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'Anglo-Saxon lead from the Peak District; where does it lead? A new approach to sourcing Anglo-Saxon lead'

By

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I certify that:

a) The following dissertation is my own original work

b) The source of all non-original material is clearly indicated

c) All material presented by me for other modules is clearly indicated.

d) All assistance has been acknowledged

ABSTRACT

The lead industry, like others, declined and then collapsed at the end of Roman Britain and both the Romano-British and Anglo-Saxons recycled metal for a long period before fresh lead appeared.

A new methodology has been developed, which uses tin as a marker for recycled Roman lead. Analysis of lead artefacts shows that along the Derwent/ Trent/ Humber corridor recycled Roman lead was continuing in use in the 5th-7th centuries, and plentiful fresh lead first appears in the record in the 9th century, with no tin. There is a widespread gap in artefacts from the 8th century, which implies that recycled lead had been exhausted.

The main source of Anglo-Saxon lead in this region is probably the Derbyshire Peak District, but the lead isotope analysis is not definitive, due to the normal constraints such as the overlap of ore field signatures. Also the analytical method gives a broad peak, which reduces discrimination. The recent method of Pollard and Bray, which asks about what differences in lead isotope ratios show rather than provenance have been employed. Some lead used for window cames may well have alternative sources to the Peak District, and is evidence for itinerant glaziers.

The analytical methods were chosen for the relatively large size of the sample chambers, enabling surface analysis of the artefact with no damage.

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LIST OF ABBREVIATIONS

EDS-SEM: Electrodispersive Spectrometry- Scanning Electron Microscope

TOF-SIM: Time Of Flight- Secondary Ion Mass Spectrometry

CHAPTER 1. INTRODUCTION

The Derbyshire Peak District today is a beautiful National Park, but in earlier periods from the Romans onwards it was in many places an industrial landscape of lead mining and smelting the ore to produce the metal. This also was the picture for other regions of the country such as the Yorkshire Dales or Somerset Mendip Hills.

1.1 GENERAL AIMS

There has been very few studies of the British lead industry or the resulting fabrication of objects, until the period of the Industrial Revolution, perhaps because the metal is neither for tools or weapons (iron) or for wealthy display or coinage (gold, silver or copper). Another reason may be the extensive reuse of both lead mining and smelting sites and the lead objects themselves, leading to a lack of physical evidence remaining.

The general aim is to investigate the lead industry, concentrating on the Peak District where mining was known in the Roman Period, and from that period to the end of Anglo-Saxon England and the Norman Conquest. Artefacts from the Derwent/Trent/ Humber Valleys will be chemically analysed for tin to examine the reuse of Roman lead and to determine when fresh new lead was introduced. In addition the origin(s) of the lead will be sought by lead isotope analysis, with the Peak District as a possible source. Also knowledge on lead mining in the Peak District and the wider related information will be critically reviewed.

1.2 RESEARCH CONTEXT

The time of interest is long, stretching from the end of the Roman Period, through Anglo-Saxon England to the Norman Conquest, over

600 years, but the majority of interest will be before the tenth century, since there is firm charter evidence of Peak District lead mining from 835 (Hart 1975, 102.

1.2.1 Lack of Information

The information on Peak District mining is scattered among, historical, archaeological and local history sources, and has not been collated. There are excellent books and journal reviews for the Industrial Revolution and afterwards but little for the Anglo-Saxon period. This is a continuing objective for the East Midlands Historic Environment Research Framework and is still stated in the present on-line version. The lead industry is also an objective for 'Metals and Metalworking; A Research Framework for Archaeology' (Bayley et al. 2008).

The lack of written historical records is expected from the Dark Ages, and losses occurred during the destruction of the Viking raids and later settlement. This lack of information on the Anglo-Saxon Period for lead mining can be extended to the absence of mining or smelting sites, and also the relative lack of lead artefacts from the period. This is due to extensive reworking of both the mines and slag heaps as industrial technology improved and even today they are being reworked, but this time for fluorspar. Most lead artefacts are utilitarian, of little value and are plain in appearance, and also lead is easy to melt and recast. Hence many lead objects over the centuries have been reused possibly many times, and even in relatively modern times ancient objects have not been recognised as having any worth and have been melted down.

There is little academic activity in the area of lead mining in Britain at the present time, although there are active groups in Germany and France. In books lead is mentioned only briefly if at all. Leahy in his book on Anglo-Saxon crafts only devotes one page to lead.

1.2.2 The Reuse of Roman Lead

The reuse of Roman material is well known, with much Roman stone and brick being used in the early Anglo-Saxon stone churches for example. Recycling was also prevalent by the Romans with many lead objects being melted down and recast. The Romans used tin solder to fabricate their larger lead objects such as water pipes and hence tin entered the lead metal supply chain, and it is not removed during subsequent processing. The Romano-British and Anglo-Saxons continued to use this recycled source of lead with its variable tin content, and this activity has been noted by a number of authors. However the presence of tin as a marker for the reuse of Roman lead in a later period has not been actively investigated.

1.2.3 Source of the Lead

There is little or no knowledge of the source of fresh lead and when it was introduced in England, and as tin containing lead was recycled that recycled metal may well be from a number of sources. The recognised technique for determining the provenance of a metal is the use of lead isotope analysis, and naturally any mixing will confound the technique. There is also the difficulty of the lead isotope signatures for British ore fields overlapping, and they also overlap with regions in North-West Europe to some degree. Recently Pollard and Bray (2014) have suggested an approach to overcome this drawback for copper, by asking different questions such as 'are there differences?' rather than seeking the metal's origin.

1.2.4 Silver

The presence or absence of silver in economically recoverable amounts has been debated for both the Roman Period with the 'ex AG' inscription on lead ingots, and for Anglo-Saxon mining with the large amount of silver in circulation in England (Tylecote 1986, 58).

1.2.5 Experimental Methods

Much analysis for trace elements and lead isotope analysis has been carried out, often on copper alloys, and a wide range of techniques have been employed over the decades as technology has improved. However one commonality has often been the need to remove a small sample of metal from the artefact for the analysis. This has limited the possible investigations, since museum collection managers quite reasonably do not want their artefacts damaged. The constraint still applies to lead objects which are perhaps not as valuable as others but are scarcer.

1.3 SPECIFIC OBJECTIVES

The specific objectives of the study are given below, and naturally after initial conclusions of a specific objective, information will be combined to give as fuller picture as possible.

1.3.1 Collect and Review Information

Information on lead mining in the Peaks is widely spread, and it will be collected together and reviewed. The potential for silver extraction will be considered here, since it is at a too low level to be detected by the analytical method used in this study. Also the origin of the wealth of the rich barrows graves of the seventh century will be examined.

1.3.2 Recycling Lead and the Appearance of Fresh Lead

Lead artefacts will be analysed for tin as a marker for reuse of Roman lead, both to determine its use and the time period. The absence of tin will indicate new virgin lead appearing.

1.3.3 Source of the Lead

Lead isotope analysis will be carried out to determine the lead source, but it is unlikely to identify a specific ore field, due to overlapping isotope signatures. Hence it may be more appropriate to examine differences, which indicate different origins for the lead. The effect of mixing on recycled Roman lead will be also be examined.

1.3.4 Sites

The presence or absence of lead on certain sites will be reviewed.

1.3.5 Experimental

The suitability of the experimental methods chosen primarily for their ability to analyse whole small objects without any damage, will be assessed.

1.3.5 Further Work

A proposal for further work is standard, but perhaps more important here, since the study of Anglo-Saxon lead mining and artefacts is a relatively empty archaeological space, and this study can be a guide to such further work.

CHAPTER 2. HISTORICAL CONTEXT OF LEAD MINING

Lead mining in the Anglo-Saxon period in the Derbyshire Peak District, did not exist in isolation, and should be viewed from the perspective of wider Anglo-Saxon life in Britain and the knowledge of Roman and Medieval mining technology. Information is limited and hence information from related activities will be used in places to support the review of mining.

2.1. ROMAN END OF BRITAIN

Over the nearly four hundred years of the Roman period in Britain there was not a uniform social or economic activity. The first two hundred years were a time of high economic activity with much importing of goods from across the continent, great wealth, urbanisation and a very large army of 40,000 at its maximum (Fleming 2010, 5) . A major part of the economy went to supply the provisions that the army needed, and it is in this period that any dated British lead pigs are to be found (Tylecote 1986, 61) The economy declined during the third century in parallel with the continent with a decrease in imports and locally produced goods gradually coming to replace them. At the same time this local production meant that a new provincial economy grew Also new building and maintenance were rare, e.g. few luxury mosaics (Fleming 2010, 7), and this implies a reduced need for lead since its major use was in stone building of all types and water systems. This trend continued with the urban cities and towns decreasing in economic importance although they were still administrative centres and country villas, often very grand, increasing in number and importance. Around 500 villas were built or extended in this period, and most were built near to an urban centre. As well as being devoted to agriculture they often had small scale industry associated with them, e.g. Gatcombe.

After the middle of the fourth century the economy declined rapidly (Smith 1984, 31) mainly due to small and large scale warfare in Britain and also on the continent; the latter causing the removal of almost all the Roman troops, who were also a major economic customer. For example the pottery industry in the 370s declined steeply and in the early 400s commercial pottery making was extinct and large parts of Britain became aceramic. Iron production in the Kent/ Sussex Weald reduced significantly in the mid fourth century and by 410 has stopped. As one result nails became rare in the 370s and disappeared by the 390s (Fleming 2010, 27). Lead is nowhere as necessary for 'civilised' life as pottery or iron, so its collapse at this time or earlier is to expected. In support of this the lead ingots found during the building of Carsington reservoir in the Peak District are dated to the fourth century, probably the second half, and are smaller than normal and have been cast in an uninscribed and rough mould (Brannigan et al. 1986, 10). It is suggested that part time farmers/miners produced the lead.

Hence it can be seen that Roman industry and trade in Britain greatly declined and ceased at the start of the fifth century, with only domestic craft production remaining.

2.2. ANGLO-SAXON

The Anglo-Saxon period covers c. 650 years of history, and cannot be covered adequately in this relatively brief summary. For a full account the books by Higham and Ryan (2013), Fleming (2010) or Hindley (2006) cover the period and illustrate all aspects of life. Here the important points relevant to the mining and reuse of lead, exchange or trade including lead and articles made of lead, and the growth of the Roman church and Mercia will be discussed, but some detailed discussion of the Peak District will be left to the synthesis of information of that area in Chapter 4. East Anglia, Lincolnshire, the

Midlands and Yorkshire are considered to be Anglian, while Southern England is Saxon with a small Jute presence in Kent, although the actual situation is more mixed and complex.

2.2.1 Migration Period (c. 400-600)

This is perhaps the true Dark Age, before the coming of the Roman church and its record taking, and hence evidence is primarily archaeological, much of it coming from excavations of cemeteries, both cremation and inhumation since not much else survives. Building was in wood and domestically produced pottery was very fragile and little survives except for the urn fields to be discussed. Much controversy has been and is around the area of how many Germanic settlers arrived, where from, did they form a whole community, a hierarchy or ethnic cleanse the original inhabitants, or did groups of Romano-British people become acculturated and hence invisible in the archaeological record (Higham and Ryan, 2015, 70). While of interest these questions are not of primary importance to the supply and use of lead.

These people were pagan, worshipping Germanic gods from their continental homelands and by cremation and much more by furnished inhumations left physical evidence of their lives (Fleming 2010, 138). For cremations it was rare for them to contain grave goods, and if present were small items such as toiletry articles, combs or broaches. However in a cremation fire any lead present will melt and run off into the ground. However many cremation urns were decorated and as well as patterns in the pottery vessel they had glass and lead inset into the neck of the urn (Fleming 2012, 22). As the cremated bones were filled into the urns these lead inserts will survive. Saxon pottery is very fragile and can be found broken, so releasing the lead inset or plug. Although complete urns will not fit into the sample chamber of the analytical equipment, these loose pieces of lead are ideal.

Inhumation burials leave a more complete record, including a variety of grave goods (Fleming 2010, 140) and in the extreme there are the princely burials such as Sutton Hoo (Bruce-Mitford 1979). These include dress broaches which were usually of copper alloy but some were of lead. Much study has been made of the type of broach and ascribing it to particular ethnic groups, (Saxons, Angles or Jutes, but also Norwegians and Frisians) but here the main interest is source of lead. Roman objects were also being deposited as grave goods (Fleming 2010, 51).

Figure 2.1 Cremation Urns (From Higham and Ryan 2015)

As has already been discussed at the end of the Roman period industry and trade went into a steep decline and by the early part of the fifth century the basic industries such as iron, copper and lead mining and smelting and even pottery had effectively ceased. This is the situation facing both the existing Romano-British population and the immigrant Anglo-Saxon settlers. When objects are found on early Anglo-Saxon sites they are often from looted abandoned Roman sites e.g. pottery, glass, dressed stone, metals (Fleming 2010, 33; 202). The raw material for most jewellery has been fabricated from recycled Roman metal (Dark 2000, 88). Pottery was being kept in use by using rivets to secure broken segments (Dark 2000, 140) and lead was the material of choice, as it had been in the Roman period (Wild 2013, 271).

One industry that did continue is the production of salt, whose importance is not recognised in the present time (Hodges 1989, 128) but was absolutely vital for preserving food until recently with the introduction of canning and freezing. Excavation at Upwich in Droitwich has shown that it was active here between the fifth century and the early seventh century and importantly for this study the evaporation pans were still being made of lead, with lead being found at the hearth level (Hurst 1992, 14; Hurst 1997).Some of the pottery found was not local. Tracks radiate from Droitwich and many have been identified as saltways from place names and later charters (Poulton-Smith 2010), showing that trade was at least regional but probably further. The river Salwarpe flooded badly in the seventh century, but by the eighth they were back in production and the town was known as Saltwic and Nennius writing in 830 called them one of the wonders of Britain. The importance of salt can be illustrated by the Bishop of Worcester in 716/7 being granted freedom from tolls in London, and he controlled several salt pans (Hodges 1989, 128). There was a royal Mercian palace at Wychbold, just out of Droitwich in the eighth and ninth centuries where the Mercian council met several times (Hurst 1992, 17).

Hodges believes that Droitwich salt was critical in the rise of London as the major trading centre of England (Hodges, 2012, 61), and Loveluck (2013) refers to the widespread importance of salt trading across the whole Anglo-Saxon period and in many places, including mainland Europe. Bruand (2008, 17) considers the salt trade along France’s Atlantic coast and comments that salt produced north of the Somme by heating the sea brine was much more expensive than from further south evaporated primarily by the sun. He does not comment on the vessels used.

Figure 2.2 Path in Salt Works (from Hurst 1992)

Salt was also produced at the Cheshire sites e.g. Northwich and Middlewich in the Roman Period and a salt pan from this period has been found (Penny and Shotter 1996, 360) near Crewe measuring 100 x 90 x 14 cm. There is evidence for late Anglo-Saxon production at the Cheshire brine springs (Higham and Ryan 2013, 422) and this may well have been in existence earlier.

In this period, with perhaps the exception of salt, the material culture was one of primarily reworking and recycling Roman material.

2.2.2 Kingdoms, Wics and the Roman Church (c. 600-Danelaw)

While the migration period was relatively static this second period was characterised by change. Small tribes coalesced to form kingdoms, industry and trade (or exchange) started to grow and although the Romano-British/ Celtic church was always present in the west of Britain the Roman church arrived in Kent in 597. Of interest to the lead picture is firstly the growth of Mercia (Zaluckyj 2001) and the incorporation of the Peak District and Mercia's often hostile relationship to Northumbria. There is then the slow growth of crafts and industry (Fleming 2010, 183) and for the present study of lead it is not important if trade is by money/barter or by gift/exchange. Finally the Roman church brought record keeping and naturally here Bede (Shirley-Price 1990) stands out, but in opposition evidence was lost from burials, since they were unfurnished with no grave goods after a transitional period. Whereas the Celtic church built in wood the Roman church at once started to build monumentally in stone (Fleming 2010, 152), and the building techniques of the day required lead.

Again the discussion will remain general as much as possible to provide the background, for the synthesis of information specifically relating to the Peak District and its lead. The three strands of kingdoms, wics and the Roman church will be approached separately, but some overlap is necessary and unavoidable.

2.2.2.1 Kingdoms

All the seven kingdoms of Anglo-Saxon Britain were well established by the seventh century (Higham and Ryan 2013, 74) but to differing degrees. Kent had an old pedigree existing from an Iron Age tribe, the Cantiaci, while Mercia in the Midlands originally, was still attempting to move westwards into the Celtic territory of Wales and also in dispute with Northumbria. Mercia, which came to include the Peak District, will be the focus here. Its name derives from the Old English 'mierce' meaning boundary or The Marches (Zaluckyj 2001, 13) and it was established from a number of Anglian tribes along the upper Trent valley, with its centres at Tamworth and Repton, with a later ecclesiastical centre at Litchfield, before spreading to cover the land between the River Thames and the Humber, and the Welsh Border and the East Coast.

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Figure 2.3 Part of Staffordshire Hoard (From Higham and Ryan 2015)

Although not the only motivation for conquest, much wealth could be accessed by warfare to gain plunder and tribute is shown by a number of rich warrior graves of the period, such as Prittlewell, Taplow, Sutton Hoo and Benty Grange in the Peak District (Higham and Ryan 2013,132), and the latter will be discussed in detail later. Other forms of wealth creation may well have contributed to these spectacular burials. Warfare was almost continuous and both Bede and the Anglo-Saxon Chronicle list a series of battles in the Peak District and its surrounding area and these are found in Hindley (2006, xxi). The Staffordshire Hoard (Higham and Ryan 2013, 173) also fits this pattern with many objects being the rich gold and jewelled parts of weapons and being dated to the later seventh century, but with contents dating from the late sixth century.

