Mobility and the reuse of Roman Roads for the deposition of Viking Age silver hoards in North West England

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Abstract

Discussions on Viking Age silver hoards in North West England have been dominated by analysis of the material compositions of the hoards. Despite a multi-century research legacy concerning the material composition of the Viking Age silver hoards, the relationship of the hoards to their transport and depositional locations has been understudied. Past analyses of the hoards' material composition have indicated that some or all of their components were likely transported overland across the Pennines to their depositional points in the North West. The relationship of the hoards to the early medieval overland transport links is studied in this paper with an optimal pathways modelling process in Geographic Information Systems (GIS). The modelling process incorporates multiple cost of vertical movement functions to simulate human agency when moving through the landscape, error inherent in the Digital Elevation Model creation process, and preferential movement on re-used Romano-British roads. As a result of this analysis, it is suggested that the median travel time from early medieval period routeways to the hoard deposition points is 16 minutes. Over half of the hoards may have been placed under 25 minutes' walk from the routeways. This finding supports an interpretation that the hoards are concealed deposits intended for retrieval, rather than ritual deposits that were not intended for retrieval.

Introduction

There are 18 Viking Age silver hoards known in England's North West (the historic counties of Lancashire, Cheshire, and Cumbria). These Viking Age silver hoards are temporally concentrated in the Tenth century and demonstrate the Vikings' material wealth and far-reaching communication network (Kershaw 2017*a*). The silver discovered in the North West ranges in provenance from as near as the Scandinavian-controlled Northumbrian Kingdom in York, and as far away as the Middle East (Graham-Campbell 2011, Kershaw 2017*a*, Kershaw *et al.*, 2021). The North West is a region of considerable interest for the study of Viking Age silver hoarding, as it has been the context from which numerous Viking-character hoards have been found since the 1600s. The North West is the region where the largest Viking-character silver hoard in the British Isles was found, Lancashire's *c.* 42.6-kilogram Cuerdale Hoard. The hoards in the North West could be of Anglo-Scandinavian or Hiberno-Norse origin (Graham-Campbell 2011, Williams 2011, Williams 2020). There was a substantial exchange of silver across the Pennines in the Viking Age. The numismatic components of several Viking-character hoards in the North West originated in York, while substantial quantities of Hiberno-Norse metalwork have been discovered in Yorkshire (Graham-Campbell 2011, Williams 2011, Edmonds 2020). This apparent exchange of metalwork across the Pennines coincided with the Viking control of and alliance between the 'linked' kingdoms in York and Dublin.

Alongside strong implications of the flow of metalwork across the Pennines, recent investigations into the early medieval routeways and communications systems in the North West have yielded a list of known Tenth-century transport nodes (Edmonds 2020) that are presumed to have been in use at a contemporary date to the deposition of the silver hoards. Specifically, communications systems formed of the framework of the remaining Romano-British road network may have facilitated exchange of silver

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across the Pennines between York and Dublin (Williams 2009, Graham-Campbell 2011, Kershaw 2017*a*). The remnants of the Romano-British road network may have been maintained in the early medieval period for efficient overland transport across the Pennines (Edmonds 2020). Despite the knowledge that the cross-Pennine communications network existed in part on re-used Romano-British roads where available, the specific courses of early medieval period routes are not known. The uncertainty in routeway positioning is due to the fragmentary nature of current knowledge on Romano-British road courses and the possibility that previously-unmentioned transport nodes exist.

This paper builds on previously-published research in this subject area and is formed on the premise that artefacts in Viking Age silver hoards may have been related to cross-Pennine communication routes between York and the North West on a re-used Roman Road system. There are two principal questions that are explored in this paper. The first of these is 'how do the hoards with known locations relate to early medieval period routeways leading away from York'? The second of these questions is 'can the hoards' relationships with cross-Pennine routeways be interpreted as a means for concealment away from the routeways'? To answer these questions, a bespoke Geographic Information Systems (GIS) modelling process was developed in ArcGIS Pro 3.0 and Jupyter notebooks. This process uses a Least Cost Pathways (LCP) methodology that takes into account human agency realized with multiple cost of movement functions, random errors inherent in the Digital Elevation Model (DEM) creation process, the visualization of uncertainty in LCP modelling using rasterized line densities, and recently re-discovered fragments of Roman Road that have been observed in the last decade via Remote Sensing methods and archaeological excavation (Ratledge 2023).

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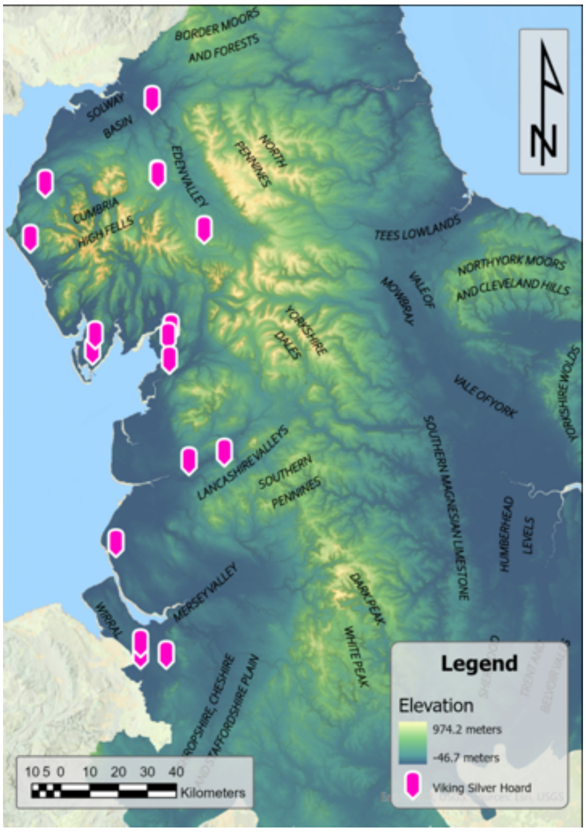

