Ingot	91.7%	5.9%	7418	9886	411	662	4915	8.4	74	57	1.0	1.1%	7.7%
RN2007_19	**SPDF_14**	Ingot	91.2%	4.5%	34079	7236	214	110	1047	0.98	12	38	0.25	0.2%	2.3%
RN2007_20	**SPDF_15**	Ingot	94.5%	3.8%	5176	10481	193	590	628	3.0	25	11	1.7	1.5%	1.6%

Table 3. Results of the elemental analysis by LA-ICP-MS. Ag and Cu in weight percent, other elements in ppm. The elements In, Ru, Rh, Pd, Cd, Ir, Te, Os and Tl below detection.

Sample No.	Ref musée	Object Type	206/204	2SD	207/204	2SD
RN2007_01	**SPDF_02**	Denier, Carolingian	18.470	0.001	15.6414	0.0003
RN2007_02	**PS_SPDF_01**	Denier, Carolingian	18.465	0.002	15.640	0.002
RN2007_03	**SPDF_03**	Coin, AS Imitation	18.474	0.002	15.642	0.002
RN2007_05	**SPDF_07**	Coin, AS Imitation	18.485	0.004	15.647	0.004
RN2007_10	**PS_SPDF_03**	Coin, AS Imitation	18.473	0.001	15.635	0.001
RN2007_06	**SPDF_05**	Coin, AS Imitation	18.486	0.001	15.638	0.001
RN2007_08	**SPDF_08**	Coin, AS Imitation	18.506	0.002	15.644	0.003
RN2007_09	**PS_SPDF_02**	Coin, AS Imitation	18.511	0.002	15.645	0.002
RN2007_11	**SPDF_04**	Coin, AS Imitation	18.501	0.001	15.6465	0.0003
RN2007_07	**SPDF_06**	Coin, AS Imitation	18.536	0.001	15.643	0.001
RN2007_12	**SPDF_01**	Dirham, Islamic	19.054	0.002	15.705	0.002
RN2007_18	**SPDF_13**	Ingot	18.643	0.001	15.650	0.001
RN2007_14	**SPDF_09**	Ingot	18.627	0.001	15.655	0.001
RN2007_16	**SPDF_11**	Ingot	18.759	0.001	15.680	0.001
RN2007_21	**SPDF_16**	Ingot	18.505	0.001	15.628	0.000
RN2007_15	**SPDF_10**	Ingot	18.509	0.003	15.634	0.002
RN2007_17	**SPDF_12**	Ingot	18.497	0.004	15.651	0.004
RN2007_13	**PS_SPDF_04**	Ingot	18.475	0.001	15.617	0.001
RN2007_19	**SPDF_14**	Ingot	18.474	0.001	15.634	0.001
RN2007_20	**SPDF_15**	Ingot	18.485	0.002	15.628	0.001

Table 4. Lead isotope ratios of the analysed objects (continued on the next page).

in the range of 3–6 wt. %. This is the standard commonly found among silver used by the Vikings. Only one object is made of unalloyed silver: the Panjhir dirham, whose elemental composition is consistent with all that is known about the Panjhir, with extremely low gold and copper values and elevated bismuth, usually in excess of 0.5 % [24]. The dirham is also the only object that is clearly made of silver refined directly before its manufacture; from now on, it will be discussed separately. All other analysed objects have levels of copper and other elements such as zinc and tin that signify re-melting: alloying, mixing and/or minor contamination of the silver immediately prior to their casting/ minting. It is, however, possible that the silver in the artefacts was previously cupelled and subsequently alloyed to a copper or copper-based alloy, in which case the lead isotope results would relate to the lead used in the last cupellation event.

In the vast majority of objects, the gold contents are high (7,200–13,300 ppm), a trait characteristic of the post-875 (reformed) coinage of Alfred[25] as well as late ninth-century Carolingian silver[26]. The ingots, however, can have noticeably lower gold contents (3,000–4,900 ppm), suggesting a different silver source. There is a general tendency for bismuth to be negatively correlated with gold, the highest bismuth contents belonging to the artefacts with the lowest gold contents and vice-versa. Lead is almost always around 0.5 to 1 wt. %, but one ingot (RN2007-19) has significantly more (3.4 wt. %). This could mean that the silver was poorly refined, leaving a surplus of lead, or it may reflect lead contamination in the alloy.

Lead Isotope Analysis Results

The lead isotope ratios separate into two main groups with the dirham from Panjhir being an outlier (fig. 2). In order to enhance the interpretation of the lead isotope dataset, Pb model ages, μ and κ-values were calculated using the methods of Albarède et al. (2012). These calculated values provide information regarding the model age of the lead and are additional ways of describing the dataset. The dirham from Panjhir is highly radiogenic, having a future model age, and thus has no relationship to the other objects in the hoard and will not be discussed in this context.

The remaining hoard objects form two distinct isotope groups: the main group is characterized by Pb model ages between 235 and 181 Ma (Triassic-Early Jurassic) while a smaller group composed of three ingots has ages between

24 Cowell/Lowick 1988; Merkel 2016; 2017.

25 Kershaw et al. in prep a.

26 Metcalf/Northover 1988; Sarah 2008.

207/206	2SD	208/206	2SD	T(Ma)	μ	κ
0.84685	0.00001	2.08441	0.0001	233	9.759	3.916
0.84703	0.00001	2.08451	0.00004	235	9.756	3.915
0.84668	0.00002	2.08455	0.00003	231	9.760	3.920
0.84649	0.00001	2.08489	0.0001	233	9.778	3.929
0.84637	0.00003	2.08433	0.0001	219	9.733	3.914
0.84594	0.00002	2.08325	0.00004	215	9.744	3.911
0.84536	0.00002	2.08458	0.0001	212	9.762	3.934
0.84515	0.00001	2.08333	0.0001	209	9.763	3.924
0.84572	0.00003	2.08362	0.0001	220	9.773	3.924
0.84389	0.00002	2.08142	0.0000	186	9.750	3.916
0.82428	0.00003	2.06363	0.0001	-75	9.895	3.975
0.83946	0.00001	2.07743	0.00004	121	9.757	3.925
0.84045	0.00002	2.08014	0.0001	143	9.779	3.946
0.83585	0.00002	2.07639	0.0001	93	9.849	3.973
0.84453	0.00001	2.08379	0.00005	181	9.699	3.921
0.84466	0.00001	2.08190	0.0001	190	9.722	3.906
0.84616	0.00003	2.08433	0.0002	232	9.792	3.930
0.84536	0.00002	2.08153	0.0001	183	9.664	3.882
0.84625	0.00003	2.08246	0.0001	215	9.728	3.896
0.84543	0.00003	2.08124	0.0001	196	9.702	3.887

143 and 93 Ma (Cretaceous) (fig. 2)[27]. Within the main lead isotope group, we observe isotopic subgroups that likely relate to slightly differing silver stocks. Notably, all the analytical data fits within the spread of lead isotope ratios in the reference datasets (outlined below). Thus, the lead isotope ratios found in the Saint-Pierre-des-Fleurs hoard objects fit well within the framework of the interpretational model.