Two kings Aethelbald (716-757) and Offa (757-796) cover the eighth century, whose end signifies the start of the Viking raids with the sacking of Lindisfarne in 793, and is known as the Mercian Supremacy. Mercian power spread across Southumbria, and in the early part of the eighth century the East Saxons had to cede control of London to the Mercians, so giving them a major wic, Lundenwic, as a trading centre (Hindley 2006, 97). Offa is famous for his dyke along the Welsh border, and he also incorporated many kingdoms directly into Mercia rather than rule through others. He also promoted trade and is known for his correspondence with Charles the Great (Charlemagne) King of the continental Franks (Zaluckyj 2001, 158). Here the focus is on tribal elites emerging into kingdoms, with a significant amount of their authority resting on their ability to extract tribute and plunder.

2.2.2.2 Trade and the Wics

Trade and industry slowly started to become re-established in the seventh century, with perhaps the first example being the first known pottery mass manufacture starting in Charnwood Forest, Leicestershire, before 600 (Higham and Ryan 2013, 144). The first trading centres, forerunners of the later wics, also known as emporia, were established in Kent (Fordwich, Sandwich) in the early seventh century where there was already a connection with the continental Frankish Kingdom (Higham and Ryan 2013, 145). The larger wics sites formed from the mid-seventh century to give the trading hubs of Hamwic (Southampton), London at Aldwych, Ipswich and York, but many smaller sites existed on the coast, with perhaps only a beach landing site where evidence for trading has been found (Loveluck and Tys 2006, 140). In addition many, other sites rich in material culture and called ‘productive sites (Hodges 2012, 30), have been found inland, such as Bawsey, Coddenham, Carisbrook and

Flixborough. Flixborough (Evans and Loveluck 2009, 159; 267; 337) is one of the major sources of lead artefacts for analysis in this study, and as well as the metal to be discussed later, pottery from the Seine, Northern France and the Rhine Valley were present, showing its wide trade connections.

At Tattershall Thorpe, Lincolnshire, a smith's collection of tools, perhaps for fine work of repair and jewellery, dating to the seventh century has been found (Hinton and White 1993, 147). This contained, as well as the tools, a variety of scrap metals such as copper alloy, silver and lead, and hence in this period crafts men were obtaining lead to repair objects and he may have had a separate larger supply of metal to make new items. Loveluck (2016, 553) discusses the specialist craftsmen more widely, and considers they may be fixed to a lord or monastery, or may travel. A more general tool set was found at Flixborough (Evans and Loveluck 2009,253), which was buried in a lead vessel in the eighth-ninth century and further lead vessels of this period come from Riby (Cowgill 1994, 212) and Bottesford (Cowgill 2009, 73), all in North Lincolnshire. They are all substantial vessels of cylindrical shape being 32.5 -52 cm diameters and 23-34 cm heights. Similar vessels are from Westerley Watercross, Willingham and possible Kenilworth, Maidstone, Folkstone and Felixstow (Cowgill 2009, 269). There is also a collection of smaller vessels from Yorkshire of a later date. Leahy (2003) in his book 'Anglo-Saxon Crafts' has a chapter on non-ferrous metalworking, but it concentrates on copper alloys and the only reference to lead is as models for broaches and the lead vessels described above.

In the first half of eighth century these emporia grew and then continued to thrive until their decline commenced in the later eighth century and perhaps trading ceased in the mid-ninth century (Higham and Ryan 2013, 248). At their height they had a well-planned infrastructure which was maintained and there was significant coin loss. Gold was replaced by silver as coinage c. 660-680 (Williams 2008, 23) and then by 730 the silver sceattas were debased, mirroring the situation in Europe. These were replaced by a new type of coinage with a purer silver content in the eighth century culminating in Offa's heavier penny. It is not known how the Kings profited from the mints and in his first edition of Dark Age Economics Hodges (1989, 177) referring to the later period of Alfred's reign states 'The question of where the silver came from has never even been asked, let alone answered'. This would still appear to be true of the whole Anglo-Saxon period, although much will have come from trade (Loveluck 2013, 345). Silver cannot be analysed with its very low levels in lead in the present study, but the possibility of English silver will form part of the later discussion of the Peak District.

In this period industry and trade expand greatly with specialist craftsmen emerging, sometimes supplemented still by agriculture.

2.2.2.3 The Christian Church

Here it is the physical building construction in stone of the Roman church that is of prime importance, and not its actual Christianity, aspects of its organisation, or its quarrels with the Celtic church. The Celtic church built it places of worship and related monasteries in wood, the construction material of all Celtic buildings and also Anglo-Saxon buildings before the arrival of the Roman church (Webb 1956, 1), and hence in the context of the study of lead is not of interest. The Anglo-Saxons continued to construct in wood for their secular buildings and also for many churches, and of these only one survives at Greenstead (Church Guidebook). Also the Celtic church had a greatly reduced importance in England after the Synod of Whitby in 664.

Lead was used in building construction in the same manner as it had been in the Roman world, and it was reintroduced into England by the Roman Church, which still built in stone on the continent (Loveluck

2013, 108 and 151), as its monumentality (Carver 2001, 1) praised and enhanced the status of both God and the Roman church. However at the beginning of the conversion, the churches were small, e.g. Bradwell or Escombe (Webb 1956, 3-4), and these will not have needed the iron ties sealed with lead used to hold large blocks of stone together, and mortar, again reintroduced, was sufficient for the smaller building stone (Wheeler 1932, 117).

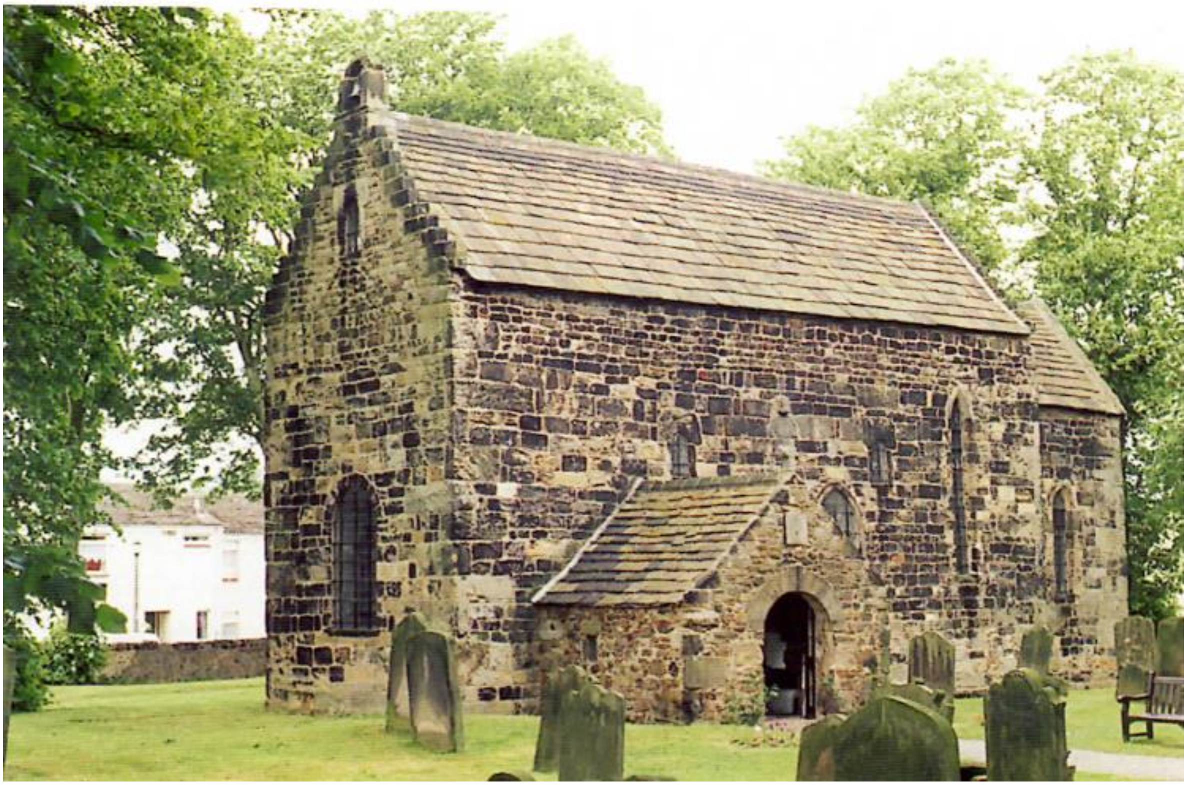

Figure 2.4 Escombe Church (From Eaton 2000)

Building material stone or brick was often, if not almost always robbed from ruined Roman sites nearby (Eaton 2000, 12), and many early churches are built in close proximity to these sites e.g. Bradwell and Canterbury. Another main use of lead was in roofing material and associated rainwater goods such as gutters and pipes, but roofs do not survive well to provide evidence or even any remains, and these may have been thatch, wooden shingle or tile instead of lead.

At Jarrow and Monkswearmouth Cramp found evidence of both limestone slates and lead being used for roofing (Cramp 1969, 37; 48), but Hodges (2012, 68) questions how representative Jarrow was compared to many smaller church and monastery buildings of the time. The oldest surviving roof is at Sompting, Sussex, on the tower (tile) and is tenth/eleventh century (Savage 1982, 153), showing the lack of evidence for early buildings.
A specialist use for lead is in glass windows, with lead cames (or cambes) providing the glazing bars used to hold the stained glass, and were of a H shaped cross section (Cramp 1969, 48; Cramp 2005-06). These will definitely have been present as stained glass windows are present, with glass fragments often being found even if the lead has been robbed out. The usage may not have been great and it will have been supplied by the glazier rather than the builder/ stone mason. It is important to note that glass windows with lead cames have been found with wooden buildings at Flixborough (Evans and Loveluck 2009, 159) and at the Tamworth watermill (Zaluckyj 2001, 221), and hence may have been common in wooden churches. As Hodges (2012, 68) has stated most churches were small, and also had few windows and these were small e.g. Bradwell and Escombe, and hence the amount of lead cames needed will be small.

Figure 2.5 Bradwell Church (From Eaton 2000)

Bede (Sherley-Price 1990), the source of so much information on this period also has some interesting observations on church building and the use of lead .In book one setting the scene for the earliest inhabitants Bede states 'The land has rich veins of many metals , including copper, iron, lead and silver'. For 627 he describes the building of a stone church on Edwin's conversion in Northumbria and in 628 one in Lincoln, which later lost its roof. For 664 he describes an existing wooden church, originally built by the Celtic church being 'covered both roof and walls with sheets of lead'. In 680 he mentions the church at Monkwearmouth newly built by Benedict (who also built the twin of Jarrow) during Northumbria's 'Golden Age'. Ripon (672) and Hexham (678) were stone churches built by Wilfred as a basilican church as in Gaul and Rome, and this is not surprising since the stone masons and craftsmen were imported from Gaul (Hawkes 1996, 66). Only the crypts built underneath the altars remain. When Benedict built Monkwearmouth (674) and Jarrow (681) craftsmen from Gaul were still needed (Hawkes 1996, 72) and some of the stonework survives and glass from the coloured glass windows has been found with glaziers again recruited from Gaul (Mitchell 2006, 168). The churches were also decorated with stone sculpture and inside with stone friezes.

Hence there are two groups of surviving early churches from the seventh and early eighth centuries; the first being in the South-East - four at Canterbury, one at Rochester and Lyminge. Recluver and Bradwell and are all built with a rectangular body with an apse to the east. The Northern group consists of Monkwearmouth, Jarrow, Hexham and Ripon and have links to Italy while Escomb may relate back to the Celtic church (Webb 1956, 1) and again the recruitment of foreign craftsmen is stated. This link is not surprising, since there was significant travel both ways between the English church and both Gaul and Rome, as described many times by Bede.

The next phase of building in the eighth century includes the still standing All Saints at Brixworth, with the nave and lower parts of the tower (Zaluckyj 2001, 223; Hindley 2006,110), and the crypt dated to c.850. It is built from reclaimed Roman brick perhaps from Leicester, rather than stone from Barnack which could have been shipped along the River Nene. It is large due to being the Abbey Church and was possibly a daughter monastery of Peterborough (Medeshamstede). Another eighth century church is the Chapel of St. Lawrence at Bradford-on-Avon (Higham and Ryan 2013, 165). Today both these buildings have tile/slate roofs, but roofs are known to be the most easily damaged and are often replaced.

There is no doubt that the new Roman church built in stone and that some lead was used in construction. However with small buildings with few small windows, and not many stone churches in the seventh and eighth centuries, it is possible that the requirement for lead was modest.

One point of interest in this period is for burials, and while they had occurred as barrows from the fifth century onwards (Higham and

Ryan 2013 128), they increased in the mid-sixth and continued into the seventh century. These were both constructed as small barrows but also burial within a prehistoric barrow occurred across England. This burial practice will be returned to concerning Derbyshire and Benty Grange. Many in Derbyshire were excavated in the nineteenth century by Bateman (Marsden 1999, 49).

The end of this time period has been chosen as the establishment of the Danelaw, since forty years earlier in 835 the Abbess of Repton granted land at Wirksworth in the Peak District to Prince Humbert 'on condition that he shall pay annually a rent of lead worth 300 shillings, to the Archbishop of Canterbury' (Zaluckyj 2001, 119). This establishes a date when lead was being produced in the Peak District in quantity and hence later periods while still important to the lead story are not concerned with when reused lead may have ceased or when fresh lead appeared. As Repton and the Peak District were in the Danelaw, control of the lead field moved to the Dane

2.2.3. Danelaw (886/890) to after the Norman Conquest (c.1100)

Raids increased in size from 851 with the Vikings staying in England over winter and in 865 the 'Great Heathen Army' arrived and in 873 Repton at the heart of Mercia was captured, with the army staying there over winter (Higham and Ryan 2013, 260). In 877 Coelwulf and the Vikings divided Mercia and Alfred and Guthrum only modified this slightly in the establishment of the Danelaw in 886/890 (Zaluckyj 2001, 245) and Mercia never recovered its supremacy . Derbyshire was now clearly in the Danelaw until its conquest by Wessex.

After Alfred, Aethalred and Aethelflaed (the Lady of the Mercians) continued the recovery of land from the Vikings, and in 917 she captured Derby and its region. Edward the Elder continued this liberation for Bakewell in 920 and built it as a burh. The Vikings had looted and destroyed most churches and monasteries for their wealth, but the Vikings then converted to Christianity and the church was re-established and the Benedictine reform of the monasteries was occurring. The tenth and eleventh centuries were a period of major church building, and these were often in stone (Higham and Ryan 2013, 321), but few survive as most were rebuilt by the Normans soon after the conquest. One example is the small parish church is St. James at Selham, Sussex and little lead appears to have been used in its construction (Higham and Ryan 2013, 322),

Figure 2.6 Selham Church (From Higham and Ryan 2015)

which may have been restricted to larger more important churches, such as cathedrals. The Norman Doomsday Book produced in 1085-6 gives a record of most of the property in England. There is rich detail for Derbyshire, giving evidence for significant lead mining at this time, which will be considered later.

The pottery industry continued to grow from its modest beginnings in Ipswich, and in the late ninth century at Stamford in the Danelaw glazing with lead first started in England, which grew in the tenth century (Hodges 1989, 182) and spread to other centres, such as Northampton, Winchester and Porchester (Richards 1991, 78). Either galena or white lead made from vinegar reacting with the lead metal was used as a flux, causing the clay to melt to give a gloss finish with yellow, orange, brown or green colours (Leahy 2003, 102).A range of pottery was made and both crucibles and tableware were distributed widely from Stamford. Glazed crucibles may have been the first items, intended for industrial use, as these appear before others forms on sites in Lincoln, York and Thetford. Several kilns were in production and others soon were in operation in other towns and were also traded widely across England, particularly in the Danelaw while it existed (McCarthy and Brooks 1988, 156). As the production increased it became one of the major forms of English pottery, and hence will have needed a major assured supply of lead.

Figure 2.7 Stamford Ware (From Laing 2003)

An alloy of lead, pewter disappears after Roman period following the trend for all metals. It was not uncommon in Roman Britain, with a number of hoards being excavated across Southern England and it did not re-appear to any extent until the ninth and tenth centuries

(20% lead) when it is used for ecclesiastical services (Haedeke 1970, 172), especially after its approval by the Council of Rheims in 803-13 and the Council of Tribur in 895 as a cheaper alternative to silver.

As well as the uses of lead in the Anglo-Saxon Period outlined above for church building and also window cames in some secular wooden buildings, such as Flixborough (Evans and Loveluck 2009,159) and the Royal Mill at Tamworth (Zaluckyj 2001, 221), it would be used for water pipes and cisterns for certain buildings, such as monasteries. A minor church use would be for lead pigments for illuminating manuscripts with white lead and red lead (Brown and Clark 2004, 5; Clarke 2004. 189). As lead became more plentiful it was used for many objects, bearing in mind its physical and mechanical properties and also the high density. Hence it cannot be used as a cutting tool and it has limited mechanical strength, being easily deformed. Hence its use as net sinkers, spindle whorls, trade tokens, cheap jewellery and pilgrim badges (Leahy 2003 165). The problem here as already referred to, is that these cheap often utilitarian items have little value and will have been recycled, so disappearing from the record.

2.2.4 West Britain and Europe

In the migration period the West of Britain was essentially still Romano-British and continued with the life style that had been established after the decline at the end of the Roman Period. Whereas the East had contacts with North-West of Europe such as Fresia and other countries of origin for immigrants and also Gaul, the West maintained contacts with the Mediterranean for small scale exchange and trade (Fleming 2010, 34). The trading originating at the wics covered the North Sea basin (Loveluck 2013, 178) in the mid period and later it became more widespread with many industrial centres and ports. In continental Europe the Franks, first Merovingians and then Carolingians, were the dominant power.