Figure 1 – Viking Age silver hoards in North West England. Note the distribution of hoards to the west of the Pennines range. Multiple hoards are located in close proximity (under one kilometer) in Flusco Pike (2) near the Eden Valley and Chester (2) south of the Wirral Peninsula. The 'Lancashire' Hoard, reported by antiquarian Beaupré Bell in 1734 (*c.f.* Blunt and Stewart 1983), does not have a precise grid reference due the circumstances of its discovery in the Eighteenth-century.

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Background

Archaeological Context

Linked Kingdoms of York and Dublin

The North West at the start of the Tenth-century has been seen as an intermediary landscape between the Irish Sea and Viking-controlled Dublin, Anglo-Saxon Mercia, and in the Viking administration in York (Higham 1992, Higham 2004, Higham 2006). In 902 AD, Norse Vikings were famously expelled from Dublin, and are presumed to have landed on the western shores and rivers of Cheshire, Lancashire, and Cumbria (Wainwright 1975, Winchester 1985, Higham 1992, Williams 2009, Graham-Campbell 2011, Lewis 2016). A legacy of Scandinavian settlement in the North West is apparent in the decades of the Tenth and Eleventh-centuries, with place names of Scandinavian origin abundant in the region (Roberts 1990, Fellows-Jensen 1989, Griffiths 2004). The Norse-aligned *Uí Ímair* dynasty are pointed to by scholars as the ruling faction in York until *AD* 954 (Smyth 1977, Downham 2007, Nebolini 2022) and are believed to have maintained links with the expelled Dublin Norse in *AD* 902 (Higham 1992, Downham 2007).

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Communication routes between the Northumbria and the North West

The most direct communication routes between York and Dublin lie in the North West. Distributions of Neolithic Group VI (Langdale) axes occur on both sides of the Pennines (Fox 1933, Bradley and Edmonds 1993). In the Viking Age, trans-Pennine routes may have been central to the ability of York and Dublin Scandinavians to communicate (Higham 1992, Graham-Campbell 2011). Important routes ran across the Pennines to Clitheroe on Romano-British roads (Higham 1998, Edwards 1998) and north-south between the Ribble Valley and Cumbria (Graham-Campbell 2011, Edmonds 2020). In addition, a log of early medieval transport nodes leading from Northumberland to the North West is set out by Edmonds (2020). Ratledge (2023) has published a number of complete and fragmental Romano-British road network courses in Lancashire, Cumbria, and Yorkshire, following an investigation of LiDAR (Light Detection and Ranging) survey data in GIS. These road courses are often revised or depicted in higher detail than those set out by Margary (1955). Metal detected single finds reported to England's Portable Antiquities Scheme (PAS) are often distributed near Romano-British roads, although no formal correlation has been established (Richards, Naylor, and Holas-Clark 2009).

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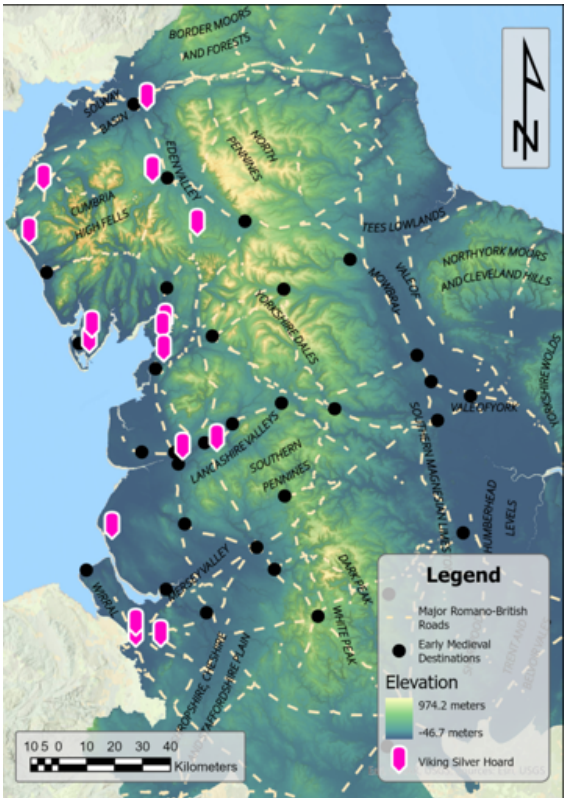

Figure 2 – Early Medieval period destinations plotted with major Romano-British road courses.

Silver economies of Northern England

In Northern England in the early tenth century, three silver economies are archaeologically-attested – an ornament economy, a coin economy, and a bullion economy (Williams 2009, Graham-Campbell 2007, Graham-Campbell 2011, Kershaw 2017*a*, 2017*b*). Anglo-Scandinavian coinage was struck in York from the mid-late Ninth-century (Blackburn 2004) and was adopted in Ireland in the late Tenth-century (Woods 2014). Silver bullion was used as a currency alongside coinage in Northern England in the late Ninth to mid Tenth-centuries (Kershaw 2017*b*). Silver bullion in the Danelaw was commonly-traded according to set weights, and was often hacked with a type of chisel to break the silver piece into smaller weight units (Kershaw 2017*b*). Complete silver ingots in the North West weigh approximately 25 grams (Kershaw 2017*a*). In the Danelaw, copper alloy weights have been found as single finds, with 0.75 gram and 4.5 gram cubo-octohedral copper-alloy weights found, and *c.* 10-40 gram oblate-spheroid copper-alloy weights found (Kershaw 2017*b*). Additionally, an ornamental silver economy is apparent in areas of Viking settlement, and likely existed alongside the bullion and coin economy (Williams 2009, Graham-Campbell 2011).