Discussion

Provenance of the Silver

Comparing the two isotope groups, the smaller, ingot-only (Cretaceous) group contains the two objects with the lowest gold and highest bismuth contents. The dependence of these source-related variables means that ore source information is partially preserved. In addition, there is potentially important information in the platinum vs gold plot. These two elements are positively correlated, but the two isotope groups show different alignments, indicating the presence of two silver stocks (fig. 3). Significantly, the lower platinum vs gold alignment contains all three of the Cretaceous ingots, regardless of the gold contents, in addition to an ingot from the main isotope group[28] which is anomalous for its lower gold and higher bismuth (discussed further below). This means that these four ingots are probably related despite other variables that appear to show otherwise. The two main isotope groups are also observed in the evidence for alloying with copper-based alloys (brass and bronze). The items in the small isotopic (Cretaceous) group are alloyed with relatively clean copper, while the items from the main isotope group (Triassic-Early Jurassic) are much more varied, ranging from copper to bronze and/or gunmetal (fig. 4). Altogether, these factors point to two differing silver stocks that are, for the most part, distinguishable by multiple variables.

In order to assess the origin of the silver in the Saint-Pierre-des-Fleurs hoard, the analytical data was compared against an extensive reference database for ninth-century silver and lead artefacts and ore sources produced by mass spectrometry techniques (fig. 5–7). The comparanda comprises:

- *Western European coinage:* ninth-century Carolingian coinage[29]; ninth-century Anglo-Saxon coinage, including issues of Alfred the Great of Wessex and Ceolwulf II of Mercia from the Watlington, Oxfordshire, hoard[30],

27 Cardon et al. 2008, cat. nos. 14, 16, 18.

28 Cardon et al. 2008, cat. no. 21.

29 Post-reform Charles the Bald coins after Sarah 2010, later coins after Metcalf/Northover 1988.

30 Obtained by LA-ICP-QMS (Kershaw et al. in prep a; Kershaw/

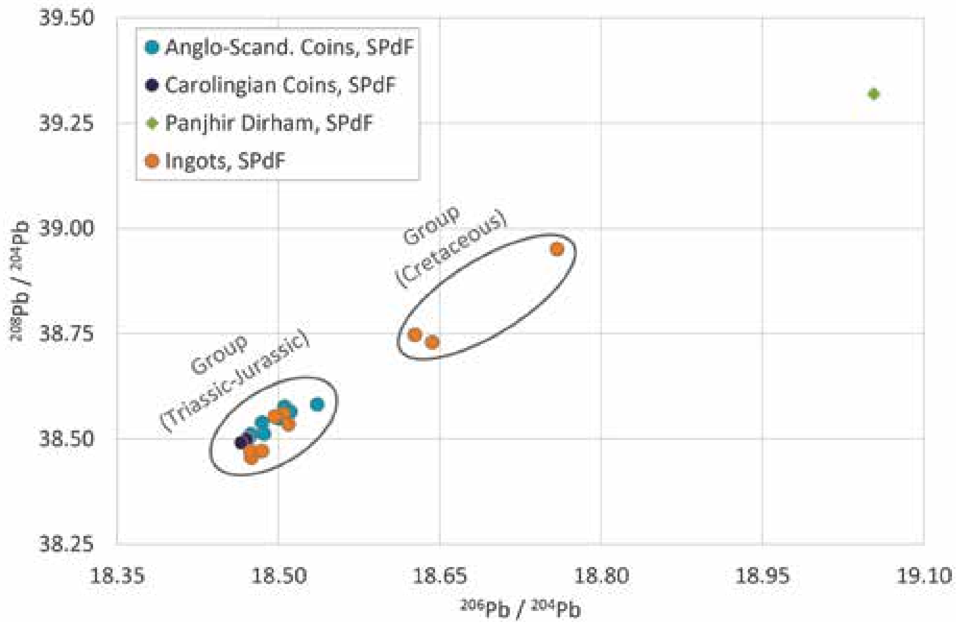


Fig. 2. The two main isotope groups in the Saint-Pierre-des-Fleurs Hoard (drawn by St. Merkel).

and Anglo-Scandinavian coinage from York and East Anglia, including imitative and 'regal' types[31].

- *Islamic dirhams:* Umayyad and Abbasid dirhams and dirham imitations (Khazar and Volga Bulgar)[32].
- *Western European lead/silver ore:* Melle, France: a major Carolingian mine and mint[33]; British lead deposits, for example Derbyshire, Mendip, Bristol Avon and Yorkshire[34].
- *Viking-period archaeological lead artefacts:* from England, including York and Aldwark Viking winter camp[35], and Scandinavia, including Hedeby, Gokstad and Birka[36]. With the exception of a small number of pewter finds from Gokstad (Norway) matching Melle lead isotope ratios, and one lead weight from Birka (Sweden), the Viking-Age Scandinavian lead finds closely mirror the lead from northern England and may share a common origin. In the figures, only the unpublished Viking-Age lead from Britain is shown.

By comparing the lead isotope ratios and gold and bismuth contents to reference data, it is possible to identify likely sources for the analysed objects.

Merkel 2019b).