For the Franks, Melle was a source, perhaps the major source, of both lead and silver (Davies 1979, 84). It was worked by the Romans and may not have closed but continued in production through the barbarian invasions, especially as the Roman Church survived and this will have required a supply of lead for its buildings. They were already in significant operation in 635 when Dagobert gave the Abbey of St. Denis near Paris 8,000lb. (3,629kg.) of lead every two years (Tereygeol 2007, 123). The gift named Metallum as the source, which is the old name for Melle. Also the Carolingian mint at Melle is first recorded in 864, when it was noted as having stayed open when many mints were closed, and therefore it was in operation before this time. The mine was closed eventually at an unknown date, but certainly well before 1603 when its re-opening was proposed. Tereygeol (2013, 7) confirms the operation of the Melle mines starting in the sixth century, when investigating the carbon left by firesetting in the mines. Lead net sinkers and other artefacts (Tereygeol et al 2010, 263) from the Port of Taillebourg on the River Charente, downstream from Melle have been linked back to Melle . However production soared in the late seventh century with the move to a silver currency (Tereygeol 2013, 3). The lead contained between 1 and 3% silver (Tereygeol, 2007 125) and total reserves were 750,000 tons lead and 1,400 tons silver. With significant losses in the total production chain, especially the smelting, the annual lead production is estimated at 340 tons. The silver is not lost in the processing and it concentrates in the lead, giving an annual silver production estimate of 4 tons. Melle's connections via its port of Taillebourg are shown by Anglo-Saxon and Scandinavian metalwork of the seventh to tenth century found there (Loveluck 2013, 195). Anglo-Saxon ships were along the French Atlantic coast, and are recorded off the Loire estuary. Here they stole lead, which was being used for salt evaporation, as in Droitwich (Loveluck 2013, 179). A review of medieval French silver mines (Bailly-Maitre and Benoit

1997, 24) confirms that Melle was the main centre for silver mining in the early Middle Ages with its high period being between the reign of Charlemagne and start of the tenth century. Both these authors and Tereygeol comment that if silver production is the major objective then the lead almost becomes a by-product or even a waste stream.

A number of lead/silver mines were operated by the Romans in Gaul, but many of these ceased with Rome's departure and were not re-opened until the late Middle Ages (Davies 1979, 78; 81). Mont Lozere in the Massif Central was producing in the Roman period, but did not re-open until the tenth century or later (Ploquin et al 2010, 100). The Fournel mine in the Hautes Alpes did not commence until the tenth century (Ancel et al 2010, 203).

The next significant lead and silver ore field to be discovered was in Germany at Rammelsberg in the Harz moutains in 968, and they were soon in high production with the lead traded along the Rhine (Loveluck 2013, 318). There may have been some small scale mining around the Harz Mountains before then from 850 with simple technology and shallow pits with a maximum depth of 40m (Monna et al. 2000, 201; Ruppert and Deike 2006, A545). Smelting was undertaken in the forested area 10 km. away as this was the source of charcoal, and was on hill tops.

2.3. LEAD MINING IN BRITAIN

Knowledge of lead mining in England (or Britain) is relatively sparse for before the industrial revolution. However for the Roman period, when significant mining activity took place in Britain, information can be gained from better documented areas of the Roman World, especially Spain for lead. Allowance for the fact that lead ore was found abundantly near the surface in Britain can be made, so allowing for simpler often opencast and less technically demanding mining techniques to be used. Progress was slow and when Agricola published ‘De Re Metallic’ in 1556 only shallow shafts and short galleries are shown and hence the technology of the Anglo-Saxon period of interest can be found by interpolation between Roman and Agricola. Written evidence is not expected from the Dark Ages but excavation of ancient mining sites are also barren as the shallow surface deposits have been destroyed by later large scale working, especially after the Industrial Revolution (Davies 1979, 148). In fact slag heaps at smelters also lack evidence as earlier slag still contained significant residual lead and hence have been reworked, often more than once.

Lead ore is predominately galena (lead sulphide, PbS) which is easily identified by both its heavy weight and also its metallic lustrous appearance. It is also found as cerussite (white lead carbonate, $PbCO_3$). Lead oxide (red) is not normally found naturally.

2.3.1 Geology

The regions of the country worked in our wider timescale of Roman to Medieval are the Somerset Mendips, Derbyshire Peak District, Yorkshire Dales (Wharfdale, Nidderdale and Swaledale), the Cumbria/ Northumberland border and Central Wales, while Shropshire and Flint also were sources to a lesser extent. These are predominately soft rock limestone regions. Devon and Cumbria are also sources of lead (and also silver) and were hard rock regions and hence were exploited at the end of the period as mining was more difficult. Therefore the geological discussion will be limited to the limestone regions (Rodgers 1977; Cope 1976). These were formed in the Carboniferous period approximately 330 million years ago. At that time these regions were covered by a warm, clear and shallow sea, in which many varieties of shell fish and coral lived. On dying the calcium rich shells fell to the bottom of the sea and over millions of years became hardened into limestone forming a layer up to 2,000ft thick. The minerals came from magma, flowing through the faults and cracks in the limestone around 180 million years ago in the Jurassic Period. As the mineralising fluid rose in the rock it started to cool and the minerals started to crystallise out of solution and were deposited in the faults and cracks eventually forming a rock.

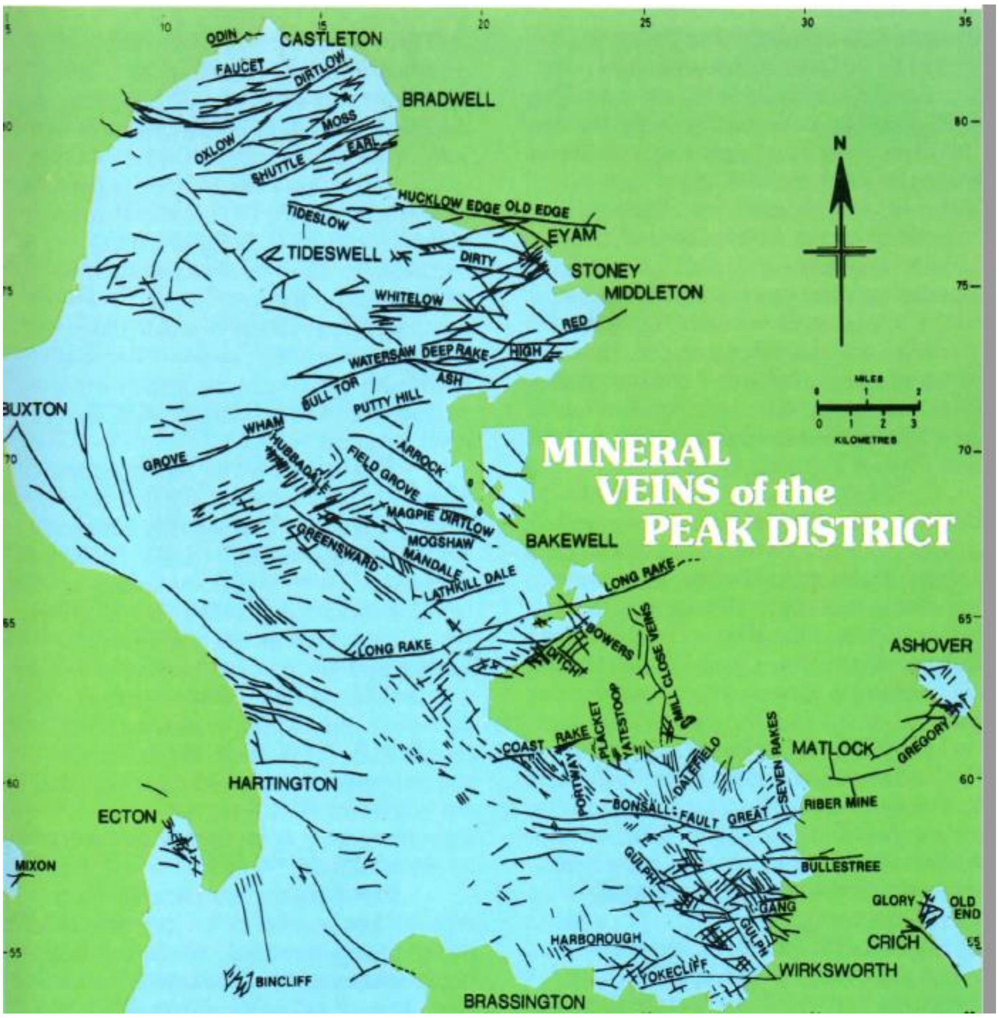

Figure 2.8 Derbyshire Lead Field (From Ford and Rieuwerts 1983)

At the end there can be a hydrothermal process when superheated water dissolves minerals and redeposits them. The minerals formed for the Peak District include galena (lead sulphide), sphalerite (zinc sulphide), fluorspar (calcium flurite), barytes (barium sulphate) and calcite (calcium carbonate). Natural environmental oxidation of the galena gives cerussite (lead carbonate) and of sphalerite gives calamine (zinc carbonate). When the results of lead isotope analysis are discussed later this similarity of geology between regions, will be seen to make ascribing an artefact to a specific region challenging.

It is interesting to note that mineral deposition will depend on temperature and hence depth in the vein. Silver will be found nearer the surface in a higher concentration, and hence assays today may well not be relevant to Roman or Anglo-Saxon mining. An example shown in Table 2.1 is from a Welsh mine where the depth is taken as related to the date of assay of the mineral (Tylecote, 1986, 69), and over only 150 years.

Table 2.1 Silver Content

Date AD	Ag g/t (ppm)
1604	734
1710	220
1811	107-122
1845	<80

2.3.2 Iron Age Mining

Cunliffe (2005, 503) states that lead was not important in the pre-Roman world in Britain, except in the late Bronze Age it was added in small amounts to the bronze to improve casting into moulds. In the late Iron Age a few lead objects are found, usually net sinkers and spindle whorls.

2.3.3 Roman Mining

Information on Roman mining is given by a number of authors (Davies 1979, 94 ; Tylecote 1986, 54) and the lead here was often mined for its silver content as well as the still valuable lead by-product, but as discussed later the extraction of silver in Britain although possible is not proven. Short galleries and shafts (Davies 1979, 97) up to 300m deep (Davies 1979, 109) and opencast were all viable options. For Britain, Pliny (Lane 1986, 13) states that lead was so easy to extract from the surface that its production was capped by regulation to protect other ore fields. Iron tools were used to extract the ore and in ancient galleries striations on the remaining walls illustrate the techniques. Iron picks were only slightly larger than modern geology hammers and for harder rock a bolster driven by a hammer was used. Fire-setting was used to break down rock faces, by heating up the rock and then cooling rapidly with water, causing the rapid contraction to crack the material. However the fire needed a good draught of air and then the smoke made the area uninhabitable (Ford and Rieuwerts 1983, 26). The narrow galleries did not need propping.

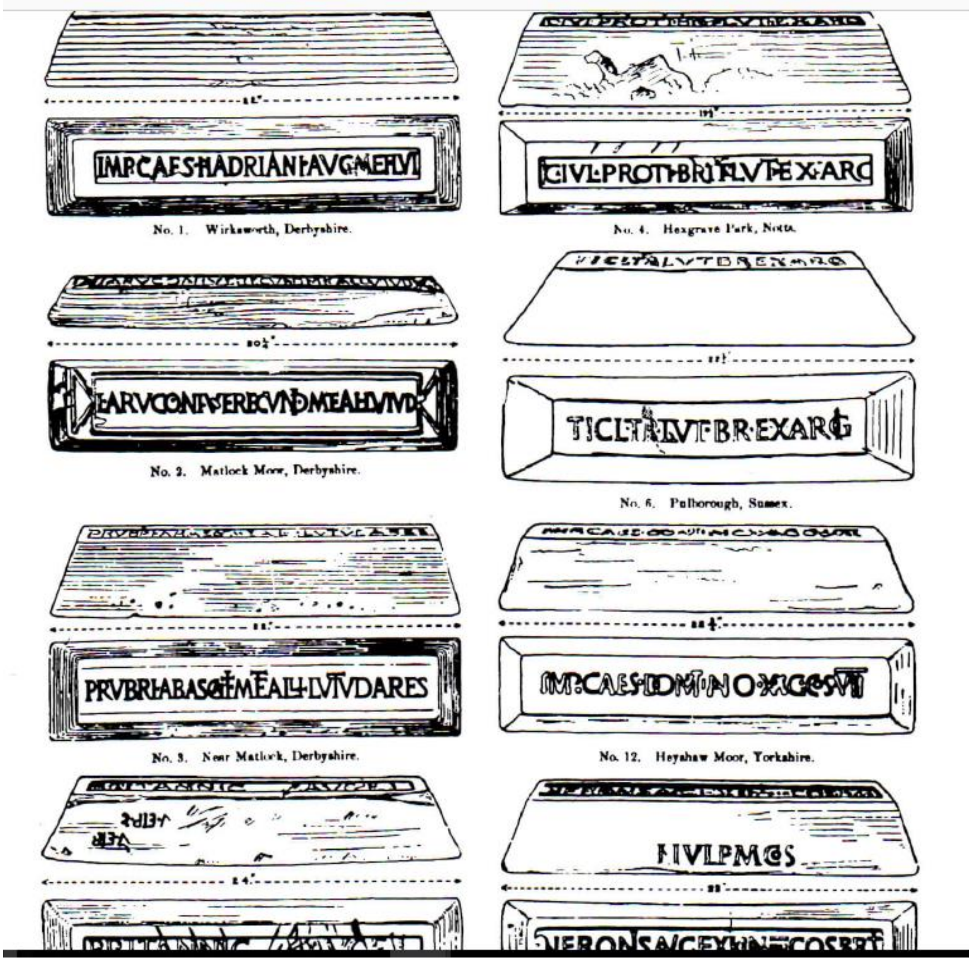

Figure 2.9 Roman Lead Ingots (From Tylecote 1986)

The ore was crushed manually and the galena sorted from the gangue, when water separation could be used due to the high density of the lead ore.
The major limitation to mining were hard rocks such as granite, which could not be practically broken without explosives and flooding which limited activity to above the water table or possibly to greater depths if a pump (Landels 1978, 66) or pumps in series were present. Also once a mine was flooded it was usually impossible to reopen. Ventilation was also a difficulty.

Smelting the lead ore to obtain the pure metal is easier than for other metals, since lead melts at 327^{o}C, although the oxide reduction requires near 800^{0}C. These types of conditions can be obtained in a normal bonfire burning dry wood or charcoal (Tylecote 1986, 54)

From Roman hearths (Tylecote 1986, 56-57) and medieval bole hills the smelting was simple and small scale, with a shallow bowl scooped out of the soil, 1-2m in diameter, or a low stone wall, both on a hill top with a gap open to the prevailing winds for a draught through the fire. Molten lead could be tapped from a channel at the bottom of the hearth.

The galena (lead sulphide) is roasted at the top of the bonfire to the oxide , which then in a continuous process further reacts with more sulphide to give the lead metal with sulphur dioxide gas as the by product. The relevant chemical reactions are given below;

$$2PbS + 3SO_2 = 2PbO + 2SO_2$$
$$2PbO + PbS = 3Pb + SO_2$$

The lead metal falls to the bottom of the hearth and can be tapped off to a mould for an ingot or pig. The Roman ingots were formed in clay moulds, made with a wooden pattern used for inscriptions (Tylecote 1986, 68) and a standard weight of 70-80. The lead purity is surprisingly high for Roman lead ingots, usually greater than 99%.

Whereas the production of lead is a low technology process, perhaps lower than pottery as a comparator, the production of silver from lead ore is more complicated and challenging as more process steps are involved with a higher temperature. The process was well known by the time of the Roman period in Britain, and was the only method in this country until quite recent time, 1833.

The technology is known as cupellation (Tylecote 1986, 58), when the lead is oxidised to litharge (lead oxide) and also any other base metals will be oxidised. Silver is not oxidised under these conditions and remains as unaltered metal. The litharge is then absorbed into a bone ash (calcium phosphate) mat laid on top of the hearth, or more simply skimmed off the surface as it floats. Some will also be lost as fume. The hearth has a shallow design to maximise the surface area of molten lead for effective oxidation from an air blast which needs to be augmented by bellows. The temperature needs to in the range 1000^{0}C- 1100^{0}C which will normally require charcoal as the fuel. Cupellation does not normally go fully to the end point, and 1% lead in the refined silver may be expected. The lead converted to litharge by-product in this process is recovered as in lead production, but only the second reduction step is required.

This silver extraction is costly and is approximately three times the cost of the original lead production. In the Roman Period it is believed that it was economic to obtain silver from lead at more than 0.06%concentration (Tylecote 1986, 61).

Roman cupellation hearths have been found in Britain, e.g. Silchester, Wroxeter and Hengisbury Head but these are thought to have been used for the purification of silver from debased coinage and not for its primary production (Tylecote 1986, 60).

The presence of significant lead deposits must have been known to the Romans before their invasion in AD 43, as the Mendip mines were in production by AD 49, as a lead pig has been found from there dated AD49. Over 90 lead pigs have been found in and from Britain and they are still being found, with one from the Mendips being found near Wells in 2016 (Brit Arch 2016, 8) . The mining areas were Mendips, Shropshire, Derbyshire, mid Wales Flintshire and the Yorkshire Dales.

Concentrating on the Derbyshire pigs, these have been found in the mining area of Wirksworth/ Matlock (8), the Humber ports (8) and the road system (8) such as Pulbright (Sussex), Rugby, Cheshunt (Hertfordshire), and Yeaveley between Ashbourne and Derby. A number of pigs are inscribed with EX ARG or EX ARGENT and this has led to a debate whether the lead did contain silver and has been desilvered. Two pigs from Derbyshire found at Brough-on-Humber still contained small pieces of galena embedded into the lead, and these will have come from the hearth at the same time as the lead. This means they would have been destroyed by cupellation. Also the galena and lead was analysed for silver. The ingot lead had more silver than the galena, which is the result expected from normal lead production and not if the lead had been desilvered. Hence the limited evidence is that Roman Derbyshire lead did not contain enough silver to be an economic prospect for desilvering (Tylecote 1986, 69). A possible cupellation hearth has been excavated at the edge of the Mendips (Aston and Iles 1986, 66), which is regarded as the most likely region for Roman silver production, if any did occur in Britain (Tylecote 1986, 69).