Hoard Composition

The composition of Viking-character silver hoards in North West England fall into three categories:

1) Ornamental hoards that contain complete silver ornaments traded by display value,
2) Bullion/hack-silver hoards that contain silver (including coins) traded by weight value,

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Horne, Tom. A Viking Market Kingdom in Ireland and Britain: Trade Networks and the Importation of a Southern Scandinavian Silver Bullion Economy. 1st edition. Routledge, 2021.

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3) Mixed bullion hoards that contain both ornaments and hack-silver.

The 42.6 kilogram mixed-category Cuerdale Hoard (Lancashire) dates from approximately *AD* 905-910 and contained a broad range of silver pieces in a lead container, with many silver ornaments, bullion pieces, and around 7,500 coins. Many of the coins deposited in the Cuerdale Hoard were freshly-minted in York preceding its deposition (Archibald 1992, Graham-Campbell 2011, Williams 2020).

The mixed-category Silverdale Hoard (Lancashire) dates from around *AD* 910 and is largely of similar composition to the Cuerdale Hoard, although its weight is roughly 1/42nd of the Cuerdale Hoard. The Silverdale Hoard features several particularly remarkable broad-band and penannular arm rings, comparable to those found at Cuerdale and the Hare Island Hoard in Ireland. The Silverdale Hoard also featured numerous ingots and bullion, around 20 coins, and fragments of a lead container (Broughton 2011). One of the coins from Silverdale is a likely Northumbrian issue and references a previously-unknown Norse-Northumbrian ruler *'Iredeconvt'/'Harthacnut'* (Broughton 2011). The bullion-category Huxley Hoard (Cheshire) contained numerous bullion pieces including flattened bracelets, a piece of hacked bracelet, an ingot, and fragments of a lead box (Oakden 2014).

Figure 3 – The Silverdale Hoard, a mixed bullion hoard featuring intact ornaments (such as arm rings) and hack-silver pieces. Image: *Boughton, D (2011) "LANCUM-65C1B4: A EARLY MEDIEVAL HOARD". Portable Antiquities Scheme, 2022.*

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Figure 4 – The Silverdale Hoard's lead container and various pieces of hack silver displayed at the Jorvik Viking Centre, York, England. Image: Author's own, 2022.

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Figure 5 – The Huxley Hoard. Note the flattened arm rings used as silver bullion, and fragments of lead box. Image: *Oakden, V (2014) "LVPL-C63F8A: A EARLY MEDIEVAL HOARD". Portable Antiquities Scheme, 2022.*

Figure 6 – The Cuerdale Hoard. Hack silver and ornaments from the *c.* 42.6 kilogram hoard on display at the British Museum, London, England. Image: Author's own, 2022.

Concealed versus ritual deposits

Ritual deposition of artefacts in wetlands is a well-known phenomenon in Viking Age Britain (Raffield 2014, Bradley 2017). In England, ritual deposition of objects in the Viking Age may have been related to wetlands, marshes, and blown sand environments, and often involves weapon deposits (Raffield 2014). In the case of silver hoards, Bradley (2017) notes that the material composition of whole and fragmentary metalwork is suggested to indicate that the hoard is non-ritual in nature. Additionally, research on Viking Age silver hoards in Gotland has demonstrated that those non-ritual deposits intended for safekeeping and retrieval were often placed in containers (Grusczcynski 2017).

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Methodology

Two principal methodological steps are key to address the research questions that drive this paper. The first of these is the creation of a suite of probabilistic LCPs displayed as line densities to describe movement between early medieval period transport nodes derived from Edmonds (2020). The second of these is the depiction of optimal paths line densities leading from the points of highest-density travel near the hoard locations to the hoard's depositional points. The GIS modelling process was implemented using ArcGIS Pro 3.0 geoprocessing tools within a Juptyer notebook.

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Creation of optimal paths

A methodology was devised to create a network suite of probability-based optimal paths that depict varying densities of travel. The base logic of the model is the use of a Monte Carlo simulation to account for error in the creation of the Digital Elevation Model (DEM) (*c.f.* Lewis 2021), multiple costs of movement functions to simulate human agency as slope is encountered, and the use of magnitude-per-unit area calculations to describe line density. The model was weighted to preference sections of digitized Romano-British roads derived from recent work by Ratledge (2023), such as the re-discovered fragments of the Lancaster-Kendal route. Five model simulations were completed to accommodate the available computing resources required to simulate random errors inherent in DEM creations.

Costs of horizontal and vertical movement

For travel on a Romano-British road course, a factor of 1.0 was applied. For travel off Romano-British road courses, a factor of 1.1 was applied. These factors were rasterized across the study area for application as the cost of horizontal movement in the model. Ramsar Wetlands of International Importance in England were used in the model as barriers to horizontal movement. These wetlands were applied in raster format, derived from a base dataset (Natural England, 2021) in shapefile format.