31 Kershaw/Merkel 2019b; Ryan et al. 1984; Metcalf/Northover 1988.

32 Merkel et al. in prep.; unpublished data.

33 Guillaume Sarah, unpublished data; Gratuze 2018; Téreygeol et al. 2005.

34 Rohl 1996.

35 Kershaw/Merkel 2019a; J. Kershaw and St. Merkel, unpublished data.

36 Merkel 2016; Pedersen et al. 2016; Stos-Gale 2004.

Dirham

In its very low copper and gold, and elevated levels of bismuth, the elemental composition of the Saffarid dirham is consistent with elemental data for other dirhams minted in Panjhir[37]. The first known dirham produced from this distinctive high-bismuth silver was struck at Andaraba in 861 (247 AH) and the use of this type of silver continues in Northern Afghanistan into the Samanid period[38]. Since it represents a sharp departure from earlier Afghan silver stocks, Panjhir-type silver must derive from new silver production that began around this time. The Abbasids minted sporadically at Panjhir from 860/1 (246 AH), with regular, albeit short-lived, minting established by the Saffarids from 873 (259 AH). The use of a new silver source fits with the establishment of regular minting at Panjhir, but may also help to explain the decade-long efforts of the Saffarids to take control of the mining town and mint[39]. The range of the lead isotope ratios from this mint are far from known. Up until now, only one other dirham from the Panjhir mint was analysed by lead isotope analysis[40]. In comparison to this example, the Saint-Pierre-des-Fleurs dirham's isotope ratios are much more radiogenic, meaning it has higher quantities of lead formed from the radioactive decay of uranium and thorium. Polymetallic lead-silver slag from the Panjhir valley, that may be associated with Islamic-period silver mining, are highly radiogenic and also exhibit future model ages, but these slags are even more radiogenic than the "Saint-Pierre-des-Fleurs" exam-

37 Cowell/Lowick 1988; Merkel 2017.

38 Ilisch et al. 2003.

39 Diler 2009, 320; Tor 2002, 293–295.

40 Merkel 2016.

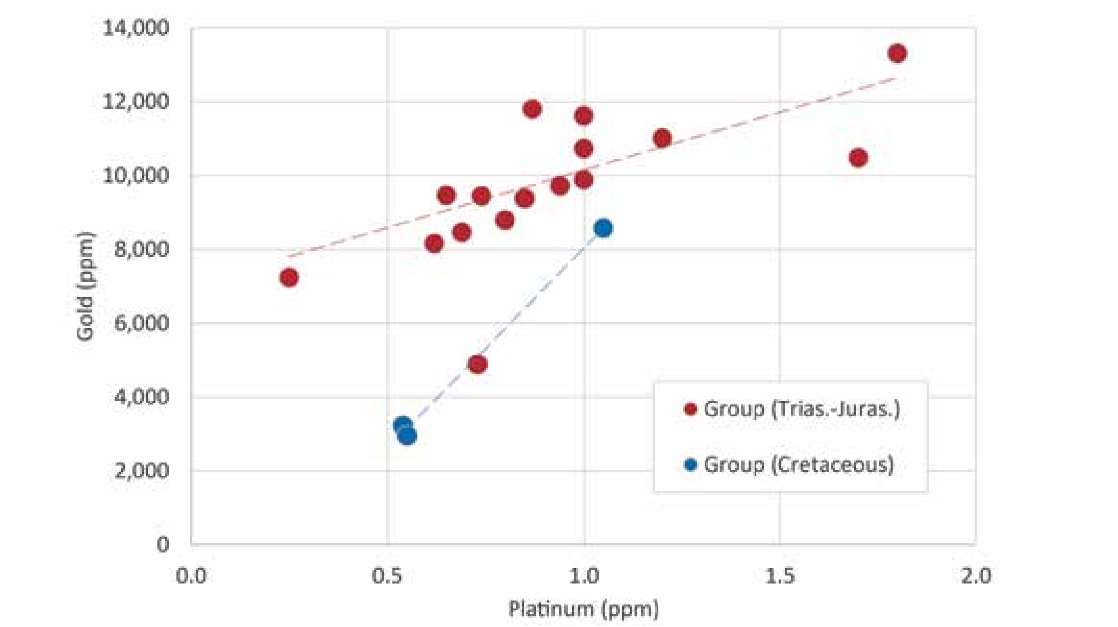


Fig. 3. Platinum vs gold plot showing differences between the two isotope groups (drawn by St. Merkel).

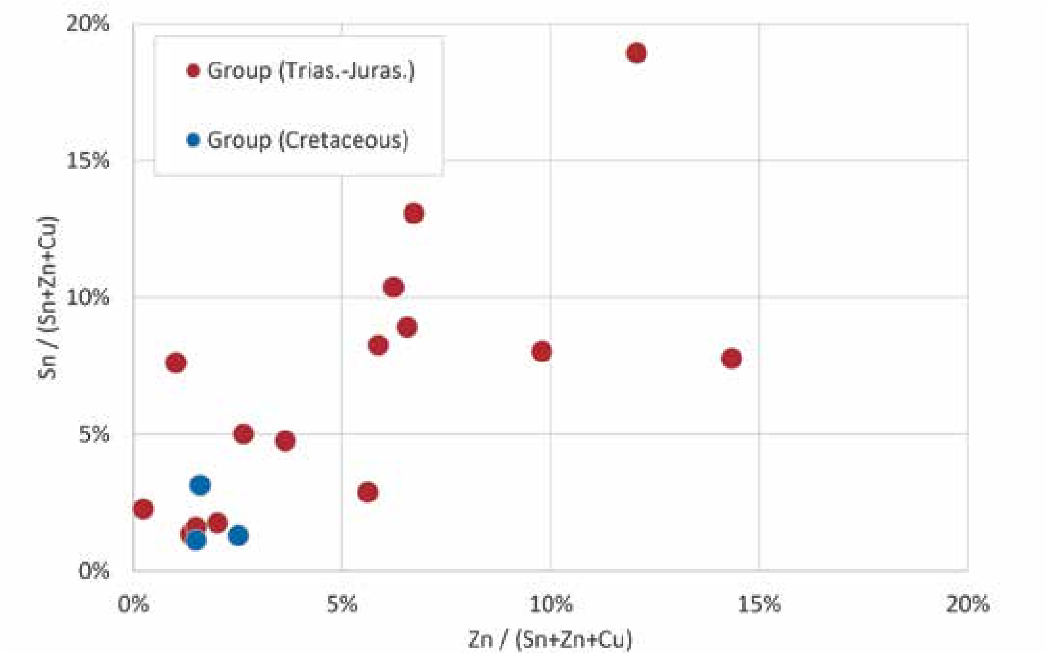


Fig. 4. Copper-based alloys in the silver: brass vs bronze plot, showing differences between the two isotope groups (drawn by St. Merkel).

ple[41]. It must be said that there is little clarity regarding the isotopic characteristics of Panjhir silver, ore sources and the organisation of production[42]. The lead isotope ratios may reflect several isotopically diverse deposits and/ or exogenous lead may have been introduced during extractive processes. Panjhir as a silver production centre appears be complex and is greatly in need of focused research.