3.4 Medieval Mining and Later

Early records show a similar mining technology to the Roman system, and this did not change until quite late, with the introduction of gunpowder for blasting to release the ore in about 1670 (Ford and Rieuwerts 1983, 22). In the 16th Century the problem of drainage at the water table was solved by driving a sough (tunnel) from a lower level in a nearby valley so draining the mine by gravity. Steam engines for drainage were introduced in the early part of the 18th century. Another advance introduced was the use of a furnace blown by bellows driven by a water wheel in the mid-16th century, rather than rely on strong winds on hill tops, and the much more efficient cupola (low arched reverbatory furnace) which also used coal as a fuel was introduced in the 1730s (Ford and Rieuwerts 1983, 37). The height of the Derbyshire ore field was in c. 1700-1750 with individual miners or small groups still present and controlling their own mines, which formed the majority of the output. This changed in the first half of nineteenth century with the arrival of large companies, such as the London Lead Company. However decline of the industry started in c. 1860 due to cheaper lead imports and the industry slowly died until the last mined closed in the 1930s (Ford and Rieuwerts 1983, 45). The lead ore field is now mined for fluorspar, the previously discarded waste mineral, extracted with the lead.

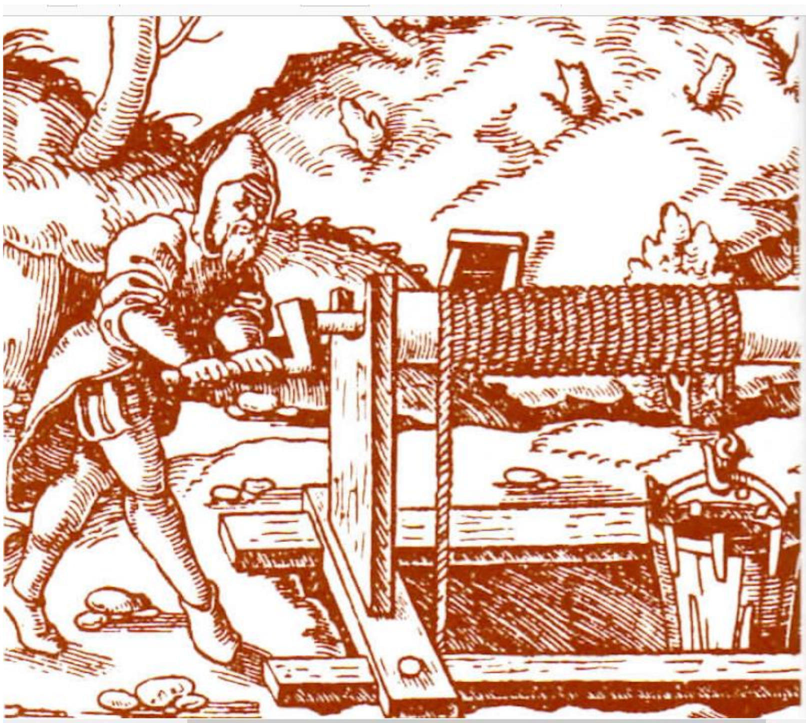

Figure 2.10 Agicola's Miner (From Ford and Rieuwerts 1983)

This picture of little change from the essentially manual mining and smelting methods of the Romans until the 16th century is supported by the first written information on mining in 1556 by the German Agricola in 'De Re Metallica'. For example he describes and illustrates winding ore out of a mine by a wooden windlass, and a mine consisting of shallow shafts and short galleries. Smelting still used the ore and charcoal mixed together in a brick furnace with mechanically driven air bellows.

2.3.5 Anglo-Saxon Mining

As previously stated there is little information on mining technology or smelting in the Anglo-Saxon period, from either written records or archaeological excavation, due to reworking of the mines and spoil heaps in later periods. However it can be assumed that as the technology outlined above for the Roman period to the 16th century was essentially similar, that this is the maximum that the Anglo-Saxons would have achieved. This is supported by the picture for technology in general, which suffered a collapse at the end of the Roman period and which did not improve for several centuries. Pottery, a staple need for all households, can be taken as an example with more known information. Pottery was poorly made in the migration period and on a domestic basis, but in the early eighth century a significant pottery industry developed in Ipswich using a slow wheel and fired them in proper kilns rather than bonfires (Fleming 2010, 195). This pottery, especially pitchers was widely traded across England. There was a smaller pottery industry based in Charnwood Forest in Leicestershire by 600, but with limited production and distribution (Higham and Ryan 2013, 144).

However some information on craft and technology can be gathered from Anglo-Saxon lead artefacts. When it is necessary to join two pieces of lead together in the process of fabricating an object the

Anglo-Saxon method was to use a simple butt or lap joint and attempt to seal the joint with a welding iron, which must melt the lead on both sides of the joint and this is difficult as the iron will cool rapidly due to the high thermal conductivity of lead. A second method is to place a lead rib behind the joint and pour molten lead into the narrow gap (Cowgill 2009, 267).

. This compares with the Roman method of normally using a lead/tin solder for jointing (Paparazzo and Moretto 1994, 61; Tylecote 1986, 75). An important consequence of the Roman use of solder is that as lead was recycled a tin content was present in the lead supply and hence artefacts. Also pewter, a lead/tin alloy often used for tableware, may have been recycled into the lead stock. This is not the case for lead mined in the Anglo-Saxon period as no solder was used in lead jointing, and this distinction will be returned to in the discussion of the chemical analysis. Many artefacts especially larger ones were made by joining sheet lead

Both these techniques are crude and are relatively easy from a practical standpoint, but from Rome through Anglo-Saxon to Medieval a challenging process was the formation of lead sheet in the first instance. This is perhaps more skilled than the mining or smelting operations. Although lead melts at 327^{o}C it will need to be hotter as when poured it will cool rapidly in the sheet mould, and hence the craftsman must work very quickly. This mould is a flat damp sand bed with wooden sides and a wood bar is used to obtain a flat bed and then to ensure an even thickness of lead is obtained from spreading the metal. As sand forms the bottom of the mould this lead surface may be somewhat pitted, whereas the upper surface will be smoother (Cowgill 2009, 273). The job is skilled and needs practice and therefore may well be concentrated at a limited number of sites probably the same as the smelters. An implication of this is that the lead sheet of whatever period when lead smelting was in operation is expected to be pure lead with no tin from recycling.

CHAPTER 3. ARTEFACT SITES AND ANALYTICAL METHODOLOGY

3.1 ARTEFACT SITES

The choice of artefacts for analysis and hence their excavation site is limited by a number of factors, but the geographical area is constrained to the Derwent/ Trent/ Humber valleys in their widest interpretation to follow any movement of Peak District lead along this trade route. The choice may miss any lead coming via the River Idle route which was used by the Romans (Patterson 2011, 168)

As already commented, lead was widely reused (Fleming 2012, 21) and hence lead artefacts of the Anglo-Saxon period are relatively rare. When interrogating open museum data bases the number of lead objects is low and this is true for the whole collection and not just items on display, which may be chosen for their visitor impact. For example the British Museum lists 33,653 Anglo-Saxon artefacts of which only 209 are lead, with 134 coming from Mucking. The Ashmolean has 3,246 Anglo-Saxon objects with only 15 being lead including 5 from Frilford cemetery, Oxfordshire and 4 from Radley Barrow, Oxfordshire.

Museums at Derby, Nottingham (University), Scunthorpe (North Lincolnshire) and Hull (East Yorkshire) were contacted and the results were variable. Unfortunately Hull did not respond and could not be contacted.

Derby surprisingly only had one piece of Roman lead and no Anglo-Saxon lead items at all. Derby was a Roman town (Patterson 2016, 77) and also houses the collection from Anglo-Saxon/Viking Repton (Zaluckyj 2001, 63). Derby stores its metal in an environmentally controlled room and therefore all metal was easily available for a physical search which confirmed the absence of lead.

Nottingham University had some lead both Roman and Anglo-Saxon sites with a significant amount of the latter coming from Flawford.

Scunthorpe was a treasure trove of lead, if that term can be applied. There were many items from a range of cemeteries across North Lincolnshire and then a very significant amount of both objects and lead sheet from Flixborough.

Descriptions of each site will now be given:

1. Margidunum was a small Roman town on the Fosse way (Patterson 2011, 11) near Bingham , Notts.

2. Little Chester was a Roman town on the Bank of the Derwent river (Patterson 2016, 77), which is now Derby

3. Flawford church is built on the site of a Romano-British villa, and was demolished in 1777 and 1779 and is near Ruddington, Notts. It was probably established in the early ninth century, and Roman roof slates were found in the rubble in the early church and the Roman tessellated floor was reused in the nave. It may have developed as a Minster church for the surrounding villages, and continued to be developed into a substantial medieval building and ten phases have been suggested (James 1994). The early phase dating is supported by the finds of a silver penny of Burgred (852-74) and Alfred (871-99) in the floor rubble. Dating of the building phases is difficult, but phase five is thought to be eleventh/twelfth century, while there is some documentary evidence for phase 8 being built at c.1280. The artefacts from the excavation are difficult to date and are probably late Anglo-Saxon and possibly Norman

4. Flixborough is north of Scunthorpe in Lincolnshire, overlooking the river Trent and not far from the Humber. It is a complex and well preserved site, providing much information as it was

developed across the centuries from the seventh to the early eleventh (Evans and Loveluck 2009), although the area was inhabited both before and after this settlement phase. The first phase commenced.700 and from the late seventh to the early ninth centuries (phase 2 and 3) the site had the attributes of an aristocratic centre of consumption with rich finds imported from the Rhineland or Northern France,, together with high quality food .At the end of this period some buildings had windows with glass set in lead cames, which is most unusual for a wooden building. The settlement changed character in the early ninth century, when a variety of craft production became pronounced, including textiles and significant lead working. Two lead vessels containing woodworking tools had been buried outside the excavation. Lead and the presence of styli for writing can imply a monastic community but the site could still be secular and it was now a centre of production rather than of consumption. This reversed in the early tenth century with consumption and hunting returning,

5. Castledyke. This cemetery lies on the southern edge of Barton-on-Humber, and hence is on the Humber estuary. It was in use from the late fifth to the seventh century, and dating depends on the artefacts (Drinkwall and Foreman 1998, 24). There are c. 200 graves.

6. Elsham is an early cremation cemetery of the fifth/sixth century containing 577 cremations, and is situated a few miles east of Scunthorpe (Squires et al 2011, 2403; Squires 2012),

7. Harpswell is between Gainsborough and the Caenby crossroad. St Chad’s church has a late Saxon tower (chance find, unpublished).

8. Sheffield Hill is in Roxby, north of Scunthorpe, and is a paired cemetery with a sixth century with both urns and inhumations and a late phase inhumation cemetery of the end of seventh century which is the source of the artefact. This has yielded a few rich graves containing gold jewellery and swords (Leahy and Williams 2001, 310).

9. Kingston on Soar (Notts) is a sixth century cremation cemetery, excavated in 1840-44 by Lord Belper after being exposed during the construction of the Pleasure Gardens for the Hall (University of Nottingham, museum collection).

10. Torksey is on the Trent at the junction with the Foss Dyke to Lincoln, and is known as a Middle to Late Saxon productive site with metal work finds (Ulmschneider 2000; Barley 1964, 165) and the Viking army stayed here over winter in 872-3.

11. Repton, together with Tamworth, was a royal centre for the Mercians (Higham and Ryan 2013, 183) until it was captured by the Vikings in 873.

3.2 ARTEFACT DESCRIPTION

The artefacts examined are shown in Table 3.1.

Table 3.1 Artefacts Analysed

Artefact	Date	Site (Museum)
Roman brooch M88.54	Roman	Margidunum (NU)
Coffin M69.149	Roman	Margidunum (NU)
Plate K9.69.106	6C?	Kingston-on-Soar (NU)
Came 5197	Late Saxon	Flawford (NU)
Sheet 5197	Late Saxon	Flawford (NU)
Came 94.14	Late Saxon	Flawford (NU)
Sheet 94.14	Late Saxon	Flawford (NU)
Font Cup	Late Saxon	Flawford (NU)
Measure weight SF 163	Roman	Derby (D)
Urn 76NJ	5-6C	Elsham (NL)
Urn 75BQ	5-6C	Elsham (NL)
Urn 75KV	5-6C	Elsham (NL)
Coin imprint TOAE	9C	Torksey (NL)
Belt Strap HPAA4	Late Sax	Harpswell (NL)
Brooch 185	5-7C	Castledyke (NL)
Brooch 189	5-7C	Castledyke (NL)
Solder SH 93 Grave1	6-7C	Sheffield Hill (NL)
Strip 7878	Mid-late 9thC	Flixborough (NL)
Mes Weight 169	10thC	Flixborough (NL)
Came 12408	Mid 9thC	Flixborough (NL)
Melt 1232	Mid-late 9thC	Flixborough (NL)
Came 2809	Mid 9thC	Flixborough (NL)
Sheet 1229	Mid-late 9thC	Flixborough (NL)

Sinker 7060	Mid 10th-early 11thC	Flixborough (NL)
Offcut 11292	Mid-late 9thC	Flixborough (NL)
Line weight 3855	Mid/late 10th –early 11thC	Flixborough (NL)
Plug 12429	Mid 9thC	Flixborough (NL)
Mes Weight 168	10thC	Flixborough (NL)
Net sinker 1865	Mid 10th –early 11thC	Flixborough (NL)
Strip 4114	Mid-late 9thC	Flixborough (NL)
Sheet 7958	Mid-late 9thC	Flixborough (NL)
Offcut 13611	Mid-late 9thC	Flixborough NL)
Offcut 13960	Mid-late 9thC	Flixborough (NL)
Melt 1368	Mid-late 9thC	Flixborough (NL)
Melt 1226	Mid-late 9thC	Flixborough (NL)