Three equations that describe the costs of vertical movement with respect to slope were used in the model. The first equation used in this model is Tobler's (1993) hiking function, given as *Equation* (1).

(1) $V(s) = 6*\exp(-3.5*\mathrm{abs}(s+0.05))$

The second equation used was the modified version of Tobler's hiking function (Márquez-Pérez *et al.*, 2017), given as *Equation* (2).

(2) $V(s) = 4.8*\exp(-5.3*\mathrm{abs}((s*0.7)+0.03))$

The third equation used to describe the cost of vertical movement was the sixth-degree polynomial following Minetti *et al.* (2002) and Herzog (2010) given below as *Equation* (3).

(3) $Cost(s) = 1337.8\, s^6 + 278.19\, s^5 - 517.39\, s^4 - 78.199\, s^3 + 93.419\, s^2 + 19.825\, s + 1.64$

Model iteration process

It is recognized that the standard errors inherent in the DEM creation process have the potential to change modelling outcomes, particularly in the case of viewshed studies (Fisher 1993) and LCP studies (Lewis 2021). Monte Carlo simulation is an accepted method of describing multiple outcomes in the modelling process (Fischer 1993, Lewis 2021) and is used here to address multiple equally probable outcomes in LCP creation. The base DEM used for this model was the United Kingdom Ordinance Survey Terrain-50 DEM product, which has a standard error of ±4m. The model was automated using a Monte Carlo simulator within ArcGIS Pro 3.0's Jupyter notebooks functionality. For each iteration, the base DEM was combined with a second DEM consisting of solely random errors according to the base DEM's standard deviation (*c.f.* Lewis 2021). One optimal path per route pairing was created for each of the three employed cost functions, using the 'Distance Accumulation' and 'Optimal Path as Line' tools in the Spatial Analyst toolkit. The Distance Accumulation tool utilizes Sethian's (1999) interpretation of the Eikonal Equation. Across five iterations of the Monte Carlo simulation, fifteen optimal paths were created per route pairing.

The steps performed by the iterating process to create the optimal paths are as follows:

1. A base DEM (OS Terrain-50) was interpolated to discrete point data and combined with random errors of ±4m to yield a new DEM with incorporated random errors.
2. The Surface Parameters Slope tool was applied to the random errors DEM to calculate degrees of slope across the DEM.
3. The Surface Parameters Aspect tool was applied to the random errors DEM to calculate the direction of downslope change in the DEM as a compass angle.
4. The on-path/off-path factors raster was given as the cost of horizontal movement.
5. The cost of vertical movement from each of *Equation* (1,2,3), respectively, was implemented in a Vertical Factor spreadsheet and used in alternating model runs.
6. One pathway was given per cost function per set of early medieval period transport hubs.

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Same as above for using functions for non-foot traffic to expand this and make it more robust for various scenarios.

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And the movecost package in R.

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Conversion to rasterized line densities

The model outputs were stored as polyline features in a geodatabase and converted to line densities. The line densities displayed areas of highest-probability traffic flow following the Monte Carlo simulation of multiple cost of vertical movement functions. Line densities were computed as a raster with magnitude-per-unit area values using the Line Density tool in ArcGIS Pro 3.0's Spatial Analyst toolkit. The line densities were computed according to *Equation* (4). The equation calculates for every cell the density of polyline features within a set neighborhood radius (*c.f.* Silverman 1986),

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(4) $$\text{Density} = ((L1 * V1) + (L2 * V2)) / (\text{neighborhood radius})$$

where L1 and L2 are the lengths of portions of lines that lie within the neighborhood radius, and V1 and V2 are magnitude values. In this case, no special weighting was added to the magnitude values and each pathway was considered equally. The neighborhood radius needs to be sufficient to account for the width of possible two-dimensional variation in course of the optimal paths. In this study, the neighborhood radius was set to 100 meters to account for all variations in course.

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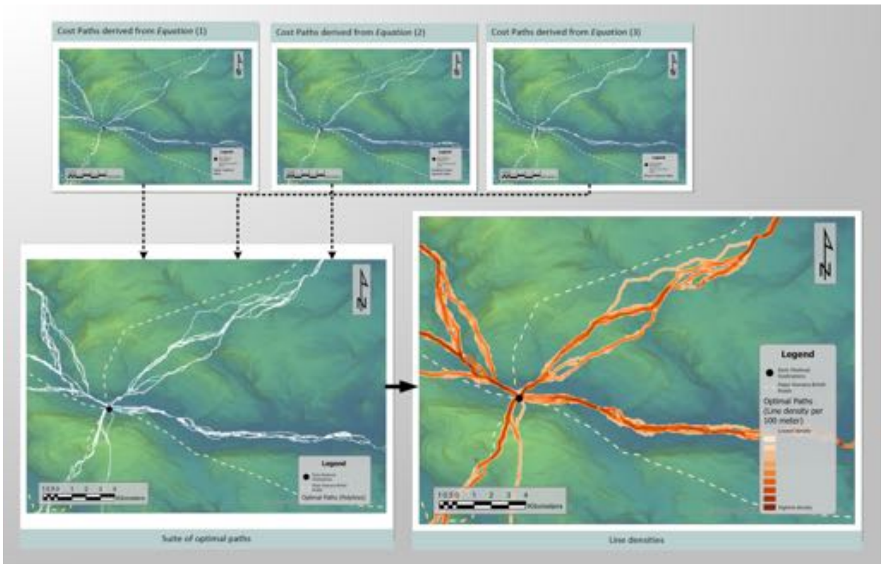

Figure 7 – The optimal paths modelling workflow. Paths formed from the cost of vertical movement according to *Equations* (1), (2), and (3) across all iterations (*n* = 5) are combined into an overall suite of optimal pathways. The suite of optimal pathways is converted into a line density raster according to *Equation* (4).