41 Merkel et al. 2015; Thomalsky et al. 2015.

42 See Merkel et al. 2015.

Carolingian Coins

Both Carolingian deniers from the "Saint-Pierre-des-Fleurs" hoard are elementally consistent with previously analysed post-reform Charles the Bald deniers and later

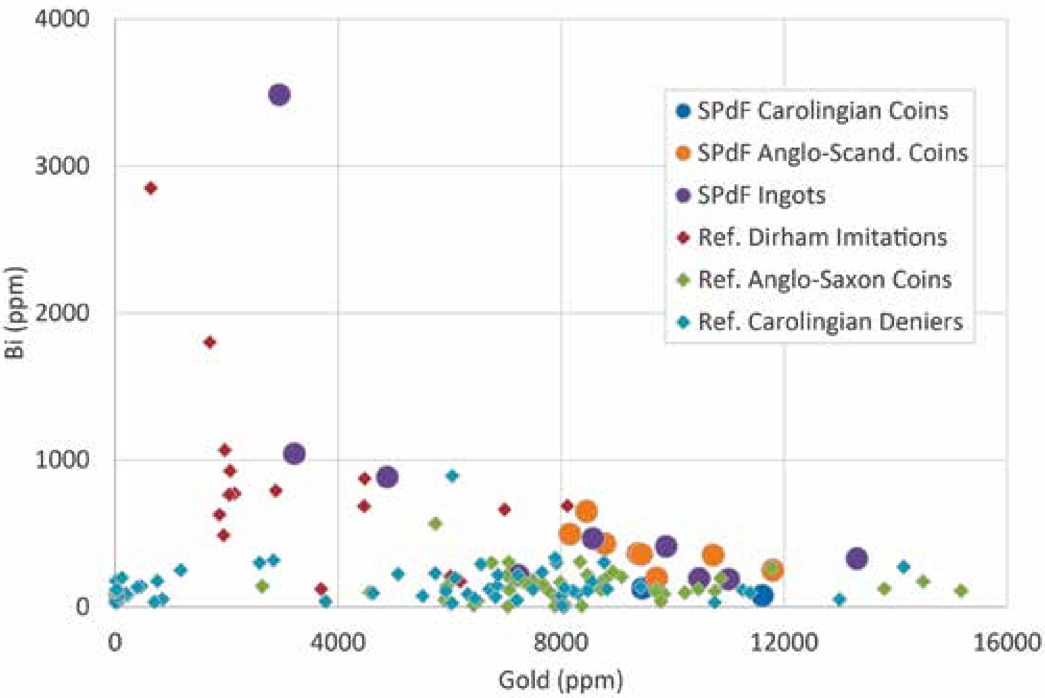


Fig. 5. Gold and bismuth plot comparing hoard items with reference data. Carolingian coins, post-864 Charles the Bald (Sarah 2008; 2010). Anglo-Saxon coins, Alfred post-875 (Kershaw et al. in prep a). Dirham imitations, ninth century (Merkel et al. in prep) (see text) (drawn by St. Merkel).

Carolingian coins[43]. The silver content is c. 94 %, as is typical for Carolingian coins minted after 864. The gold and bismuth levels are also consistent with previous results, with respectively c. 1 % and c. 100 ppm (fig. 5). Isotopically, they are very close to each other and consistent with both Melle ore (fig. 6) and Carolingian deniers minted at Melle (fig. 7). Two interpretations of these results are possible. First, it can be proposed that Melle silver constituted the major part of the metal in circulation in *Francia Occidentalis*, since coins from both Beauvais and the Loire valley have lead isotope ratios consistent with Melle ore. Second, one could also imagine that lead from Melle was dominant in the kingdom of Charles the Bald and his successors. After the long period of debasement in the middle of the ninth century, there was a need to refine the silver currency to bring it up to a high standard. It may thus be that cupellation taking place in western Carolingian mints conferred the Melle LI fingerprint to coins that may be constituted of silver from different origins. At the moment, there is no proof of Carolingian lead and silver mining other than at Melle, but we cannot exclude the possibility of the existence of other sources or that imported silver entered the silver stock.

Anglo-Scandinavian Coins

Despite the fact that the Anglo-Scandinavian coins include both early and late issues, they form a moderately homogenous geochemical group, a finding which adds support to the notion that this was a well-organised and controlled coinage. They plot isotopically in a 'mixed group' cluster, which straddles the edges of the Melle and British lead (represented here by archaeological lead from Viking-Age York and the winter camp of Aldwark, North Yorkshire), suggesting a predominant contribution from western European silver (fig. 6). Isotopically, the group is a particularly good match for late ninth-century Anglo-Saxon coinage and silver artefacts (fig. 7), although three coins[44] plot closer to Melle and the two Carolingian deniers analysed in this study. Western European silver likely provided the bulk of the raw material for the coinage, suggesting that the earliest Anglo-Scandinavian coin production was fuelled by resources won in Western Europe.

However, the bismuth contents are high relative to both Anglo-Saxon and Carolingian silver (c. 200–650 ppm, compared with 100–300 ppm for Anglo-Saxon and Carolingian coin) (fig. 5). This group thus also appears to have a minor contribution from a higher-bismuth source: potentially, Islamic dirhams. Dirhams circulated widely in the Danelaw, but dirham silver could have also been imported to the Danelaw in the form of ingots or other