Figure 3.1 Artefacts

Figure 3.2 Artefacts

Figure 3.3 Artefacts

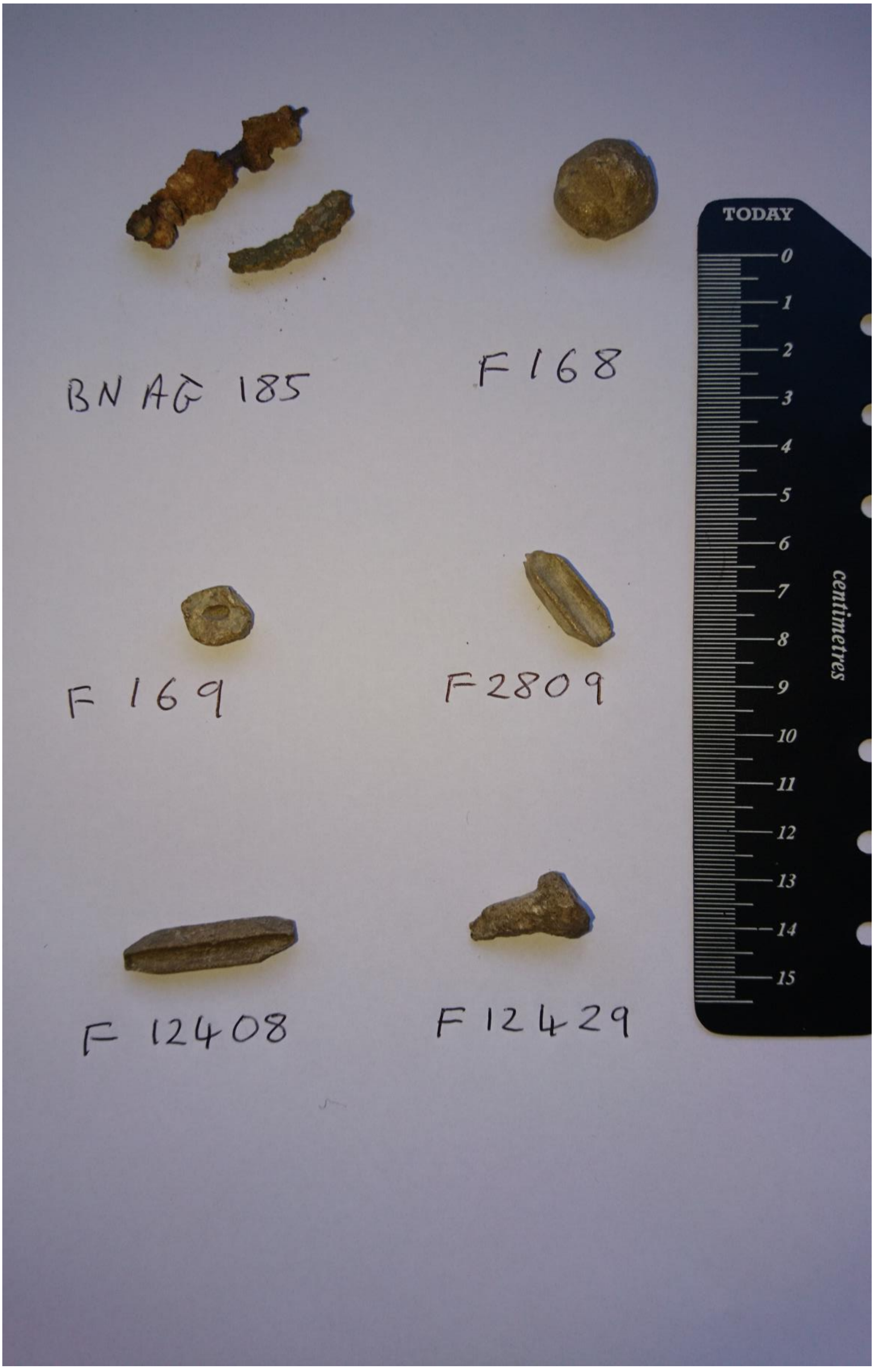

Figure 3.4 Artefacts

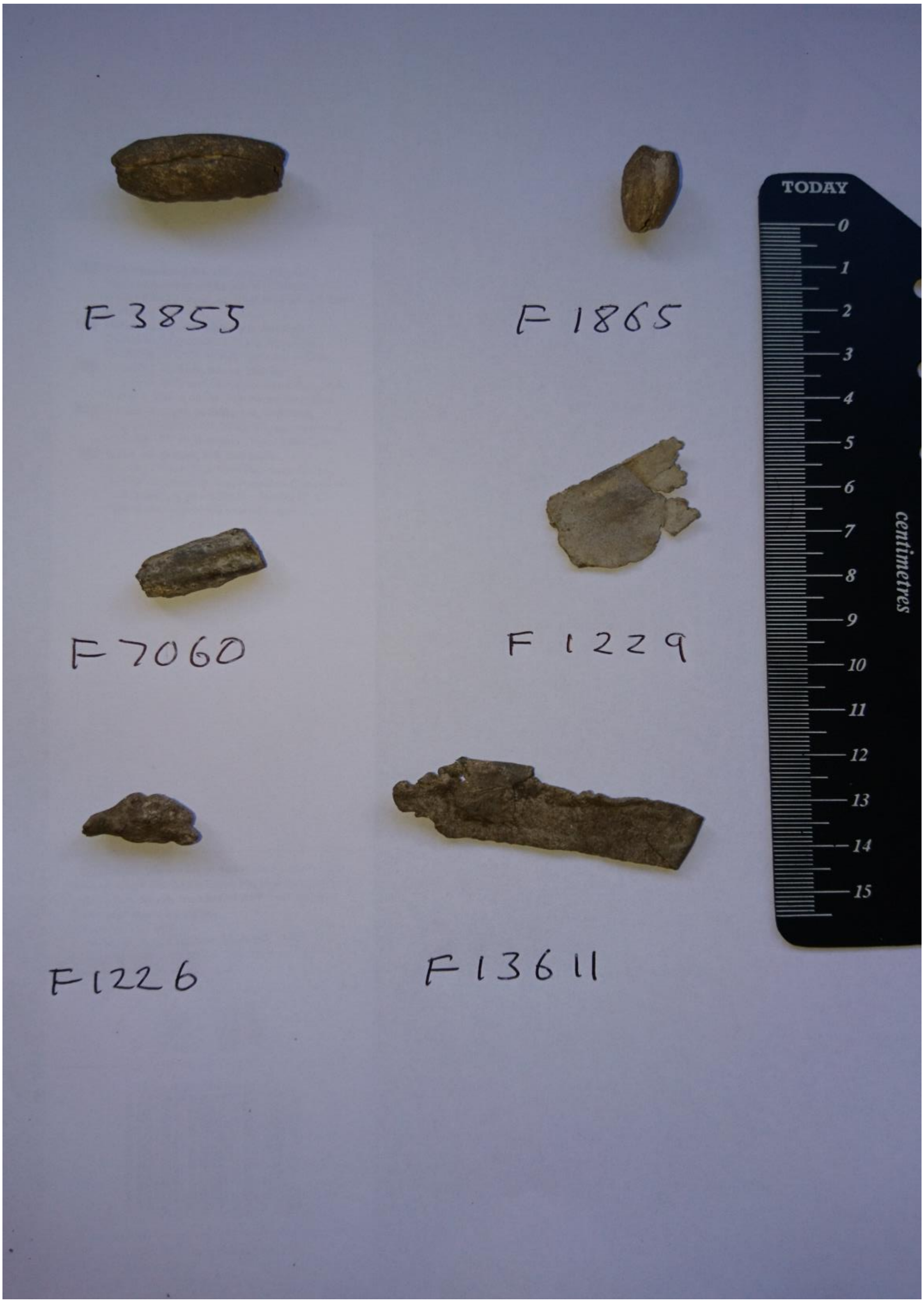

Figure 3.5 Artefacts

3.3 ANALYTICAL METHODOLOGY

3.3.1 Choice of Analytical Methodology

Tin is a good marker for the reuse and recycling of Roman lead, from its inclusion in the metal from tin solder and pewter (Section 2.3.5). Hence a method is required to measure tin, but a low level of quantification or high accuracy is not needed, as the only requirement is to determine its presence or absence. However this approach will not be acceptable if the presence of silver is being sought in the lead, as it is present, if at all, at very low levels in Britain.

The origin of the lead source is determined by lead isotope studies, and there are many concerns about the approach such as mixing sources or contamination when a tiny amount of lead in a coin is being analysed and these will be discussed below (Section 3.3.4.1). Many of the problems can be avoided by asking the correct questions, as promoted by Pollard and Bray (2014, 1), and further discussed in the results (Section 5.3)

One of the critical restraints is to persuade museum collection mangers to loan the investigator the necessary artefacts. Although lead artefacts are not normally prized exhibits for museum display for the visiting public, as being neither rich jewellery nor weapons they are surprisingly rare. Hence it is much easier to obtain the artefacts if no damage is anticipated, i.e. it is not necessary to remove some metal from the object for the analysis to proceed. For some analytical techniques it is necessary to have a solution (certain mass spectrophotometers) or a highly polished exactly horizontal surface (microprobe). Naturally there is a limit to the sample chamber size of any piece of equipment, and so in practical terms only smaller objects can be analysed whole.

A range of equipment was available at the University of Nottingham. An EDS-SEM system was chosen over a microprobe, since precise accuracy and low detection levels are not required for tin (Heron and

Pollard 2008, 44). This does mean that silver cannot be determined. There is the major advantage of a whole specimen fitting in the sample chamber of 9x9x3 cm, which will encompass the great majority of artefacts of interest. The microprobe would have necessitated the removal of a small piece of lead, mounting it in resin and polishing to a sub-micron finish. As an added practical difficulty here, in preliminary work it was found that the polishing paste used in the final stages of sample preparation did not polish but became embedded in the soft lead.

For lead isotope work a TOF-SIMS technique was chosen, with the critical advantage of a similarly large sample chamber of 9x9x3cm to the EDS-SEM, so allowing whole artefacts to be analysed. It has the disadvantage of not being quantitative between elements, unless a calibration curve is produced, but is quantitative between isotopes of a particular element. Hence it is satisfactory, as elemental analysis is to be carried out by the EDS-SEM. A second disadvantage is that isotope peak resolution is relatively poor compared to other forms of mass spectrometry especially with rough surfaces, but even with the best equipment it is often impossible to ascribe the artefact to a particular ore field as the isotope signatures overlap across ore fields and an ore field may have a range of isotope ratios. These aspects are discussed later (Section 3.3.4.1).

Much fuller details of the range of possible analytical techniques can be found in the standard archaeological science textbooks such as Pollard and Heron (2008) and Henderson (2000)., or standard scientific texts. An exception is perhaps the relatively new technique of TOF-SIMS, for which no references for lead analysis have been found, although it has been used to investigate ancient glass (Henderson 2012, 2143).

3.3.2 Surface versus Bulk

Both techniques measure the surface layers of the object and this is not an issue for TOF-SIMS, where the interest is the distribution of the different lead isotopes. However for the EDS-SEM work it is a potential problem due to possible surface enrichment of certain elements. Lead will corrode to lead oxide and lead carbonate and both may dissolve over time, whereas tin is more chemically stable, This can lead to tin being artificially high at the surface depending on soil conditions, and a Roman object with 2% tin in the bulk had a 10% surface concentration (Tylecote 1986, 77). This is not a difficulty in the present study as the actual presence of tin is the marker for reuse of Roman lead and a precise figure is not required. There may well be some soil still adhering to the surface giving peaks for aluminium, silicon, carbon and oxygen, but these will not affect the validity of the analysis. It may appropriate to normalise the tin content on lead for comparisons between objects (Tylcote 1986, 77), but as stated previously it is only the presence of tin that is important.

Another factor that will affect results for both techniques is that while the optimum surface is flat and horizontal, they will work adequately with rough surfaces at an angle, which is the reality for whole unprepared artefacts. Both techniques produce results using the equipment’s software packages and these results are shown in the relevant tables in Chapter 5. Computer output in the form of Excel workbooks is available for inspection.

3.3.3. Energy Dispersive Spectroscopy-Scanning Electron Microscopy (EDS-SEM).

This technique is a variant of X-ray fluorescence spectrometry, where X-rays of different energy levels are produced and detected when an object is hit with high energy electrons in an electron microscope, with each element having characteristic X-rays. If the wavelength of the X-rays is measured instead, the instrument is in the wavelength mode (microprobe). As lead is electrically conducting, carbon coating is not necessary. The artefact is placed in the sample chamber and hence the geometry is variable rather than the ideal of a flat polished surface, and this is a major cause of the results variability (Taylor 2015, 14). Fuller details of the technique are given in Heron and Pollard (2008, 38) or Henderson (2000, 14).

The equipment was the Quanta 650 eSEM with a 150 mm X-ray max Oxford Instrument detector, ran at 20 kv with spot size 4. It is in the Interface and Surface Analysis Centre of the University of Nottingham. For the archaeological specimens both the limit of detection and accuracy will c. 0.2% (Steer pers. comm.)

3.3.4. Lead Isotope Analysis

3.3.4.1. Review of lead isotope Analysis and Ore Fields

Lead isotope analysis was developed by geologists first from the radioactive decay of uranium, and then adapted successfully by archaeologists for their needs, starting with Brill and Wampler (1967). Essentially four isotopes of lead exist with atomic weights of 204, 206, 207 and 208 and theoretically an ore field can be defined by the ratios of the isotopes, with 208/206 and 207/206 often being used and 204 neglected as it is small. However difficulties abound (Heron and Pollard 2008, 325; Bayley et al. 2008, 36) such as the variation in an ore field, using ore samples available to the ancient miner and in sufficient numbers, how the ore field map is constructed, and not least that many ore fields overlap. Certainly British ones do and also others such as France. Figure 3.6 shows the overlap clearly. For example Rohl and Needham (1998) in an extensive examination of Bronze Age metal could not distinguish the British sources by lead isotope analysis alone.

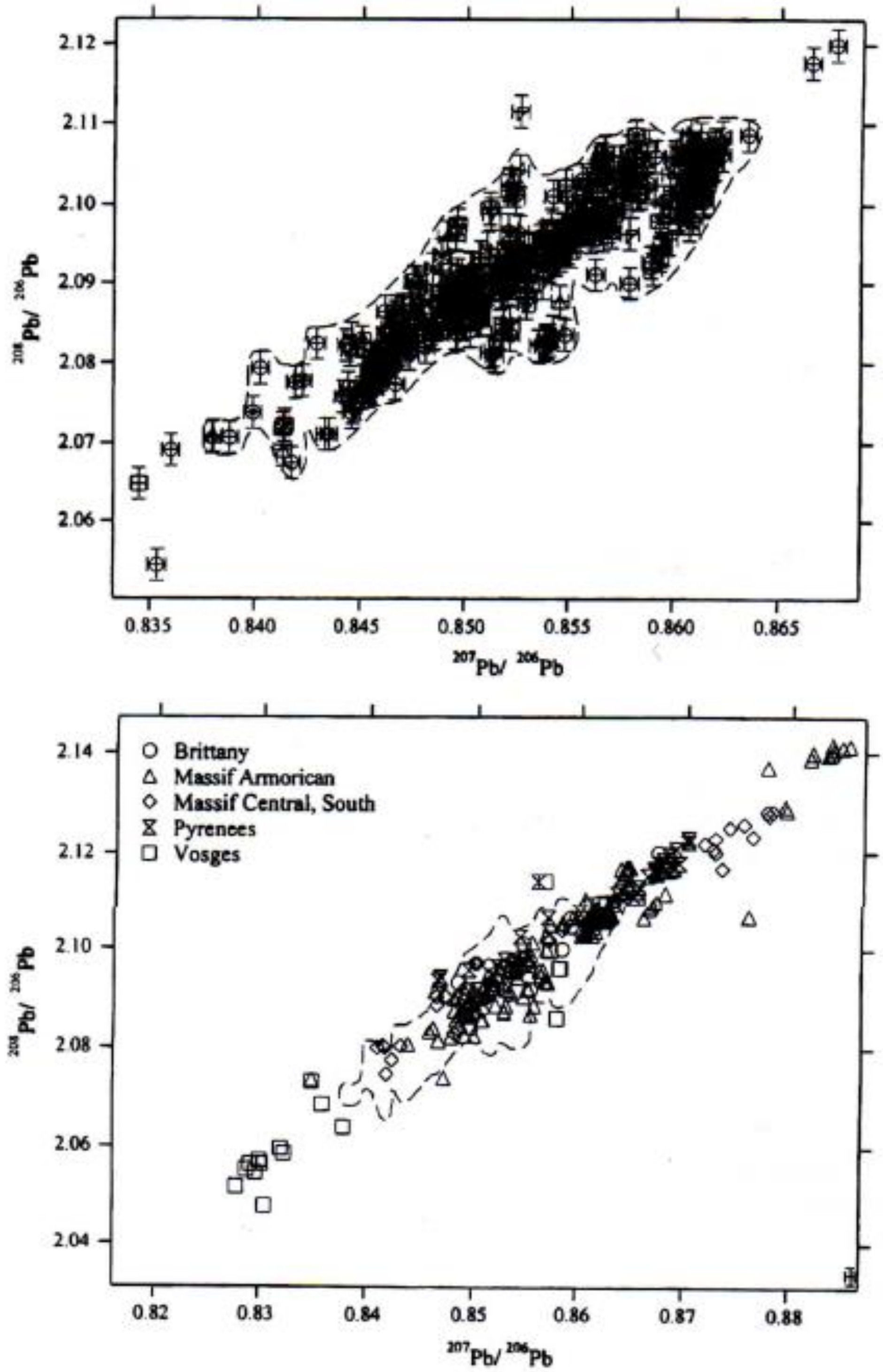

Figure 3.6 (From Pollard and Heron 2008)

Top:Galenas from British Lead Sources

Bottom:French Galenas superimposed on British Ore Field

A review of the difficulties surrounding lead isotope analysis is needed and this will be done here, although as geology is heavily involved it could be placed it that section. Also the literature is extensive and can only be briefly considered. Firstly in the 1990s there were extensive disagreements between archaeology groups about the validity of methods and results e.g. Budd et al. (1993, 241) or Tite (1996, 959) which captures much of the debate, and this seems to have somewhat stifled studies. In addition British researchers have concentrated on using trace lead found in copper or silver artefacts to determine a metal's origin and little has been done on lead objects. In fact the only recent studies found for lead are with German (Durali-Mueller) or French (Baron, Tereygeol) groups.

For the present study it is acknowledged that metal mixing may well have taken place, masking a metal's origin, and the ore fields overlap and this is discussed in Section 5.3 where Pollard and Bray's approach modified to the present circumstances is used to overcome the restrictions. Also fractionation does not occur for lead (Tite 1996, 959). On a practical note Stos-Gale and Gale (2009, 198) show that surface sampling at lead levels above 500ppm (present samples are 'pure' lead) is satisfactory and will avoid any matrix affects.

3.3.4.2 Time of Flight-Secondary Ion Mass Spectroscopy (TOF-SIMS)

This variant of mass spectrometry has a primary high energy ion beam which impacts the surface and releases both ions and neutral material in a process known as sputtering. The ions then enter a time–of–flight tube and are separated since the lower mass ions have a higher velocity. The ions are then detected by a multi-channel plate, before the software is used to calculate the relative isotope amounts present in the sample. Full details of the theory and general methodology can be found in Vickermann and Briggs (2001), and for this machine in Armitage (2013).

The equipment is a TOF-SIMS IV from ION-TOF Gmbh. The primary ion source is a 25 kv Bismuth liquid metal ion gun (25 kv, 1.0 pA pulsed target current, 10 kv post acceleration), with a flux of low energy electrons (20eV) for charge compensation. A notable practical issue compared to EDS-SEM was the latter operated at low vacuum taking 5-10 minutes to pump down, whereas the TOF-SIMS operates at ultra-high vacuum, and for some samples such as the badly corroded urn stoppers an overnight pump down was necessary. It is in the Laboratory for Biophysics and Surface Analysis at Nottingham University. Accuracy here is more complex and will be considered with the results.

CHAPTER 4 ANGLO-SAXON DERBYSHIRE AND LEAD MINING

The East Midlands Archaeological Research Framework for Derbyshire (Barrett, 2006) states 'The importance of the lead industry as a basis for wealth and importance of the White Peak also needs to be reassessed, despite the attendant difficulties in addressing the origins of the industry'. This is continued in the latest version on line (East Midlands Historic Environment Research Framework) under Section 6H for 'Assess the evidence for extractive industries in the late Anglo-Saxon and Viking periods', and as part of this 'the development of lead mining and the smelting of lead ores in the Derbyshire uplands' is a key component. This area of study is also an objective for' Metals and Metalworking; A 'Research Framework for Archaeology' (Bayley et al. 2008, 68).

In this chapter existing evidence will be documented and reviewed and later there is a re-examination of published analytical data of lead artefacts, especially their tin content, to indicate the probability of recycling..