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Departure pathways modelling

To analyze the relationship of the hoard depositional points to the generated optimal paths, two analytical methods were employed. Five departure points set at regular intervals of 100-meters were generated along the highest optimal path densities at a perpendicular angle to the hoard locations. These departure points were used to calculate optimal paths using the same modelling process as above, from the areas of highest density to the hoard depositional points. Walking times in this analysis were estimated assuming an average walking speed of 1.4 meters per second.

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Results

Optimal Path Performance

The network suite of optimal paths largely mirrors the Romano-British roads on a regional scale. However, in some instances, the optimal paths deviate from the Romano-British road courses (see discussion of *waingates* below). Many of the routes showed evidence for early medieval period use. In particular, routes from Aldborough to Ilkley, Ilkley to Preston, Penrith to Ingleton, Kendal to Barrow-in-Furness, and Broughbridge to Richmond showed positive evidence for use in the early medieval period. Furthermore, this analysis finds that the silver hoard depositional locations are placed with a median walking time of 16 minutes away from the routeways depicted in this model.

Relationship of routeways to Single Finds

Single finds from the PAS are typically recovered by metal detectorists and can be viewed as artefacts which have likely been accidentally lost by their owners, perhaps while travelling through the landscape (Kershaw 2017*a*). The distribution of PAS single finds are biased towards metal detecting tendencies, the availability of permission to detect in certain areas, and Romano-British road courses (Richards, Naylor, and Holas-Clarke 2009). However, the presence of single finds in an area can be viewed as positive indicators that activity took place within a landscape. Single finds from the early medieval period were found to relate to several of the high-density optimal paths in this modelling process and are presented here as one means of model performance assessment.

The Ilkley-Aldborough Pennine crossing contained several single finds that were used to validate model performance. Four early medieval period single finds are recorded south of the Romano-British road line and near the optimal paths in this model. The first is a cast lead weight (PAS 'Find-ID' SWYOR-6F5978) of 22 grams that is thought to date from *AD* 850-1000, and has been compared to Hiberno-Norse weights of the same mass (Downes 2020). The second single find is a Ninth-century Carolingian copper-alloy brooch (SWYOR-906685) that may have arrived in England from Viking activity (Downes 2008). The third of these is an incomplete bowl mount (YORYM-0A4CAE) dating from *c. AD* 600-800. Finally, a *c. AD* 750-950 copper alloy Thomas Class A, Type 2 strap end (YORYM-2EE1EE) was recorded near the optimal paths.

In the Lancashire and Cumbrian routes, single finds were also closely associated with the model outputs. The optimal paths between the Ribble Valley and Ilkley contained six Viking Age single finds distributed within *c.* 500-meters from the points of highest density. These artefacts included two copper ingots (LANCUM-53BBB4, LANCUM-9CB512), a Swedish-Varangian style scabbard (LANCUM-692561), and a late Tenth-century Petersen Type X sword pommel (LANCUM-682DB1). On the north-south route that runs between Penrith and Ingleton, a gold Viking-type finger ring (LANCUM-ED5E96) was found that parallels forms from Ireland in the late Ninth and early Tenth-centuries (Boughton 2008). Routes from Kendal to Barrow-in-Furness and Lancaster demonstrated positive evidence for stray object loss with both a Viking-import Irish stick pin (LANCUM-332D63) and a 10th-11th-century quillion (LANCUM-F7D49D) recorded in the PAS.

Comparison with documentary and placename evidence

The optimal paths in this model additionally performed well in Lancashire when compared to post-medieval documentary evidence. The antiquarian John Leland famously recorded the route taken northwards from Preston towards Lancaster (Smith 1909). Leland gave particular mention to bridges and distances travelled. In *c.* 1540, Leland writes that he crossed the Savick Brook 'one mile without Preston'. It is recorded by Ratledge (2023) that the Romano-British road that passes through Moor Park in Preston crosses another Romano-British road (modern Watling Street Road) near the Savick Brook. This crossing point is presumably the crossing point that Leland used, as it sits nearly 0.95 miles north of the post-medieval boundary of Preston in the Moor Hall/Gallows Hill area. The optimal paths in this model performed well in this context, as the paths crossed Savick Brook at the same point as Leland in the 16th-century.

Optimal paths across most iterations divert north near the modern village of Roecliffe (North Yorkshire), away from the small wetland at the River Tutt. Waingates Lane is located northwards of the small wetland in this location. A *waingate* is defined as a 'wagon street', a placename believed to date

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from *c.* 1700 originating from Yorkshire's West Riding (Smith 1961). Here, the denoted 'wagon street' diverts *c.* 200-meters from the Romano-British road course and may be associated with poor drainage near the River Tutt. The modelled optimal paths reflect this local topography and placename by also diverting northwards.

Hoards' relationship to routeways

Areas of high-density early medieval period travel suggested by this modelling process are located up to *c.* 60 minutes' walk from the depositional points of Viking Age silver hoards in North West England. A concentration of 11 hoards in the North West were located in the sub-25 minute travel time range. Furthermore, all hoards that are known to have been deposited with containers (*n* = 5) were located in the sub-25 minute travel time range.