43 Metcalf/Northover 1988; Sarah 2010.

44 Cardon et al. 2008, cat. nos. 5, 6, 10.

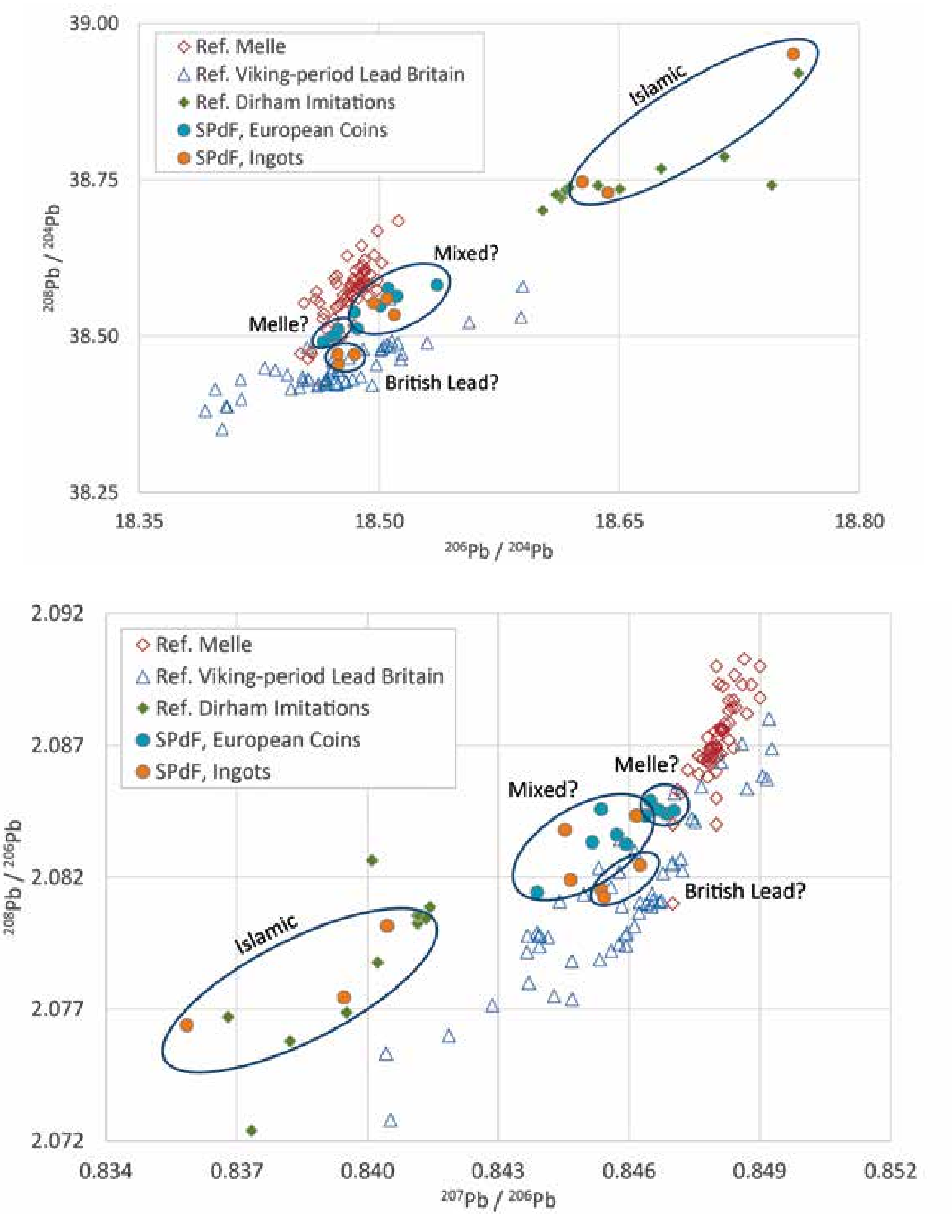


Fig. 6. Lead isotope ratios of hoard items compared with reference data. Melle reference data (Gratuze 2018; G. Sarah, unpublished data; Téreygeol et al. 2005). Dirham imitations, ninth century (Merkel et al. in prep). Viking-Age lead from Scandinavian contexts in Britain (York and the Viking camp site of Aldwark) (Kershaw/Merkel 2019a; in prep) (see text) (drawn by St. Merkel).

cast Scandinavian silver products, and recycled to supply the nascent coinage[45]. Notably, our data[46] for slightly later Anglo-Scandinavian coins, minted in the Danelaw around the turn of the tenth century, indicates that they have bismuth contents in the range of 400–700 ppm, more in keeping with the contents observed here, although these later Anglo-Scandinavian coins also have lead isotope ratios consonant with a more evenly mixed Islamic/ Western

45 Kershaw 2017.

46 And that of Metcalf/Northover 1988.

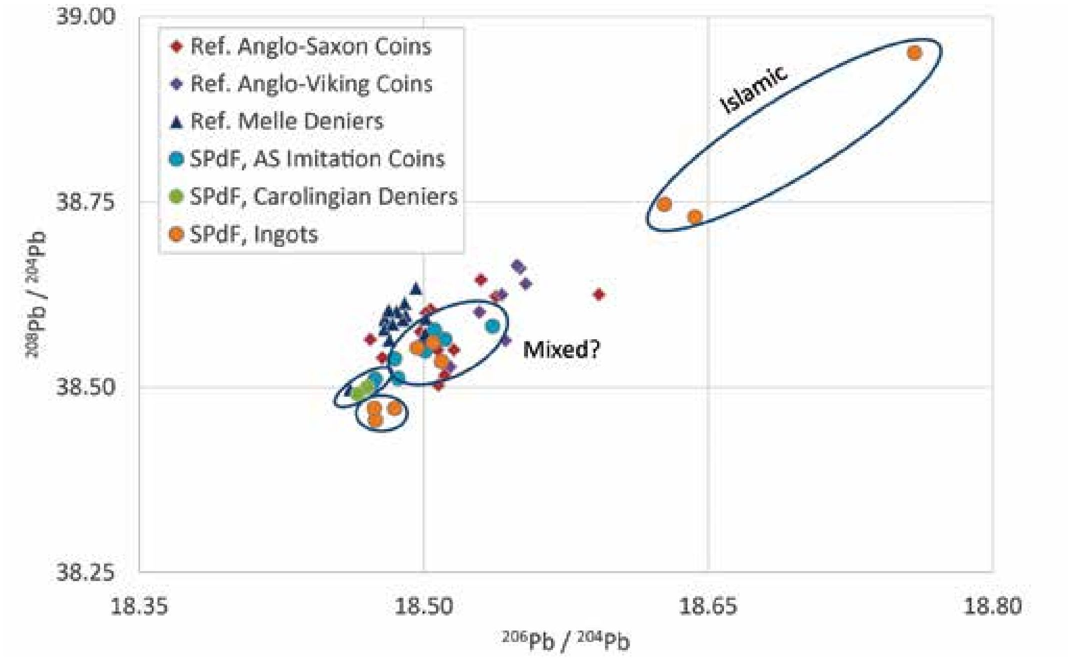


Fig. 7. Lead isotope ratios of hoard items compared with Western European coinage reference data. Anglo-Saxon and Anglo-Viking coins (Kershaw/Merkel 2019b and unpublished data; Ryan et al. 1984). Carolingian Melle deniers (Sarah 2008) (drawn by St. Merkel).

European silver source[47]. Overall, the sources of silver available to the newly established Scandinavian leaders in the Danelaw thus appear to reflect a majority western European source, with a smaller contribution from eastern silver from the Caliphate.