4.1 Written Evidence.

4.1.1 Bede (Shirely-Price 1968)

Bede has already been discussed, and he makes no specific references to lead mining in what is now the Peak District, but does mention a church covered in lead in 664 on Lindesfarne
and for the Monkwearmouth and Jarrow stone churches, Benedict still needed to import building craftsmen for their construction in the late seventh century. This skill was not transferred as in 764 Abbot Cuthbert wrote to Lull at Mainz asking for glaziers (Cramp 1969, 24)

4.1.2 St Guthac's Coffin.

This is often referred to as the earliest mention of Derbyshire lead, when the Abbess of Repton is reputed to have sent a coffin made of Wirksworth lead in 714 for St. Guthlac's burial at Crowland in the Fens around the Wash (Zaluckyj 2001, 119, Repton Church 19628). However many Roman coffins will still have been in existence at that time, as they are even today, and other records show the coffin may have been sent from East Anglia (Gallyon 1973, 133). Also as shown by the earlier discussion on lead vessels (Section 2.2.5) the knowledge and skill in casting lead sheet and its fabrication requiring lead to lead joints was lacking and hence a coffin which is a substantial object may well have been beyond the capabilities of local craftsmen.

4.1.3 Tribal Hidage

Angles came into Derbyshire via the Trent Valley, as indicated by pagan burials (Hey 2008, 59) dated to the mid-sixth century, and will have been into the Peak District by the mid-seventh century. Mercia has been discussed and the capital of North Mercia was most likely Derby (Northworthy), and under Penda many tribes were incorporated into Mercia. Bede records in 655 that Penda was supported by 30 British and Anglo-Saxon chiefs. The Northumbrians occupied the Peak for a short period after this, but were soon expelled by Wulfhere. There is still some dispute on the date of the Tribal Hidage; seventh century or less likely Offa's reign, and who composed it; Mercia or Northumbria (Zaluckyj 2001 17), but it is recognised as a list of the tribes in Southumbria. In the Peak District there are the Pecsaete or dwellers of the Peak and hence this area has a distinct tribal boundary surrounded on three sides by gritstone moors, or it could be larger. Interestingly in the map drawn by Hart (Zaluckyj 2001, 16) for the eighth century from a variety of sources including the Tribal Hildage has Wirksworth positioned just outside the Pecsaete and in North Mercia. If the document is a form of tax assessment as most commentators believe, the Pecsaete's contribution was based on 1,200 hides, which when compared to others is relatively high. This suggests that the population was high in an area of poor agriculture (Barnatt and Smith, 2004, 56) and hence perhaps indicates that a supplementary form of occupation was occurring; lead mining.

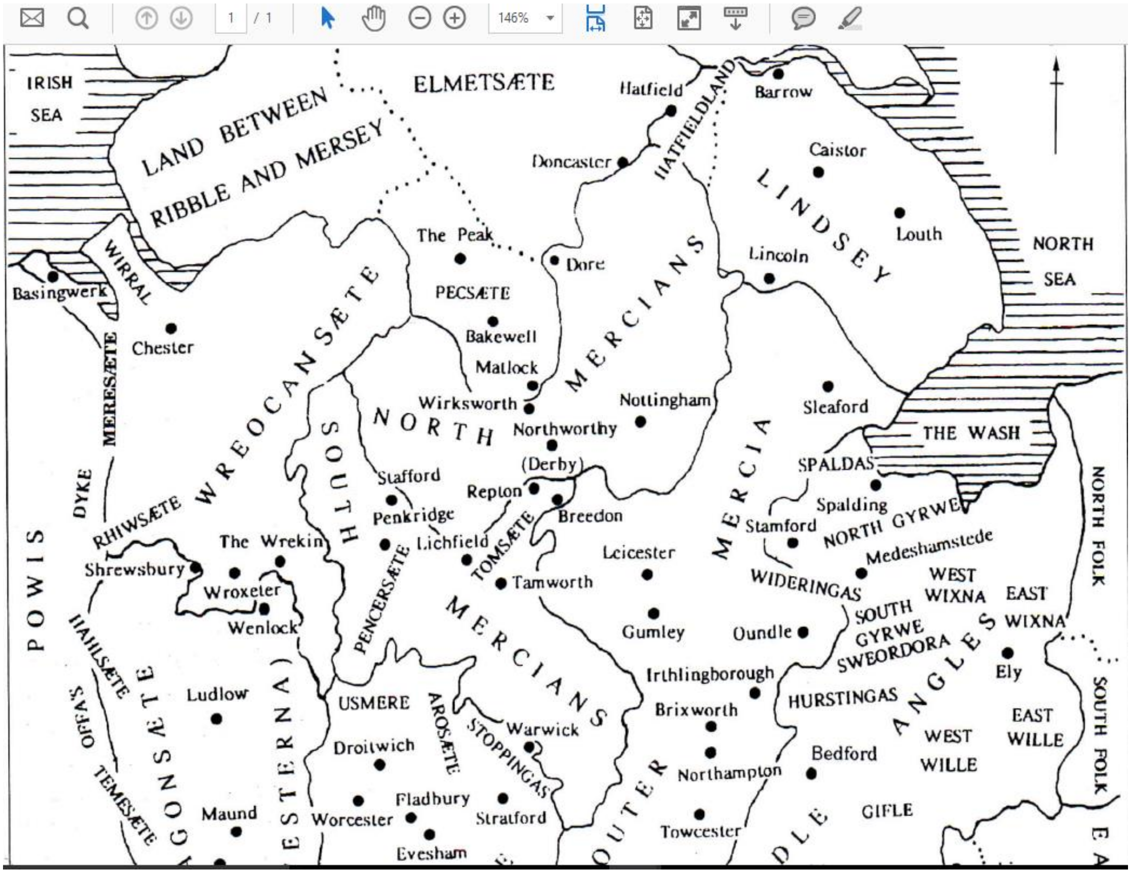

Figure 4.1 Map of Mercia (From Zaluckyj 2001)

4.1.4 Anglo-Saxon Chronicle

The Pecsaete of theTribal Hidage have a long survival as they are mentioned in the Anglo-Saxon Chronicle for 920 with a reference to Bakewell in the 'Peacland',and in a charter of 963 for Ballidon the 'district of the Pecsaetan' is mentioned (Hey 2008, 61). The Anglo-

Saxon Chronicle also records many battles within the area, mostly at its edges as discussed in Section 2.2.2.1.

4.1.5 Charters, Mints and Other

There is a charter from 835 by the Abbess of Repton giving land at Wirksworth to Humbert in exchange for an annual rent paid in lead to Bishop Ceolnoth at Canterbury (Tylecote 1986, 70; Hart 1975, 102). A number of manors combined sent 18kg of silver to the mint at Derby (Tylecote 1986, 71) in the eleventh century. The next recording of lead is in the Pipe Rolls for 1163 and in 1170 lead from the Peaks was sent to Westminster and Woodstock (Kirkham 1968, 100). Lead was transported to the Humber and Boston for export and earlier in the ninth century Peak District miners sent lead to Canterbury by the Trent and Humber (Loveluck 2013, 187; Hart 1975, 102). Although not specifying the origin, Archbishop Wilfred in 700 obtained lead for his church in York (Hodges 1989, 127). Alcuin (735-804) is recorded as sending tin to Archbishop Eanbald II of York for his church tower, but Grierson believes this should be read as lead (Hodges 1989, 127). Also with unspecified origin, lead is recorded as being landed at Quentovic for the Abbey at Ferrieres (Hodges 1989, 127). Hooke (2001, 166) believes the Peaks were lightly settled with predominately seasonal pasture, much as today, until woodland increased for royal hunting and a tenth century charter for Ballidon supports this suggestion.

4.1.6 Doomsday Book

The Doomsday Book of 1086, which is at the end of the historical period of interest and over two hundred years from the first mention of lead in the Peaks records at least seven places for lead production, and it is assumed that these are smelters (Tylecote 1986, 70)

Mestesforde (Matlock) 1

Wechesworde (Winksworth) 3

Badequela (Bakewell) 1

Aisseford (Ashford) 1

Crice (Crich) 1

The manor of Hope's annual assessment included five cart loads of fifty lead sheets each, which as well as indicating lead production shows the fabrication of lead sheet at or near the smelting site. Later when much of the Peaks was a royal hunting forest, lead mining still continued (Loveluck 2013, 261; Barnatt and Smith 2004, 111-13)

4.1.7 Celia Feinnes

Celia Feinnes was an adventurous English woman, who travelled widely across England in the late 1600s, a period well after that of the Angl0-Saxons. A description of a lead mine is valuable as at this late date a mine is still dug like a well with space for one man to be let down on a rope and pulley to dig the ore.

4.1.8 Daniel Defoe

Daniel Defoe also recorded a trip around Britain taken in the 1720s (Slack 2007, 94) and he passed through Brassington on his way from Wirksworth to Buxton.. He describes a mine with a narrow shaft, and being worked by only a few men with simple tools.

4.1.9 Modern Authors

Many modern authors have commented on lead production and also the possibility of silver extraction, but most do not refer to any evidence. If evidence has been provided, then it will be discussed separately. Perhaps Barnatt and Smith (2004, 49), both of whom have worked in the Peaks for many years with the Peak District National Park Authority, can summarise the position. Their comments are mainly for the Roman period but also apply to the Anglo-Saxons as well. 'Whether the local lead ores contained silver is a matter of debate. The ores from post-medieval contained very little, but this may reflect selective mining of silver rich deposits at an earlier date'

4.2 Landscape Evidence including Excavations

Barnatt and Rieuwerts (1998, 51) again warn of the difficulty of finding evidence of mining due to later working. In the Peaks the almost vertical lead ore veins will be destroyed by later working. Also spoil heaps were reworked in the late sixteenth to early seventeenth centuries when the ore hearth was introduced, and again in the late eighteenth century with the cupola furnace. Even in the twentieth century they were reworked yet again, but this time for fluorspar.

4.2.1 Prehistory

Very limited finds are from this period , being fragments of a lead axe from Mam Tor and possibly a portion of a lead torc from above Gardom's Edge near Baslow (Barnatt 1999, 22), and there is no proof that they are from Peak District lead, although it is a reasonable assumption.

4.2.2 Roman

Lead ingots from Derbyshire have been reviewed under lead production (Section 2.3.3), and the numbers found both in the area and more widely show lead production definitely occurred in the Roman Period.

Roman forts are well known in the Peaks with the arrival of the Roman Army in late 70s (Barnatt and Smith 2004, 47) with Navio and Melandra Castle (Erdotalia ?) further along the Roman road to Manchester. Ryknield Street (the modern A38) may be important as it links the edge of the mining area with Droitwich c. 55 miles from Derby where the Derwent valley and Ryknield Street cross (Dodd and Dodd 2000, 20). Hence there was a clear route for the possible transport of lead for the evaporation pans of the salt works, both in Roman and Anglo-Saxon times.

Many ingots are stamped ‘Lutudarum’ and its position is hotly debated, with many believing in or near Wirksworth, and now Carsington has its supporters(Barnatt and Smith 2004, 49) with evidence for small scale lead processing (Barnatt 1999, 24) as well as lead pigs. There are other suggestions and Lane (1986) has devoted a book to supporting the case for the Wilnes at the confluence of the Derwent and Trent as a distribution centre.

In this period the Romano-British settlements were similar to the farms of the Iron Age (Barnatt and Smith 2004, 49). Roystone Grange, near Ballidon, has been excavated (Hodges 2006) from prehistory and in the Roman period demonstrates a small farm with small fields and use of the upland. Hodges (2006, 84) proposed that a field wall dated to the second century was over a mined small lead rake, giving evidence for mining, but recently a new assessment of the wall has given the possibility of a medieval date(Barnatt and Smith 2004, 50).

4.2.3 Romano-British after 400

This is the true Dark Age and little is known of this period. One indication that a Christian community survived into and perhaps through this period is a number of names containing ‘eccles’ which is from the Latin ‘ecclesia’ meaning church. There is Eccles House near Hope and Eccles Pike west of Chapel-en-le-Frith (Barnatt and Smith 2004, 54). Perhaps most significant is Ecclesbourne River rising near Wirksworth and flowing through Duffield to the Derwent. Wirksworth church itself has an unusual form, in that its surrounding graveyard is circular, with houses built around its circumference, which is an indication of an ancient foundation (Hey 2008, 70)). Carl Wark is perhaps a fort built by the British to deter the Anglian penetration of the Peaks (Savage 1999). At the Roman villa site at Carsington where Roman lead was found, in the excavation Anglian pottery was found in the surrounding ditch, difficult to date but from the fifth or sixth century (Barnatt and Smith 2004, 56)

4.2.4 Anglian (Mercia)

4.2.4.1 Barrows

As the Angles entered the Peak District from the south and the Trent valley by the mid seventh century (Hey 2008, 61) they may have had a number of possible relationships with the indigenous British population, and perhaps some occurred together at the same time. These range from ethnic cleansing, a new hierarchy with Anglians as chiefs to British tribes undergoing acculturation to the new Anglian society (Barnatt and Smith 2004, 56). Whatever the society these people were buried in old Bronze Age barrows, which are relatively numerous in the White Peak, or in newly constructed barrows. Thirty eight burials and possibly twenty four more have been listed (Barnatt and Smith 2004, 56). These were known as 'hlaw', which is now changed to 'low'. Mound burials are the main evidence in this early Anglo-Saxon period in the Peaks.

Bateman (1861) excavated a number of barrows and many finds suggested a wealthy community burying its dead with rich grave goods. His most spectacular find was in 1848 at Benty Grange near Monyash, where he excavated a warrior chief's helmet. This helmet consists of iron bans forming a cage like structure to which horn plates were attached. Intriguingly as decoration it has both a Christian cross in silver and a pagan boar with garnet eyes, showing it to be from the period of conversion to Christianity.

Figure 4.2 Benty Grange Helmet (From Hey 2008)

Although containing grave goods, often a guide to a pagan burial, this person and others from other barrow burials were buried east-west in the Christian manner for inhumations. This helmet indicates the burial of a chief of significant importance, as the only similar helmets have been found at the important sites at Sutton Hoo and Coppergate , York. The burial also included grave goods of silver ornaments and silver crosses, a leather cup decorated with silver and fragments of hanging bowls. Other barrows have yielded weapons including shield bosses and swords, which are rare and again indicate a warrior of importance. There are also female burials and again these can contain rich grave goods such as their broaches. At White Low (Winster) Silver jewellery set with garnets was found, and Bateman at Galley Low (Brassington) excavated a gold necklace again with garnets.

In 1869 Lucas excavated the Barrow at Wigber Low at Kniveton (Marsden 1999, 62) and found another rich Anglian burial with gold and silver objects and an iron sword, and these are now in the British Museum. Wigber Low is also important for being excavated to modern standards in the 1970s by Collis (1983) and fully reported. He found that the site consisted of seven or more burials and managed to reconstruct the appearance of the site in the seventh century. Finds from this campaign include knives and spears and a sword and it is suggested that the burials are of a family group. These incredibly rich graves in the White Peak in the seventh and probably second half of the seventh century are important, as well as in their own right, for indicting how wealthy the local population was, or at least its ruling class. This will be returned to after the lead working at Wigber Low is discussed.

Evidence of lead working on Wigber Low was found (Collis 1983, 87) but unfortunately no dating was possible, except that it occurred after the Anglian inhumations in the barrow. It was a crude bole operation with no evidence for cupellation for silver, which was at a low level of 39- 122 $g.t^{-1}$. In addition as already mentioned for Roman lead this metal had a higher concentration of silver than the ore, due to the concentration during the smelting process.

Hodges (Hodges and Smith, 1991) reviews the evidence for settlement in the White Peak and believes that after a fall in population after the Roman withdrawal, settlement grew again with the Anglian penetration in the seventh century with a number of societal organisations possible and an Anglian elite most probable. In a small paragraph he comments about the Anglian settlement 'In addition lead was needed in small quantities for the construction of minster churches'. Loveluck (1995, 84) suggests that the rich graves are the result of competing native and Anglian elites displaying their wealth and hence status, with the former adopting Anglian culture. There is also the external pressure from an aggressive and expanding

Mercia. Loveluck discusses the source of the wealth in the seventh century Peak District and since agriculture was and still is relatively poor in that rocky limestone region with thin soils, an alternative should exist. This source is proposed to be lead and he suggests that the craft skills for lead making have survived from the Roman production, until lead is needed again for stone church construction by the Roman church in the latter half of the seventh century. He also quotes the supply of lead for St. Guthlac's coffin in 714 and the charter of 835 for the supply of Wirksworth lead to Canterbury. The rich grave goods in the barrow burials could have been imported into the Peak District by barter/ trade or a gift exchange.

4.2.4.2 Dykes

The Grey Ditch (a dyke) is clearly post Roman as it is constructed over a cultivated field which contains Romano-British pottery sherds.

Figure 4.3 Grey Ditch (From Hey 2008)

This is not unexpected as it lies near the Roman fort of Navio, and cuts the Roman road from there to Buxton. Hence it controls access from the Hope valley to the White Peak and its lead field (Bell 2012, 52). The ditch is to the north and hence the dyke could be a boundary in the early phase of Anglian settlement against the British to the north, whereas already stated several ’Eccles’ names survive. Other possible Anglo-Saxon dykes are Calver Cross Ridge Dyke and the Longstone Edge Cross Ridge Dyke which have similar features to the Grey Ditch. It is possible that the Carl Wark fort is also from this period.

4.2.4.3 Churches

Minster churches were built at Derby, Ashbourne, Bakewell, Chesterfield, Hope and Winksworth (Hey 2008, 67). St. Mary’s Winksworth has a sculptured stone coffin lid with scenes from the life of Christ and has been dated by its style to c.800 (Hey 2008, 71) and may be contemporary with the wall sculptures inside Bredon on the Hill church (Williams 1996, 25). There is also the Wirksworth miner, a carving showing a miner with his pick and basket, originally found at Bonsall and is thought to Saxon although difficult to date (Zaluckyj 2001, 119). Bakewell church also has a collection of Anglo-Saxon sculptured crosses and grave lids of varying dates, found when the church was rebuilt in the 1840s. There are also crosses in many churchyards, which again may cover a range of dates and are of two main styles, Mercian and Viking, and most are now thought to be from the Wessex conquest of the Danelaw (Higham and Ryan 2013, 58). The Doomsday book records six churches that are pre-Norman at Hope, Bakewell , Darley, Wirksworth, Ashbourne and Bradbourne, the latter still having some of the Anglo-Saxon building remaining

Figure 4.4 Wirksworth Miner (From Zaluckyj 2001)

4.2.5 Viking

In 870s the Viking took control of the Peaks for a while as the Danelaw, but the absence of typical Scandinavian place names such as ---by or ---thorpe in the region demonstrates that they did not make a lasting impression. This is probably because the occupation was short with Mercia/Wessex returning in the early 900s.