	Name	County	Category	Deposition Date Range (AD)	Container	Off-path travel time (minutes)
1	Cuerdale	Lancashire	Mixed	905-910	Lead	20.6
2	Huxley	Cheshire	Bullion	900-910	Lead	10.1
3	Silverdale	Lancashire	Mixed	900-910	Lead	5.9
4	Harkirk	Lancashire	Mixed	910-915		16.0
5	Dean	Cumbria	Coin	915-925	Lead	16.1
6	Lancashire	Lancashire	Coin	910-920		
7	Chester (St. John)	Cheshire	Coin	915-920		0.5
8	Warton/Carnforth	Lancashire	Mixed	920-929		10.4
9	Flusco Pike (2)	Cumbria	Mixed	920-929		32.0
10	Scotby	Cumbria	Mixed	935-940		60.9
11	Flusco Pike (1)	Cumbria	Ornament	920-939		29.6
12	Orton Scar	Cumbria	Ornament			37.0
13	Eccleston	Cheshire	Bullion			10.5
14	Barrow-in-Furness	Cumbria	Mixed	900-930		46.8
15	Chester (Castle Esplanade)	Cheshire	Mixed	965-970	Pot	4.0
16	Halton Moor	Lancashire	Mixed	1025-1030	Silver Cup	16.2
17	West Coast Cumbria	Cumbria	Mixed	850-950		55.2
18	Furness	Cumbria	Mixed	955-957		17.6

Table 1 – Approximate off-path travel times from the optimal paths to the hoard locations, given in minutes.

Hoards related to cross-Pennine routes were the Cuerdale, Halton Moor, Scotby, both Chester hoards, and both Flusco Pike hoards. The Scotby Hoard is related to routes at the Tyne Gap. The Flusco Pike hoards are related to routes in the Eden Valley. The Cuerdale Hoard is related to routes in the Pennine Dales Fringe and Lancashire Valleys. The Chester hoards are related to routes through the Southern Pennines.

Hoards related to North-South travel along the west coast of Lancashire are Silverdale, Wharton/Carnforth, and Halton Moor. Hoards related to the West Cumbria Coastal Plain North-South routes are the Dean and West Coast Cumbria Hoards. The Huxley and Eccleston hoards are likely related to travel south from Cumbria.

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Commented [SL61]: Refer to the table here.

Commented [SL62]: Do you think that the other hoards sub-25 minutes might therefore have had containers which are no longer archaeological visible? Bags or baskets for instance? Worth considering!

Commented [SL63]: Again point to your table to SHOW this rather than just stating it.

Commented [SL64]: Aha! Need to point to this table earlier on where I asked for one :)

Commented [SL65]: Refer to images (likely some that you need to add in) to show these relationships.

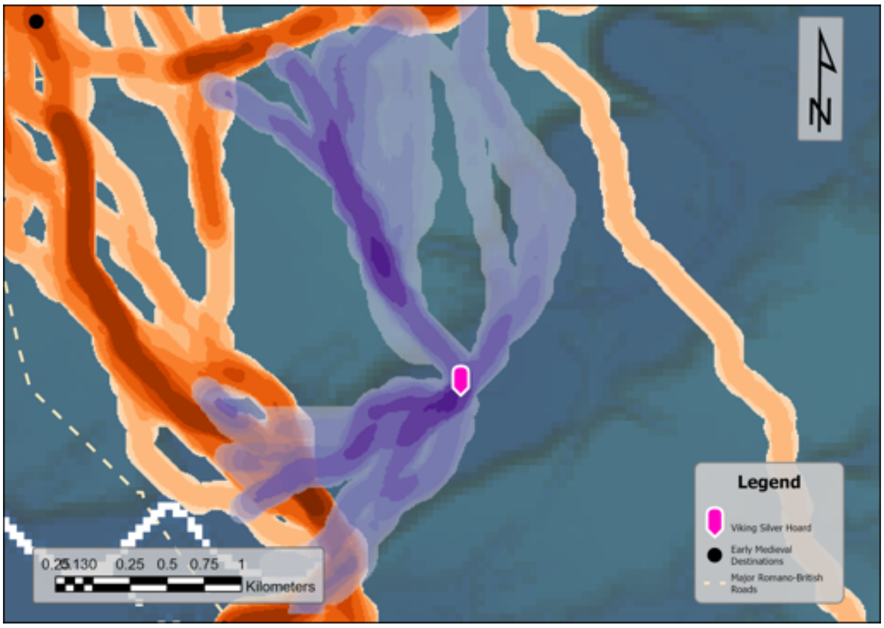

Figure 8 – Off-path departure line densities leading to the Cuerdale Hoard. Routeways between Early Medieval Destinations are shown in orange, with segments of highest density shown in dark red, and segments of low density shown in light red. The off-path departure points are shown in violet, with highest density segments in dark violet, and lowest density segments in light violet.

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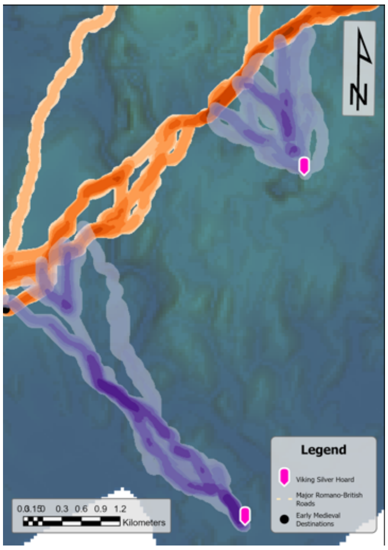

Figure 9 – Off-path departure line densities leading to the Furness and Barrow-in-Furness Hoards. Routeways between Early Medieval Destinations are shown in orange, with segments of highest density shown in dark red, and segments of low density shown in light red. The off-path departure points are shown in violet, with highest density segments in dark violet, and lowest density segments in light violet.