Ingots

The ingots are heterogenous and can be split into three different groups (fig. 6, 7). The first comprises the three ingots which are isotopically distinct from the other hoard items and have Cretaceous model ages (cat nos. 14, 16, 18). All three are regular and finger shaped, with two carrying multiple nicks. Their higher 208/204 and 206/204 lead isotope ratios signal a major contribution of lead coming from silver from the Islamic Caliphate. This is supported by the high bismuth (1000–3500 ppm) and low gold content (< 0.3 %) of two of the ingots (cat nos. 16 and 18), although the third ingot has lower bismuth (400 ppm) and higher gold levels (0.8 %), despite having comparable lead isotope values (fig. 5).
Within our eastern coin dataset, these ingots relate especially closely to a group of mid-to-late ninth-century dirham imitations, which most likely come from Khazaria (fig. 5, 6). Khazaria, north of the Caspian Sea, was an important station on the dirham/furs/slaves trade route connecting the Islamic world to the northern lands. It produced imitation dirhams from the 830s, but especially from the 860s, to fulfil a Scandinavian demand for silver left void by the decline in official Abbasid coin output[48]. Research on the source of silver used for these coins is preliminary, but there are isotopic parallels in ore sources in north and northwest Iran and with dirhams minted in the Lesser Caucasus: Khazar imitation dirhams could thus represent a mixed stock of sources adjacent to the Caspian Sea. This silver could ultimately derive from silver produced in the Islamic territory; however, as a stock, its characteristics indicate that it is derived from a pool of silver sources that is both geographically and chronologically constrained.
It is probable that the two ingots with the low gold values were cast from silver originally deriving from dirham silver, potentially in areas such as the Danelaw but perhaps more likely within Scandinavia, where silver sources appear to have been less diverse. Notably, the fineness of these ingots, 91.3 % and 93.0 % (table 3), is lower than seen among official ninth-century and earlier dirhams, which typically contain just 1–2 % copper, reflecting a usual concentration in the silver after production. However, ninth-century Khazar imitation dirhams usually have 3–4 % copper and can contain as much as 8 %[49]. The high concentrations of copper seen in the ingots do suggest a degree of alloying or contamination. Similar levels of fineness are observed among cast silver artefacts from ninth-century hoards from the Swedish Baltic islands of Gotland and Öland, which also possess lead isotope values that indicate a predomi-

47 Kershaw/Merkel 2019b.

48 Jankowiak in prep.

49 Merkel et al. in prep.

nately eastern, Islamic origin[50]. This suggests the possibility that dirham silver was accidentally contaminated by minor amounts of copper-based alloys during recycling, as might occur if, for instance, silver casting was carried out adjacent to the working of copper alloys and/ or if the same crucibles were used to melt both silver and copper-alloys. The elemental contents of the third ingot, however, may reflect an admixture to dirham silver of Anglo-Saxon and/ or Carolingian silver, and it seems most likely that such an event occurred within the Danelaw.

Three further ingots belong to the isotopically 'mixed group', which also contains many of the Anglo-Scandinavian coins[51]. Two ingots have high gold and low bismuth contents similar to those observed in the Anglo-Scandinavian coinage[52]. However, the 'plaque coupée' with stamped ornament[53] has elemental characteristics more analogous to dirham stocks and, as noted above, plots with the small ingot (Cretaceous Pb model age) group in the lower platinum/ gold alignment in figure 3. The mixed group was interpreted above as a majority Western source with a contribution from Islamic silver. It is possible that, in the case of this item, the eastern, Islamic lead component may have been overshadowed by lead from European sources, in which case the ingot may in fact derive from a majority Islamic source. Whatever the case, the overlap with Anglo-Scandinavian coinage suggests that this ingot group was cast in the Danelaw, using the same or similar silver stocks utilised for the production of coin.

The final group of three ingots comprises two 'regular' ingots and one 'plaque coupée'[54]. They are offset from both Melle and the mixed cluster with lead isotope ratios consistent with British lead. One of these ingots, a 'regular' type[55], has a high lead content (3.4 %) which could mean that the last cupellation was not carried out to completion. The elemental compositions are not clean enough to argue for cupellation directly before casting, but it is possible that these ingots were cupelled (with British lead) prior to alloying with small amounts of copper, which could have introduced a range of elements to the alloy. The source-relevant elements, such as gold and bismuth, parallel many other objects in the Triassic-Jurassic isotope group, suggesting that the ultimate source of the silver is related to Carolingian and/or Anglo-Saxon sources or the 'mixed group', rather than an Islamic silver stock.

Final Comments and Conclusion

Given the large quantities of coin and plate described in written sources as being acquired by Scandinavian raiders during their raids on the Continent, it might be expected that Scandinavian wealth resources in the Danelaw relied wholly or largely on Continental or Anglo-Saxon silver. It is clear that this silver was indeed an important source in the early years following Scandinavian settlement: it is the majority source in the Anglo-Scandinavian imitative coinage, which appears to have been a large and well-controlled series, and can also be identified in a sub-set of ingots. Given that the Anglo-Scandinavian imitative issues emulate Two-Line coins of Alfred of Wessex, it may well be that Alfredian coins – obtained either via trade across the Danelaw 'boundary' or via earlier raiding activity, were used as raw material at the Anglo-Scandinavian mints. It is, however, also likely that wealth accumulated during the decades of raiding in England and on the Continent prior to settlement was funnelled into coin (and bullion) production.

Nevertheless, the most striking finding is that western European silver did not provide the sole raw material for the Anglo-Scandinavian coin economy. In their moderate bismuth contents, the Anglo-Scandinavian coins and 'mixed group' ingots reflect a contribution from Islamic silver, whether in the form of extant dirhams melted down within the Danelaw, or dirham silver cast into artefact forms within Scandinavia and subsequently imported. Two further ingots appear to be made predominantly from dirham silver, potentially from a stock that is similar to silver circulating in Khazaria in the middle of the ninth century, and are likely to have been cast within Scandinavia. It is clear that dirham silver circulated widely within the Danelaw. To date, over 80 dirhams have been found singly in Scandinavian-settled regions of England[56], while 124 dirham fragments have been recorded at the Viking winter camp of Torksey, Lincolnshire (occupied 872/3): important evidence that the Viking Great Army arrived in England with eastern silver, and indeed continued to receive freshly minted dirhams during its campaigns[57]. Dirhams are also a common, though usually modest, component of Viking-Age hoards in Britain and Ireland[58]. Our lead isotope and trace element analysis of later Anglo-Scandinavian coinage from the Danelaw suggest a significant contribution from Islamic silver[59]. The analytical data presented here shows that they were also recycled into new forms of wealth within the early stages of the dual-currency economy of the Danelaw.