4.2.6 Late Saxon/ Norman

4.2.6.1 Bole Excavation

During an excavation in 2004 prior to laying a new sewer by Seven Trent Water at Maiden Green between Hope and Bradwell, a shallow smelting hearth was uncovered, surrounded by walls which may have been of turf (Garton and Guilbert 2009). Lead galena from the limestone plateau perhaps from Monsal Dale has been identified along with lead slag within the hearth. The temperature of smelting was high enough to vitrify the sandstone, but the shallow depth of combustion suggests a limited number of production runs. Charcoal was from local species mainly hazel, alder and birch, and was predominately of twigs, which agrees with the expected pattern for this period of brush wood and ore being mixed together. Radio-carbon dates for two twigs from the hearth area give calibrated data which indicates a possible period each side of the Norman Conquest. As such this is the earliest date for a confirmed Anglo-Saxon excavation of lead mining in the Peak District. As commented before most if not almost evidence has been destroyed by later medieval and industrial period mining. Perhaps because this appears to be a temporary hearth just outside a lead field it has not been destroyed.

4.2.7 Modern (after 1500)

This is a well-studied period, perhaps because much still physically remains to be explored especially underground. The Peak District Mines Historical Society has an excellent journal, and a museum at Matlock Bath. The book by Ford and Rieuwerts (1983) covers this industrial phase. Harris (1971) covers the general industrial archaeology of the Peak District, including lead mining.

4.3 Local History

Several authors and local groups have published accounts of their village, and three relate to the lead field settlements, and like most local histories they concentrate on the more recent past rather than before the industrial revolution.

Brassington (Slack 2007) is in the White Peak not far from Carsington and was a lead mining village with a long history. The Roman road known as ‘the Street’ passed close to the village, and

Carsington and nearby Roystone Grange have already been reviewed. No Roman mines have been identified on Carsington Pastures, and opencast mining is assumed. Angles settled the valley as they did the rest of the White Peak, and farmed with evidence of strip cultivation remaining in the field patterns. One of the rich barrow burials, Galleylow, containing a gold necklace with garnets is close to the village. The earliest written record is in the Doomsday Book for the Manor of Brassington. In this there is no mention of free landowners or 'sokemen' who were Danish and hence Danish occupation of Brassington is unlikely. Again like the Roman Period there is no evidence for lead mining, although Wirksworth is only few miles away. One of the earliest records for lead in Brassington is in the Hundred Roll of 1275, when Dale Abbey had the right to the tax on their part of the lead field.

Bradwell is a village near Hope, and the book (Evans 1912) is a facsimile of the first edition of 1912. The finding of a Roman lead pig is noted, but there are no other entries until the Doomsday Book reference for Bradwell.

Chatsworth is now a grand estate (Barnatt and Bannister 2009, 133) and little mining took place on the main estate as it is outside of the limestone plateau, except at Cracknowl Pasture where open cast features of unknown age exist. The wealth of the Cavendishes came from copper at Ecton Hill.

Wirksworth has been known to be a main centre of the lead field, since the Roman presence, and Wiltshire and Shone (2016) have recently published a well-researched history of Winksworth. Wirksworth had thermal springs until the building of drainage soughs for the lead mines in the 1600s destroyed them and the streams, and this reliable water supply may have been a major reason for an early settlement here. The town was a Roman settlement, with pottery and coin hoards being found, and also there are numerous other Roman remains in the surrounding area. Although Lutudarum is clearly in the Ravenna Cosmography its position is not clear, although Wirksworth is a major contender. As already discussed many lead pigs are inscribed with some form of Lutudarum or an abbreviation. From the early 600s there was constant warfare between Northumbrians, Mercians and British across the Peak District and Wirksworth will have been involved especially as it was on a number of roads. Wiltshire and Shone believe that the battle of Caer Lwytcoed in 636 was at Wirksworth when the Northumbrians were defeated and much plunder obtained. Interestingly it is recorded that a bishop was killed, and this gives evidence for a major church, and possibly the Wirksworth Stone may commemorate this murder. The church is a minster church, named for St. Mary which can indicate an early foundation, either surviving from Roman times or founded early by Mercians. Other local place names suggest a British presence, such as Breamfield, Wallstone farm and Idridgehay, as well as the Ecclesbourne River. Again the reference to lead in a charter of 835 is made. There are still questions about the meaning of the name and at present the best option is fortified enclosure or estate.

Another recent book is by Bunting (2006) and this reviews historic industries of the Peak District from a popular viewpoint. The origin of Golconda mine near Brassington is said to be Anglo-Saxon and the Odin mine at Castleton is believed to be Danish, and this origin is supported in other sources but all without evidence. Records from the sixteenth century record silver coming from the Nestus mine at Masson Hill, and in 1656 soldiers were sent to Youlgreave to disperse miners who were preventing searches for silver in their small mines. The Ball Eye mine near Bonsall outside Cromford had lead with a silver content worth extracting at 20 oz per ton or 0.056%

(Rodgers,1977,115) and this refining continued until the early nineteenth century, but assays taken in the last century were much less (Ford and Rieuwerts 1983, 107). It may be significant that the lead isotope signature for the Ball Eye mine of Pb 208/206 is 2.0915 whereas the other Derbyshire mines have a ratio around 2.08 with the highest at 2.084 so making the Ball Eye an outlier (Rohl 1996, 176). Hodges (2006, 76) reports that silver mines existed in the eighteenth century at Ball Eye and Masson Hill,near Matlock. Other mines with a reported silver content include Millclose at Darley, Odin at Castleton and Mill Dam at Hucklow. Rodgers (1977, 74) also reports that native silver has been found in the joints of the Ible Sill, Via Gellia.

4.4 Other Mining Areas

This is essentially a statement of negative evidence which is always difficult and open to question, since showing that little activity has been reported in the mining areas is not the same as none has occurred. As can be seen from the above for the Peak District little direct evidence has been found there for the Anglo-Saxon period, and this is with an active National Park Authority and the Peak District Mines Historical Society.

No trace of Anglo-Saxon occupation at Charterhouse in the Mendips has been found, and there is no mention of it in the Doomsday book (Gough 1930, 48). Here there is positive evidence for absence of lead working, as physical evidence for a cessation in mining during the Anglo-Saxon period is provided by a mass spectrograph analysis of a speleothem from GB Cave near Charterhouse for lead. This clearly shows lead deposition in the Roman period and a slow build up to the sixteenth century, but none for the Anglo-Saxon age (McFarlane et al. 2014, 431).

As a comparator, there is little evidence for early tin mining in Devon and Cornwall (Gerrard 2000) until after the Norman Conquest.

4.5 Pollution

Lead pollution, laid down over the centuries in ice fields, peat bogs or river sediments, can be a guide to when significant lead mining took place in an area or the wider world. However small scale craft smelting may not show, as it is lost in base line noise. Also it is often just assumed that the lead pollution is coming only or predominately from the nearest ore field, with the prevailing winds sometimes being considered. Strictly lead isotope analysis, as discussed earlier, should be employed to determine origin (Komarak et al 2008, 562). The literature is very extensive

Roseman et al (1997, 3413) have examined Greenland ice core and show by lead isotope that most deposition was coming from Spain in the Roman period with a very small British component. The total reduced to base line after 220 and did not increase again until slightly at 746 and then significantly by 1009. They do not discuss any lead from Asia, and the results are too generalised to discuss Britain, let alone the Peak District. Lindow peat bog near Manchester has been analysed and shows the expected rise in lead deposition in the Roman period, but significantly decreasing already by 250 (Le Roux et al. 2004, 502).Interestingly it also shows deposition from 200 BC , giving support to the proposal that British lead was mined before the Roman invasion. Lead levels then remain low at almost but not quite baseline until c. 700-750 when they increase rapidly to c. 950 and then stay somewhat constant for five centuries until the industrial period commences. The dates are from a few experimental points, and could be later. From lead isotope work, the lead is from a British source, but the results cannot differentiate to a specific ore field.

CHAPTER 5 DISCUSSION OF RESULTS

Firstly each section of the results, that is synthesis of Peak District information, analysis for tin by EDS and determination of the lead's origin by lead isotope analysis, will be addressed separately, and then the crossover of information will be combined to give the fullest picture possible.

5.1 Synthesis of Peak District Information.

The gathering together of information (Chapter 4) is in itself a result, since before it has been widely distributed. However when it is reviewed certain conclusions can be proposed.

5.1.1 Silver

Perhaps the largest unknown for mining lead in the Peaks during the Anglo-Saxon period is the presence or otherwise of silver in the ore and its extraction. This present study cannot analyse for silver as it is below the level of detection for EDS and although its presence is indicated by the lead isotope results, the technique is not quantitative unless a calibration curve is produced. Hence only existing information, often of an incomplete nature can be considered. If silver was extracted, then very large quantities of lead will be available as a by-product and will almost be a waste stream.

Silver has been discussed in general in Section 2.3.3 and for the Peaks in various sections in Chapter 4. The argument for silver rests on three connected points. Was the silver present in sufficient quantity, was the extractive technology available and was the processing economic? These, certainly the latter two, will change as the Anglo-Saxon period stretching from the early fifth to the middle eleventh century proceeds.

There is information available which demonstrates that silver was most probably in sufficient quantities in the lead to make extraction worthwhile in certain circumstances, which will be outlined later. The Ball eye mine had lead with a 0.06% silver content (Rodgers 1977, 115) and this was operating as a silver mine in the eighteenth and early nineteenth centuries (Hodges 2006, 76) and silver was also coming from the Masson Hill mine during the same period. Native silver has also been found in the joints of the Ible Sill (Rogers 1977, 74). Bunting (2006) describes reports of silver from Masson Hill and Youlgrave in the sixteenth and seventeenth centuries. In the late 1600s Celia Feinnes on her travels through England reports that silver was found in the lead. The Doomsday book only records lead works, while Tylecote (1986, 71) reports 40lb (18 kg) of silver was sent to Derby mint by several Derbyshire manors. The abbess of Repton was controlling lead production in 835. There is no evidence of silver production earlier and this includes a lack also from the Roman period.

In terms of technology it unlikely that the Romano-British or early Anglo-Saxons would have had the technology (Section 2.3.3) as it is more complex and requires higher temperatures than for lead. A fact which may support Anglo-Saxon silver extraction is that due to the geological formation process, the richest ore is nearest the surface and will be worked first (Tylecote 1986, 69). A Welsh mine went from 0.07% in 1604 to less than 0.008% in 1845. It is possible that the required knowledge for silver extraction was brought in by the Roman church when it was well established and controlled the lead supply. The Abbess of Repton was involved in lead for church use in a charter of 835. Perhaps the knowledge was transferred from Melle, which supplied lead to the Frankish church.

However the economics of extraction have also varied with time (Tylecote 1986, 61) as technology improves. In the Roman period the economic level was 0.06% and in 1780 0.027 and in 1923 it was down to 0.009%. Extraction by cupellation is expensive being about three times the cost of the lead. The economics are complicated by the widespread use of slave labour in the mines (Davies 1979, 14) by the Romans and also slaves and tied labour were used widely by Anglo-Saxons. In addition it is known that Anglo-Saxon craftsmen, certainly in the earlier periods, were usually part-time, also practising agriculture as well (Fleming 2010 193; Barnatt and Smith 2004, 113). Another aspect of economics is how great the need is for a commodity? The change to a silver coinage occurred in 660-680, which is probably too early for Derbyshire production, but when the Arab supply began to fail in the early mid-ninth century, it may have been able to contribute to the silver supply. The same is true for the large amounts of silver paid later in Danegeld from Alfred's reign, which may tie in with the failure of Arab supply via the Baltic. Very large sums of silver were paid in the late Saxon period, e.g. £10,000 (991), £16,000 (994) and a further total of £221.000 up to 1018 (Higham and Ryan 2013, 345), but taxation, existing silver coinage and church wealth will have contributed the majority.

Modern authors have had a variety of views often unsupported, but Barnatt, the Peak District National Park archaeologist should have the last word and he (Barnatt and Smith 2004, 49) believes that silver was 'probably' produced in the Peaks, and this conclusion would appear reasonable in the light of limited evidence presented here.

5.1.2 Barrow Burials

Anglo-Saxon burials in barrows (650-700, perhaps earlier) are one of the main pieces of archaeological evidence for an Anglo-Saxon presence in the Peak District, on the limestone plateau, and some of the burials are very rich in grave goods. Loveluck (1995, 84) and others have ascribed this wealth to the start of lead mining with the arrival and growth of the Roman church and its need for lead in the construction of its stone buildings. This may well be justified but there are caveats and other sources of wealth are possible, with all or some contributing.

Firstly the church is only slowly becoming established, and the number of stone churches in the seventh century is small, and they are physically small with few small windows for glass and lead cames. Churches are reviewed in Section 2.2.2.3. In addition they are for the seventh and eighth centuries usually made from recovered Roman masonry with mortared walls and no large stone blocks requiring iron clamps secured with molten lead. The evidence for roofing is poor as this part of a building never survives. Bede notes a lead roof while Cramp (1969, 61) has excavated Jarrow and found part stone slates and part lead. She also found lead cames for the window glass and lead cames will still be needed for glass windows whatever the style or size of the building, church or otherwise, even if it is constructed of wood e.g. Flixborough. In 664 Bede records the church on Lindesfarne being covered in lead and Monkwearmouth was built in 674 and Jarrow in 681. These two churches still required foreign craftsmen as did the earlier southern churches, with Canterbury being the first. In further building of the Northern monasteries in 764 (Cramp 1969, 24) foreign glaziers were still needed. Both masons and glaziers are recorded. Hence at this point lead could be brought by the builders and as they were from Gaul, it could come from Melle (Section 2.2.4). Glazing cames are of a small H cross-section design with the glass fitting into the hollows. It will be difficult to cast uniformly to a standard size and probably comes from abroad with the glazier, or at least the moulds do, being protected knowledge as a trade secret. Hence of account of both the timing and the possible external source of lead it cannot be assumed that lead for the church was the basis of wealth.

However lead could still be the source of the rich graves, but from supplying the salt works at Droitwich and probably the Cheshire brine springs (Section 2.2.1). Lead has been found at Droitwich for this

period (Hurst 1992, 14). The importance of salt is often ignored or at least under emphasised today, as it has a minor part in the preservation of food. However in medieval times it was essential to life. Early Saxon pottery was friable and not suitable for salt pans and also would not be nearly as efficient in evaporation of brine due to its poor thermal conductivity compared to lead. Iron was also in short supply and this will have corroded quickly in the presence of salt.
As already discussed it is unlikely that silver was being extracted, even if lead mining was undertaken. Another source of wealth was the normal tribute collection as in other regions, but the Peaks are agriculturally poor and between the fourth and seventh centuries there were a downturn in the climate, which would have made farming more difficult. The other general form of wealth creation was to steal it and the Peak District's inhabitants were allied to Mercia and at war with Northumbria (Section 2.2.2.1) so giving rise for many opportunities for plunder. The Staffordshire Hoard (Higham and Ryan 2013, 173) of war booty was found not far away just off Watling Street near Litchfield. Hence , while lead may have been extracted in the seventh century its use could have been for salt pans instead of or as well as church building, and both normal tribute and war plunder could have contributed to the rich barrow graves.

5.1.3 Lead Production

Although lead production may have been in existence in the seventh century, its production was small, if reserved for salt pans or a small number of churches. St Guthlac's coffin is 714 but its origin is in doubt, and also did Anglo-Saxon craftsmen have the skills necessary for such a large object. The Repton Charter of 835 is more secure recording both a significant amount of lead and routine production as the lead rent was annual. The pollution record (Le Roux 2004, 502) shows the start of lead pollution c. 750 rising tenfold by 900, when the major phase of stone church building and Stamford pottery production commenced. The major finds of lead at Flixborough (Evans and Loveluck 2009) come from mid-late ninth century. Hence it can be suggested that Peak District lead production starts in a meaningful way in the ninth century.

5.2 Reuse of lead by identifying the presence of tin

The reuse of all metals by succeeding generations is well known and continues until today, when Derby Cathedral in 2017 is having its lead roof removed, recast at a foundry and then the same lead replaced. Two major periods of massive reuse of lead have occurred during our history and the second does not affect this study, as it was the dissolution of the monasteries. There is ample written and archaeological evidence (Carter 2006, 43) for this and it was sufficient to lower the market price of lead (Slack 2007, 56). The first occasion was the reuse of Roman lead by the Romano-British and then Anglo-Saxon populations (Fleming 2012, 9) and this period is the focus of this study. Reuse also includes the addition of new virgin metal to the reused lead stock if this occurred.

As has already been discussed early lead mining activity including smelting, has been comprehensively destroyed by later larger scale mining. Lead objects do not normally have the same value as the precious metals, gold, silver and copper or the iron for tools and this is reflected by the few lead artefacts in the British and Ashmolean museums (Section 3.1). However copper alloy artefacts are relatively common and Pollard (2015, 697) has been investigating news ways of analysing trace metal data, which acknowledges that with reuse mixing of metal occurs. This compares with the simpler and perhaps optimistic use of trace metal fingerprints to identify the provenance of a metal artefact (Pollard et al. 2015, 700). Pollard uses the three trace metals found regularly in copper alloys, tin, lead and zinc, with a cut-off of 1% which is below the levels for normal definitions of brass and bronze. They take a large data set from four sources (c, 5340 samples) and use the presence or absence of a metal to classify the type of metal in use in a particular period from Iron Age to Late Saxon, and then use the comparison of the trace metals within and between types to examine its history.