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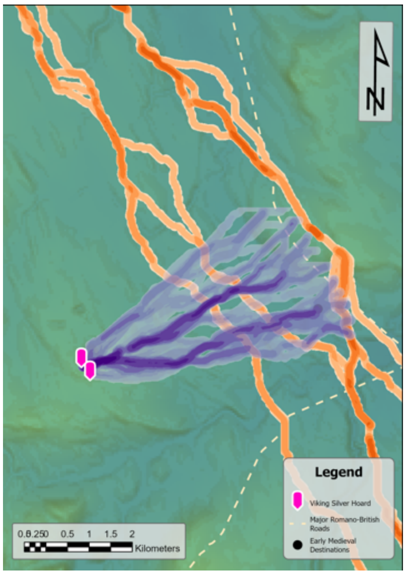

Figure 10 – Off-path departure line densities leading to the Flusco Pike Hoards. Routeways between Early Medieval Destinations are shown in orange, with segments of highest density shown in dark red, and segments of low density shown in light red. The off-path departure points are shown in violet, with highest density segments in dark violet, and lowest density segments in light violet.

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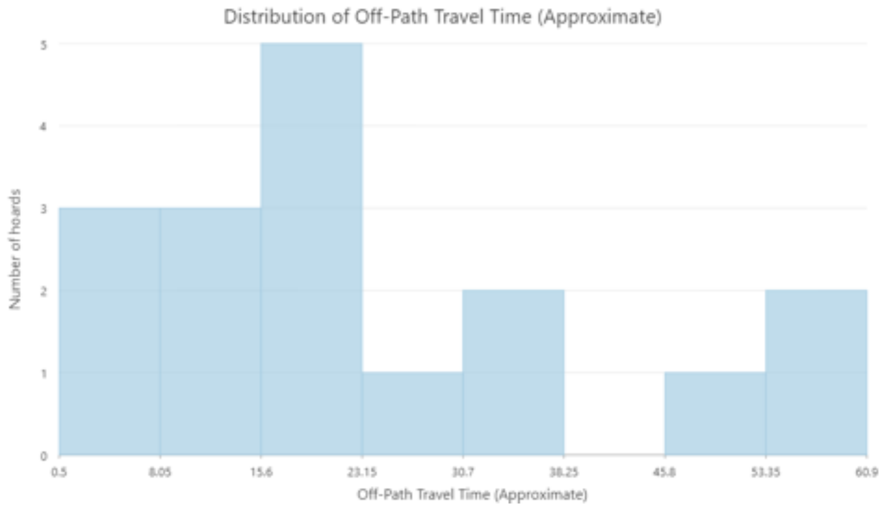

Figure 11 – The distribution of approximate off-path travel time in minutes. The range of approximate off-path travel times was up to *c.* 60 minutes' walk from the nearest points of highest density in the optimal path network. The median off path travel time is 16.0 minutes. There is a concentration of 11 hoards that were located in the sub-25 minute walking time zone.

Discussion

Concealed deposits

Debates have prevailed in Viking Age hoarding studies as to the ritual or non-ritual status of individual hoards. It has been suggested by Gruszczynski (2017) that hoards can be viewed as ritual in nature if they are deposited in areas that are impossible to retrieve, and several authors (Raffield 2014, Bradley 2017, Gruszczynski 2017) suggest that wetlands are a location frequented for ritual deposition of objects. However, Bradley (2017) states that it is difficult to discern the wetland status of hoards. None of the hoards in the North West were located in Ramsar-designated wetlands. Although further study of the relationship of the hoards to wetlands can be undertaken, preliminary indications from this study are that the hoards conform to a non-wetland depositional context.

Further clues to the non-ritual status of the hoards in this analysis are the presence of containers and economically-valuable objects. Gruszczynski (2017) suggested that containers indicate that hoards are intended to be retrieved. Six of the hoards in the North West were buried with containers, and the presence of organic containers in the other cases cannot be ruled out due to soil preservation conditions. Bradley (2017) suggests that Viking Age hoards are non-ritual in nature if they contain artefacts of whole or fragmentary nature. Bradley's implication is that the hoards are intended to be retrieved if they contain objects that will be of future economic use to the owner. All of the hoards in North West England are composed of objects that were of current economic value at the time of their deposition.

If hoards are ritually-deposited if they are placed in areas that are impossible to retrieve (Gruszczynski 2017), the hoards in the North West were by implication non-ritual deposits, as they were deposited in areas that were highly-retrievable within "short" walking distances of major routes. Based on an analysis of its material composition, it is possible that the Cuerdale Hoard was in transit from York (Williams 2011) or assembled in the Ribble Valley, a central meeting place between York and Dublin (Graham-Campbell 2011). However, the hoard was deposited en-route, suggesting that the location chosen was an intermediary stopping place. The deposit location is on a dry rise near the riverbank – the hoard was only discovered when the decision was made to construct a wider river channel and bank in 1840. The depositional location was on the opposite side of the bank from the east-west Romano-British

Commented [SL66]: Where is this referred to in text?

Commented [SL67]: Again SHOW this with a map of the wetlands and their locations to show they don't fall within these zones. Also worth suggesting palaeoecology/palynology studies to look for past wetlands as an area of future research.