Finally, we note that both Anglo-Scandinavian coins and some of the ingots share a common or similar origin, identified above as a mixed silver stock. A similar phenomenon has earlier been observed for Hedeby, where it has been demonstrated that a late ninth-century Scandinavian coin series, the so-called KG 7, was cast from the same eastern silver stock as ingots and hack-silver, with both the coins and part of the bullion likely cast at Hedeby itself[60]. That both coins and bullion derived from the same or similar silver stocks raises important questions concerning the decision to mint coins, the Scandinavian leaders' ability

50 Kershaw et al. in prep b.

51 Cardon et al. 2008, cat. nos. 15, 17, 21.

52 Cardon et al. 2008, cat. nos. 15, 17.

53 Cardon et al. 2008, cat. no. 21.

54 Cardon et al. 2008, cat. nos. 13, 19, 20.

55 Cardon et al. 2008, cat. no. 19.

56 Kershaw 2017.

57 Kershaw 2017; Woods 2020.

58 Naismith 2005; Sheehan 2001, 56.

59 Kershaw/Merkel 2019b.

60 Merkel 2016, 118–120.

and willingness to enforce the use of coin to the exclusion of bullion, and the apparent continued demand for, and use of, bullion even when an official coinage was widely available. Indeed, with official coinage and bullion utilising the same silver stocks and thus being of similar fineness, it is likely that coins and ingots/ hack-silver were weighed together within bullion transactions. The bent and tested condition of the Saint-Pierre-des-Fleurs Anglo-Scandinavian imitations, together with their hoarding with items that could only be traded through weighing and testing, are a reminder that, although a large and organised coinage, Anglo-Scandinavian issues were ultimately treated as bullion in Scandinavian hands. Although produced as a formal and legal exchange medium, the Anglo-Scandinavian issues flowed between coin and bullion economies[61].

Literature

Albarède et al. 2012
F. Albarède, A.-M. Desaulty, J. Blichert-Toft, A geological perspective on the use of Pb isotopes in archaeometry. Archaeometry 54, 2012, 853–867.

Blackburn 2011
M. Blackburn, Viking Coinage and Currency in the British Isles (London 2011).

Cardon et al. 2008
T. Cardon, J. C. Moesgaard, R. Prot, P. Schiesser, Le premier trésor monétaire de type viking en France. Denier inédit d'Eudes pour Beauvais. Revue Num. 6 (164), 2008, 21–40.

Coupland 2011
S. Coupland, A Checklist of Carolingian Coin Hoards 751–987. Num. Chronicle 171, 2011, 203–256.

Cowell/Lowick 1988
M. R. Cowell, N. M. Lowick, Silver from the Panjhir Mines. In: W. A. Oddy (ed.), Metallurgy and Numismatics 2 (London 1988) 65–74.

Diler 2009
O. Diler, Islamic Mints, vol. 1 (Istanbul 2009).

Gratuze et al. 2018
B. Gratuze, C. Guerrot, D. Foy, A. Arles, F. Téreygeol, S. Baron, Les galets de verre au plomb carolingiens issus des scories de Melle : élaboration et distribution. In: M. Bompaire, G. Sarah (eds.), Mine, Métal, Monnaie, Melle. Hautes Etudes médiévales et modernes 111 (Geneva 2018) 87–110.

Ilisch et al. 2003
L. Ilisch, S. Lorenz, W. B. Stern, H. Steuer, Dirham und Rappenpfennig. Mittelalterliche Münzprägung in Bergbauregionen. Zeitschr. Arch. Mittelalter, Beih. 17 (Bonn 2003).

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Jankowiak in prep
M. Jankowiak, Classifying and interpreting Viking-Age dirham imitations. In: M. Jankowiak (ed.), Dirhams for Slaves: Slave Trade between the Islamic World and Northern Europe in the Ninth and Tenth Centuries (in prep).

Flament et al. 2017
J. Flament, G. Sarah, F. Téreygeol, Litharge cakes from Castel-Minier (Ariège, France): Understanding strategies of the cupellation in a multi metals workshop from the 14th century. In: I. M. Ruiz, A. Perea (eds.), Archaeometallurgy in Europe IV (Madrid 2017) 269–281.

Kershaw 2017
J. Kershaw, An early medieval dual-currency economy: bullion and coin in the Danelaw. Antiquity 91, 2017, 173–190.

Kershaw/Merkel 2019a
J. Kershaw, S. W. Merkel, Lead isotope analysis of lead objects from early medieval York. Unpublished Report for the York Archaeological Trust (Oxford 2019).

Kershaw/Merkel 2019b
J. Kershaw, S. W. Merkel, LA-ICP-MS analyses of Anglo-Saxon and Anglo-Viking issue coins from the British Museum. Unpublished Report (2019).

Kershaw et al. in prep a
J. Kershaw, S. W. Merkel, A. Matzen, Elemental LA-ICP-MS analysis of Anglo-Saxon coins in the Watlington, Oxfordshire, hoard (in prep).

Kershaw et al. in prep b
J. Kershaw, S. W. Merkel, J. Oravisjärvi, E. Koojiman, M. Kielman, The scale of dirham imports to the Swedish Baltic in the ninth century: new evidence from archaeometric analyses of early Viking-Age silver (in prep).

Kershaw/Merkel in prep
J. Kershaw, S. W. Merkel, Lead isotope analysis of lead objects from Viking Great Army winter camp at Aldwark, North Yorkshire (in prep).

Le Maho 2005
J. le Maho, Les Normands de la Seine à la fin du IXe siècle. In: P. Bauduin (ed.), Les fondations scandinaves en Occident et les débuts du duché de Normandie (Caen 2005) 161–179.

L'Héritier et al. 2015
M. L'Héritier, S. Baron, L. Cassayre, F. Téreygeol, Bismuth behaviour during ancient process of silver-lead production. Journal Arch. Scien. 57, 2015, 56–68.

Lowick 1976
N. Lowick, The Kufic coins from Cuerdale. British Num. Journal 46, 1976, 19–28.

McKerrell/Stevenson 1972
H. McKerrell, R. B. K. Stevenson, Some analyses of Anglo-Saxon and associated oriental silver coinage. In: E. T. Hall, D. M. Metcalf (eds.), Methods of Chemical and Metallurgical Investigation of Coinage (London 1972) 195–209.

Metcalf/Northover 1988
D. M. Metcalf, P. Northover, Carolingian and Viking Coins from the Cuerdale Hoard: An Interpretation and Comparison of their Metal Contents. Num. Chronicle 148, 1988, 97–116.