A related method of examination can be used for lead, to attempt to determine when the reuse of Roman lead ceased and when freshly mined lead appeared. This new approach is to analyse for tin in the lead to determine when recycling ceased and when fresh lead first appeared. The presence of tin in Roman lead artefacts and its absence in Anglo-Saxon lead (Section 2.3.5) is commented on by Tylecote (1986, 75) and he identifies Roman lead/tin solder in England from two artefacts found in Silchester. He also shows an absence of tin in Roman ingots from all British sources. His first artefact after Roman is from 1130 again demonstrating the lack of interest or availability in Anglo-Saxon lead artefacts. Cowgill (2009, 273) comments that the lead used by early Anglo-Saxons was reused Roman lead with 0.3 to over 1% tin content. Hence it should be possible to trace the reuse of Roman lead and the introduction of newly mined Anglo-Saxon lead by the presence of tin, introduced by solder or possibly pewter.

However unlike the literature data sets used by Pollard with 5340 samples for copper, the lead data from the literature is embarrassingly sparse and mainly Roman. Tylecote (1986, 62) in his Table 38 shows the absence of tin in Roman lead ingots from all parts of Britain. However his Table 43 has 29 artefacts examined with 15 analysed for tin, showing tin present in in all artefacts usually c. 1%, except for sheet lead when it is absent. Northover (2009, 83) reports the analysis of Roman lead finds from Winterton Roman villa, which is a few miles north of Scunthorpe, where 67 out of 71 finds had a tin content greater than 0.1%, and 28 had more than 1% tin. Two finds could be classed as pewter or containing high levels of solder. He also quotes Cochet's work in France on a larger Roman data set, where again tin is present in the majority of finds analysed, being from 0.3 to over 1%. He reports that the three lead vessels from Bottesford, Lincs (Northover 2009, 83) did not contain any tin and these are dated to late Saxon. Mueller et al (2007) have recently been examining Roman lead artefacts found in Germany, but are concentrating on lead isotope studies and are not reporting trace elements. Hence the data is limited, but it convincingly shows that reused Roman lead contains tin from solder as a marker. It is to be expected that as well as being reused the lead will be mixed coming from a number of artefacts melted down. The exception may be if lead sheet is reused as this may still be virgin metal and not contain tin.

The data for the tin content of the artefacts analysed are given in Table 5.1 with the experimental details having been presented in Section 3.3.3.

Table 5.1 Tin Content of Lead

Artefact	Date	% tin abs	% lead	%tin as %lead
Roman brooch (Margidunum, NU)	Roman	26	40	65
Coffin (Margidunum, NU)	Roman	0	93	-
Plate K9.69.106 (Kingston, NU)	6C?	0	90	
Came 5197 (Flawford, NU)	Late Sax	0-1.2	40-68	0-1.76
Sheet 5197 (Flawford, NU)	Late Sax	0	99	

Came 94.14 (Flawford, NU)	Late Sax	1-5	90	1.1-5.6
Sheet 94.14 (Flawford, NU)	Late Sax	0	99	
Font Cup (Flawford, NU)	Late Sax	50	20	
Measure weight (Derby, D)	Roman	0	30	
Urn 76NJ (Elsham, NL)	5-6C	4	40	10
Urn 75BQ (Elsham, NL)	5-6C	1	50	2
Urn 75KV Elsham, NL)	5-6C	1.5	57	2.6
Coin imprint TOAE (Torksey, NL)	9C	0	50	
Belt Strap (Harpswell, NL)	Late Sax	1	36	2.8
Brooch 185 (Castledyke, NL)	5-7C	1	25	4
Brooch 189 (Castledyke, NL)	5-7C	12	21	57
Solder (Sheffield Hill, NL)	6-7C	20	20	100
All Flixborough (NL)	Mid 9C onwards	0		

Notes.

1. The Roman brooch was identified as silver gilt on pewter, but most silver was worn away.
2. Flawford sheet 94.14 still had a nail in place, identified as iron
3. The Torksey sheet had the imprint of a Carolingian coin, and traces of silver could be detected in the imprint
4. Brooch 185 had an iron pin
5. NU:Nottingham University Museum, D;Derby Museum, NL; North Lincs Museum

As the apparent lead content varies due to soil contaminating the surface to differing degrees, the tin is also calculated as a percentage on the lead to normalise the data, which is somewhat artificial, but does remove the effect of soil deposits (Tylecote 1986, 77). However whichever form of tin results is used the actual numerical figure is not important, since it is the presence or absence of tin that is critical, indicating that the metal comes from reused Roman stock. A very important point to note is that the Flixborough artefacts are not included in detail in Table 5.1, since none of the seventeen items analysed contained lead.

The limited Roman results show the expected picture of no tin for lead sheet, from which a coffin would have been constructed. The measuring weight from Derby does not contain tin, but as it will have been made from filling a mould the measuring weight will be controlled volumetrically and hence a known specific gravity is required. Weights and measures were strictly enforced in the Roman world.

The cremation urn stoppers from Elsham and broaches from Castledyke are all from 5/6/7th century graveyards and hence reused Roman lead was still being used then. Kingston-on-Soar is a similar cremation cemetery, but the lead has no tin. However the artefact is clearly unmelted lead sheet, which is unlikely from a cremation cemetery, and due to the uncontrolled excavation and unspecified donation to the University Museum, it is probably form a later period. The Torksey sheet imprinted with a Caroligian coin maybe Charles the Bald (Loveluck pers. comm.) who reigned 843-877. The lead is tin free and hence fresh lead was available in the second half of the ninth century. It is intriguing that this imprint occurred, as it will damage the coin, and also all foreign coins were melted down and recast as local coinage.

The large sample from Flixborough mainly from mid-ninth century, but continuing up to early eleventh, shows no tin content, and supports the view that virgin lead was reaching the Lincolnshire Trent valley in the mid-ninth century .The results are consistent with the very limited Anglo-Saxon data from Bottesford. It also importantly shows that tin was not entering the lead supply chain, even if the lead was being recycled, and this also applies to sheet from Kingston-on-Soar if this is late Saxon.

The Flawford results are interesting in that the lead sheet shows the expected tin free picture but both window cames give the presence of tin. This is most probably due not to the reuse of Roman lead but the reuse by a glazier of his scrap which will contain tin from the solder used to join the cames supporting the glass. This material is imprecisely dated and could be late Anglo-Saxon or possible early Norman, when English lead was widely available.

The Harpswell belt strap has only the general designation of Late Saxon, and in this period lead was relatively plentiful. The tin may have been added deliberately for improved rigidity or accidently from mixing metal stock.

The solder from Sheffield Hill as identified as such on the museum label, was obtained from sieving the soil of a grave, and is a few tiny fragments of a few mm diameter. Analysis confirms it is solder and it could be a particle of solder knocked off an object or evidence for the use of solder in the seventh century.

The extensive Flixborough artefacts, comprising both objects and lead sheet and melt do not show any tin. The samples chosen are representative of the collection which is extensive, the majority of items being small pieces of lead sheet or melt.. Hence it is not from a recycled lead sheet e.g. a Roman coffin, but represents new lead entering supply chain.

The negative evidence of the scarcity of artefacts from the late seventh to the mid ninth century seen here is often ascribed to the change in burial practise changing from pagan with grave goods to

Christian unaccompanied burials. This pattern is repeated in the British Museum collection with 209 lead artefacts, and only one between early seventh and late ninth century. This is a lead bulla of Coenwulf of 796-821 found in Italy. However the absence may be due to the supply of recycled reused Roman lead running out which will affect the general archaeological record, until a new supply is found. From the above arguments this new source is well on stream by the mid ninth century.

5.3 The Source of Lead by Lead Isotope Analysis.

The pros and cons for lead isotope studies have been discussed in the methodology section (Section 3.3.4.1), and also the reasons for choosing the specific method of TOF-SIMS. Two points will be emphasised here as they affect the manipulation of data and both are a result of the relatively poor resolution of isotopes by the method and the surface roughness of the samples. Rather than produce a sharp peak, almost a single vertical line, the TOF-SIMS gives a broader peak. This wider peak hides the lead plus hydrogen peak. For example the Pb207 plus hydrogen i.e. 208 will under the Pb208 peak. This can be addressed approximately by taking the ratio of Pb208 and Pb208 plus hydrogen and applying it to the lower peaks as a correction (Scurr pers. comm.). This is also shown in Table 5.2. The other problem is where to define an actual peak, as it gradually merges with the baseline. The choice of peak boundaries was made by an experienced TOF-SIMS analyst used to analysing a wide range of materials (Dr D Scurr) and agreed with the author. Although these boundaries are arbitrary it was not thought acceptable to alter them to obtain a particular result. A further point is that the small peak for Pb204 is too small to ascribe boundaries with any confidence, and hence this peak and its ratios will not be further considered.

Pollard et al (2014, 1) have also considered how lead isotope data can be used in a different manner to simply trying to determine the provenance of metal in an artefact, which reduces the problems of recycling and mixing metal and the well-known overlap of lead isotope signatures from different geographical regions and the range of values that can come from a single ore field. It also helps minimise the analytical problems of the preceding paragraph. The approach is to ask 'Could these objects have come from source X?' or 'Are these objects from A the same as those from B?' rather than the much more open question of 'Where do these objects come from?'. He suggests the use of the isotope ratios of 208/206 and 207/206.

Table 5.2 Lead Isotope Analysis

Artefact	208/206	207/206	Corr 208/206	Corr 207/206
Modern	2.57	1.32	2.44	1.19
Roman Brooch	2.34	1.12	2,22	1.01
Plate K 69.	2.15	1.16	2.04	1.04
Fl came 5197	2.35	1.00	2,23	0.90
Fl came 94.14	2.37	1.03	2.25	0.93
Fl font cup	2.50	1.24	2.38	1.12
Urn 76NJ	2.16	0.92	2.05	0.83
Urn 75BQ	2.23	1.08	2.12	0.97
TorkseyTOAE	2.19	0.95	2.08	0.86
Brooch 185	2.15	1.02	2.04	0.92
Brooch 189	2.20	0.99	2.09	0.89
Solder	1.93	0.93	1.83	0.84

Flixborough				
Strip 7878	2.18	1.03	2.07	0.93
Mes wt 169	2.17	1.06	2.06	0.95
Came 12408	2.17	1.47	2.06	1.32
Melt 1232	2.15	1.06	2.04	0.95
Came 2809	2.19	1.04	2.08	0.94
Sheet 1229	2.13	0.91	2.02	0.82
Sinker 7060	2.15	0.95	2.04	0.86
Offcut 11292	2.14	1.08	2.03	0.97

Notes

1. The corr columns refer to the data with the PbH correction.

The data as shown cannot be used for ascribing provenance, as already discussed from the problems of PbH and peak width resolution. There is also the general point often used as a criticism of lead isotope work of metal mixing during recycling and obviously here the early metal containing tin has been recycled, perhaps a number of times. However some very interesting facts emerge if the similarities and differences of the lead ratios are examined.

Taking the uncorrected data first, the first trend to emerge is that the Flixborough data is quite constant (except for came 12408) suggesting that it all comes from one ore field. This is especially true for 208/206 ratio, and there is a suggestion in the 207/206 ratio that at 0.91 and 0.95 the sheet 1229 and sinker 7060 may be different. The major difference is for came 12408, whose 207/206 ratio is high (and also 206/204 is anomalous, indicating an alternative source). If the other Anglo-Saxon artefacts are then examined, and allowing for some minor mixing of sources during recycling, many give the same result for 208/207 as Flixborough (plate K69, urns, Torksey imprint and broaches).In a similar manner for 208/206 ratio there is a possible division for 207/206 ratio between 0.9s and 1.0s. This demonstrates a similarity of source between Roman and fresh Anglo-Saxon supply.

There are also some significant differences, which as well as being logical and giving information, do validate that the differences measured are real. The first is modern lead, obtained from a scrap metal merchant, which will have come from outside Europe and has a very different profile. The next is the Roman silver gilt brooch, again with a significantly different 208/206 ratio, which as a relatively valuable piece of jewellery may well be of an ex-England source, being brought into this country by its owner or as an object for sale. The two Flawford cames have a raised 208/206 ratio (very close to the Roman broach) and this suggests being brought to the site by a travelling glazier, supported by the fact they contained tin. The Flawford font cup is also high in both ratios, and an imported piece of church plate is quite likely to have been imported.

When the corrected data are examined, there is a similarity with Peak District results for 208/206 but not for 207/206. The normal caveat applies of the British lead fields being difficult to separate by lead isotope analysis. Tereygeol (2010, 2640) has the only lead isotope data found for Melle and he expresses results in terms of 206/204, 207/204 and 206/207, 208/207. The undesirability of using 204 in the present study has already been discussed. The 206/207 inverted to give 207/206 shows Melle at 0.849-0.847 which is not distinguishable from the range of present corrected results. The Flixborough strip 7878 can be taken as representative, and when calculated as 208/207 the results are Melle at 2.26 and Flixborough at 2.23, which again are similar, but the similar geology must be remembered.

The TOF-SIMS cannot quantify elements, but it has identified some silver present in the ascending order of Flixborough sheet 1229<

solder< Torksey. The Torksey lead is known to have silver (~ 1%) from the silver coin imprint, also identified by EDS. The solder may have been used to solder a silver object so retaining some silver. The Flixborough lead sheet is not easily explainable, No evidence for silver was found for the solder or lead sheet by EDS.

5.4 Combined Results

Here the three main strands of information, EDS and LIA will be combined, and it will be seen that they support each other and do not conflict. The individual conclusions from Sections 5.1 to 5.3 above will not be repeated e.g. silver or barrow burials. These conclusions also do fulfil the objectives set out in Chapter 1. The only major issue is the relatively small numbers of artefacts analysed, from which to draw conclusions.

5.4.1 Analytical Methodology

The use of equipment with a large sample chamber has allowed the analysis of artefacts with no damage occurring to them, which has greatly aided the provision of samples from museums. The EDS-SEM is excellent for determining the presence of tin to investigate recycling, but the TOF-SIMS gives broad peaks which also hide a PbH peak. Hence TOF-SIMS cannot give the origin of a lead artefact to a specific ore field, but this is a universal problem with any technique, as ore field signatures overlap and an ore field may well have a variety of isotope ratios. However Pollard approach of asking about differences mitigates this difficulty.

5.4.2 Recycled and New Lead

Using a new methodology of determining recycled lead from the presence of tin, Roman lead has been reused in the fifth, sixth and into the seventh centuries, on a large range of artefacts from crude cremation urn stoppers to Anglo-Saxon broaches. No fresh lead has been found. There is little data in the literature, and this is in agreement.

Fresh lead appears at Flixborough in the mid-ninth century, and from the large amount discarded there was a significant supply of the metal. This good supply is supported by its use for net sinkers, which will be expected to be lost in use. Other factors supporting a fresh lead supply in the ninth century are:

The Wirksworth lead charter of 835.

Lead pollution increases from c. 750.

The Torksey coin imprint is likely to date from 843-77.

Pollard proposes a new copper supply in middle Saxon period.

There appears to be a gap in any lead supply in the eighth century, which is supported by a lack of artefacts of this period in the British Museum. Alternatively any lead supply was diverted to church building, and this has not been found in any quantity.

5.4.3 Lead Source

As stated earlier the isotope ratios cannot be used to specify an origin for the lead, and although the corrected 208/206 fits the Peak District 207/206 does not. However from the modern lead and the Roman broach results it will distinguish between possible lead sources. Hence Pollard’s approach of interrogating differences and similarities has been used. As the early period lead has been recycled, it has been produced from mixed metal stocks, but it still has a similar profile to the fresh Flixborought material, implying a similar source. The best and obvious assumption is the lead is coming from the Peak District. This is supported by;

The Trent is an obvious distribution route.

Pollution starts in Manchester in c. 750.

Charter evidence in Peaks in 835.

Peak District smelters recorded in Doomsday Book.

There is no evidence for Anglo-Saxon mining in any other ore field.

A further conclusion is that window cames may have a different lead source and this is supported for Flawford cames by the presence of tin. This suggests itinerant glaziers bringing their own lead cames or using local lead in their moulds into the late Saxon period. The small H cross-section cames will be difficult to cast, and may well be part of their craft knowledge.

5.4.4 Barren Sites

The present study has not given any information to explain why some sites are barren and others plentiful for lead artefacts, and again the number of sites is small. A proposal is that the sites with lead have been deserted and hence hidden, while barren sites have been occupied and plundered.

5.5 Future Work

The whole area of Anglo-Saxon lead mining and artefacts is neglected, and hence there are many opportunities for further productive study.

An obvious need is for more samples along the Derwent/ Trent/Humber corridor e.g. Tattershall Thorpe smith, Catholme and Beverley, and wider e.g. Mucking.

There is an especial need for late seventh to eighth century samples if any exist in the apparent collections gap for this period. Jarrow/ Monkwearmouth should provide such material. There is also a need for window cames from all periods to investigate the proposal for travelling glaziers more fully.

Study can be expanded to cover Stamford ware lead glaze, lead salt pans and lead vessels (fonts, hoard containers), and to other adjoining periods such as Roman and Norman. The possible supply of Melle lead should be investigated.

Different mass spectrometry equipment can be used to obtain accurate isotope ratios, but the well-known difficulties in ascribing an origin will remain. The purity of Anglo-Saxon lead across time from the bulk rather than the surface should be analysed e.g. microprobe. Both these approaches will necessitate a small amount of metal being cut from the artefact. A more sensitive analytical method may reveal any silver, but in view of the reworking of mines and recycling of artefacts this is unlikely.

CHAPTER 6 BIBLIOGRAPHY

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