Commented [SL68]: Great! Link up to my note above and mention earlier.

Commented [SL69]: This is a little confusing here - is Bradley arguing they aren't ritual if they contain either (which would surely rule out all hoards), or do you mean that if there's a combination type hoard it can't be ritual?

Commented [SL70]: Take a step further here so therefore… what do YOU think here?

Commented [SL71]: Up to 60 mins isn't exactly short but many of the others are.

road leading away from Preston towards Pennine crossings past the Lancashire valleys. The hoard was located approximately 2 kilometers from the Roman bridge at Walton-le-Dale and one kilometer from the river crossings indicated by the optimal paths model. Thus, if elements of the hoard from Ireland arrived by ship, the depositors likely would have sailed between one and two kilometers past popular Ribble crossing locations before choosing a location to bury the hoard. If elements of the hoard arrived by land, the depositors may have left popular land routes for some one to two and a half kilometers. Measured in minutes' walking time, the results of this project indicate that the Cuerdale Hoard may have been deposited approximately 20 minutes' walking time from high-traffic pathways.

Commented [SL72]: Still need to get to the point/meaning - so what does this therefore all mean for the actions/decisions behind their deposition? What does your modelling ultimately suggest? You can tell us some of this before the conclusion.

Similarly, another case study are the Silverdale and Wharton/Carnforth hoards, both buried approximately one-half kilometer from the optimal paths' highest density segments through the modern Silverdale vicinity in northern Lancashire. The indicated walking times from high-density areas lends an estimate of approximately six to ten minutes' walk from the main paths. If portions of these hoards arrived by land, they likely would have departed from the main routes and crossed a series of hills that separate the routes from the hoard locations. If portions of the hoards arrived via the Irish Sea, the likely landing place would have been a natural harbor of the Morecambe Bay *c.* two to three kilometers away.

Commented [SL73]: Half a km or 1.5km?

In all instances, the hoards were buried up to one hour's walking time away from high-traffic areas of the landscape, with a concentration of deposits in the under-25 minute category. The hoards were likely intended to be retrieved due to the economically-valuable components deposited together in a container in most instances, with further non-ritual indications coming from the doubtful wetland status of the deposits addressed. The summation of the elements discussed here depict a framework where the hoard depositors chose locations away from high-traffic routes, as the economically-valuable hoard components were likely transported on those routes from their various origin points to their final depositional location. Furthermore, the depositors may have chosen locations that were peripheral to high-density traffic flow to assist in their concealment from others on the routes, and to ensure the safekeeping of the deposit in anticipation of the owners' return.

Commented [SL74]: Great! :)

Conclusion

Commented [SL75]: More of this in the intro please.

Viking Age silver hoards in the North West are often viewed as being deposited in an intermediary landscape between York and Dublin. However, the nature of the relationship between specific courses of routeways and depositional points was unclear, leaving unresolved questions in the scholarship related to why certain locations were chosen to bury Viking-character silver hoards in the study area. Furthermore, this research gap has allowed debates to persist on the hoards' relationship to overland transit and the intent of the depositors to return for the hoards. To move towards resolving these debates, optimal pathways were implemented that took into account re-discovered Romano-British road segments, uncertainty in DEM production, and the agency of multiple walkers in the landscape via multiple cost of vertical movement equations.

This study has targeted two specific previously-understudied research questions relating to the silver hoards as discussed in the introduction. Firstly, this study set out to examine the relationship of the hoards to their routeways. It was shown that the hoards' depositional points are related to early medieval communications routes between Northumbria and the Irish Sea region. The links between Northumbria and the Irish Sea are significant as they were the locations two hubs of Viking influence in the area – the 'linked kingdoms' of York and Dublin, which were sources of Viking bands operating on the western shores of England in the early Tenth-century and the apparent influx of Scandinavian settlers in the North West at this time. Secondly, this study set out to test if the hoards were concealed deposits intended for retrieval. It was shown that further to the hoards being related to the early medieval period routes, the hoards were buried up to one hour's walk from the routes, with a median walking time of 16 minutes. Eleven of the hoards in the study were located within a sub-25 minute walking time. Taken together with the presence of other non-ritual elements, such as containers in some instances, the hoards are viewed as a group of similar deposits that were concealed from routeways and intended by their depositors to be retrieved.

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Conflict of interest disclosure

The author has no financial conflicts of interest in relation to the content of the article, in compliance with the rules set out by PCI.

Data, scripts, code, and supplementary information availability

The grid coordinates of artefacts recorded through the Portable Antiquities Scheme (PAS) are restricted to users with Research-level access, subject to Crown Copyright and the conditions, responsibilities, and stipulations of the 1996 Treasure Act of the United Kingdom of Great Britain and Northern Ireland. Therefore, the grid coordinates of specific artefacts discussed in this article are not publicly-available.

Commented [SL76]: Absolutely fair, however I do think some of this data is available publicly - so it would be preferable to provide as much as possible and redact the rest to ensure the best balance between FAIR and CARE data practices.

The nodes/destinations however aren't protected so their grid references MUST be supplied.

Python scripts used to perform the optimal pathways modelling depicted in this paper are available in .txt format at Wilcox, Wyatt Oneal. (2023). Mobility and the reuse of Roman Roads for the deposition of Viking Age silver hoards in North West England (Supplemental Material) (Version 1). CAA 2023 Amsterdam: 50 Years of Synergy, Amsterdam, Netherlands. Zenodo. https://doi.org/10.5281/zenodo.8003626.

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