Moesgaard 2007
J. C. Moesgaard, A Survey of Coin Production and Currency in Normandy, 864–945. In J. Graham-Campbell, G. Williams (eds.), Silver Economy in the Viking Age (Walnut Creek 2007) 99–122.
Merkel 2016
S. W. Merkel, Silver and the Silver Economy at Hedeby (Rahden/Westf. 2016).
Merkel 2017
S. W. Merkel, Between the Bronze Age and the Middle Ages: New Investigations of Slag from Panjhir, Afghanistan. In: P. Eisenach, Th. Stöllner, A. Windler (eds.), The RITaK Conferences. Der Anschnitt, Beih. 34 (Rahden 2017) 271–283.
Merkel 2019
S. W. Merkel, Provenancing Viking Age silver: methodological and theoretical considerations and a case study. In: J. Kershaw, G. Williams (eds.), Silver, Butter, Cloth: Monetary and Social Economies in the Viking Age (Oxford 2019) 206–226.
Merkel et al. 2015
S. W. Merkel, B. Bräutigam, S. Klein, A. Hauptmann, The Analysis of Slag from the Panjhir Mining Region, Afghanistan: An Investigation of (Medieval) Silver Production Technology. Arch. Mitt. Iran u. Turan 45, 2013, 231–249.
Merkel et al. in prep.
S. W. Merkel, J. Oravisjärvi, J. Kershaw, Lead isotope analysis of silver reveals Islamic wealth (in prep).
Naismith 2005
R. Naismith, Islamic coins from early medieval England. Num. Chronicle 165, 2005, 193–222.
Naismith 2017
R. Naismith, Medieval European Coinage, with a catalogue of the coins in the Fitzwilliam Museum Cambridge 8, Britain and Ireland c. 400–1066 (Cambridge 2017).
Pedersen et al. 2016
U. Pedersen, T. Andersen, S. Sionsen, M. Erambert, Lead isotope analysis of pewter mounts from the Viking ship burial at Gokstad: on the origin and use of raw materials. Archaeometry 58, 2016, 148–163.
Pernicka 2014
E. Pernicka, Provenance Determination of Archaeological Metal Objects. In: B. W. Roberts, C. P. Thornton (eds.), Archaeometallurgy in Global Perspective: Methods and Syntheses (Heidelberg 2014) 239–268.
Pernicka/Bachmann 1983
E. Pernicka, H.-G. Bachmann, Archäometallurgische Untersuchungen zur antiken Silbergewinnung in Laurion. III. Das Verhalten einiger Spurenelemente beim Abtreiben des Bleis. Erzmetall 36 (12), 1983, 592–597.
Rohl 1996
B. M. Rohl, Lead isotope data from the Isotrace Laboratory, Oxford: Archaeometry database 2, galena from Britain and Ireland. Archaeometry 38, 1996, 165–180.
Ryan et al. 1984
M. Ryan, R. Ó Floinn, N. Lowick, M. Kenny, P. Cazalet, Six Silver Finds of the Viking Period from the Vicinity of Lough Ennell, Co Westmeath. Peritia 3, 1984, 334–381.
Sarah 2008
G. Sarah, Caractérisation de la composition et de la structure des alliages argent-cuivre par ICP-MS avec prélèvement par ablation laser. Application au monnayage carolingien (PhD Thesis, Université d'Orléans) tel-00391932.
Sarah 2010
G. Sarah, Charlemagne, Charles the Bald and the Karolus Monogram coinage, a multi-disciplinary study. The Num. Chronicle 170, 2010, 227–286.
Sarah 2019
G. Sarah, From Local Supply to Long-Distance Trade Networks: Fingerprinting Early Medieval Silver. In: J. Kershaw, G. Williams (eds.), Silver, Butter, Cloth: Monetary and Social Economies in the Viking Age (Oxford 2019) 189–205.
Sarah/Gratuze 2016
G. Sarah, B. Gratuze, LA-ICP-MS Analysis of Ancient Silver Coins Using Concentration Profiles. In: L. Dussubieux, M. Golitko, B. Gratuze (eds.), Recent Advances in Laser Ablation ICP-MS for Archaeology (Berlin/Heidelberg 2016) 73–87.
Standish et al. 2021
C. Standish, S. Merkel, Y. T. Hsieh, J. Kershaw, Simultaneous lead isotope ratio and gold-lead-bismuth concentration analysis of silver by laser ablation MC-ICP-MS. Journal Arch. Scien. 125, 2021, 105299.
Sheehan 2001
J. Sheehan, Ireland's Viking-age hoards: sources and contacts. In: A. Larsen (ed.), The Vikings in Ireland (Roskilde 2001) 51–59.
Stos-Gale 2004
S. Stos-Gale, Lead isotope analyses of the lead weights from Birka, Sweden. In: I. Gustin (ed.), Mellan gåva och marknad: handel, tillit och materiell kultur under vikingatid (Stockholm 2004) 324–332.
Téreygeol et al. 2005
F. Téreygeol, S. Hoelzl, P. Horn, Le monnayage de Melle au haut Moyen Age: état de la recherche. Bull. Assoc. des Archéologues de Poitou-Charentes 34, 2005, 49–56.
Thomalsky et al. 2015
J. Thomalsky, B. Bräutigam, M. Karaucak, S. Kraus, Early Mining and Metal Production in Afghanistan: The First Year of Investigation. Arch. Mitt. Iran u. Turan 45, 2013, 199–230.
Todt et al. 1996
W. Todt, R. A. Cliff, A. Hanser, A. W. Hofmann, Evaluation of a 202Pb-205Pb double spike for high-precision lead isotope analysis. Geoph. Monog. Series 95, 1996, 429–437.
Tor 2002
D. G. Tor, A Numismatic History of the First Saffarid Dynasty (AH 247–300/AD 861–911). The Num. Chronicle 162, 2002, 293–314.
Wiechmann 1996
R. Wiechmann, Edelmetalldepots der Wikingerzeit in Schleswig-Holstein. Vom „Ringbrecher" zur Münzwirtschaft. Offa-Bücher 77 (Neumünster 1996).
Woods 2020
A. Woods, Viking economies and the Great Army. Interpreting the precious metal finds from Torksey, Lincolnshire. In: J. Gruszczyński, M. Jankowiak, J. Shepard (eds.), Viking-Age Trade: Silver, Slaves and Gotland (Abingdon 2020) 396–414.