“ARROWMAN”

AN ANALYSIS OF A POSSIBLE MEDIEVAL COLD CASE FROM POULTON, CHESHIRE.

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This research was carried out in collaboration with The Poulton Research Project and Liverpool Museums Conservation Centre.

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Abbreviations

SK535	Skeleton 535 “Arrowman”
^{14}C	Carbon 14
SEM	Scanning Electron Microscope
AD	Anno Domini
BC	Before Christ
MNI	Minimum Number of Individuals
LC_1	Lower Left Canine
M^1	Upper Right First Molar
AMS	Accelerator Mass Spectrometry
CEJ	Cervicoenamel Junction
X-ray CT	X –ray Computered Tomography
I.M.S	Industrial Methylated Spirit

Abstract

A bodkin arrowhead was recovered from within the thorax of a human skeleton (SK535) from the medieval cemetery at Poulton, Cheshire. This skeleton was a single burial with an east-west orientation. The skeleton had an unusual burial position with the right arm flexed at the elbow and the antebrachium crossing the thorax. The left arm was in the more usual extended position. A metal object was recovered from under the right arm within the thorax. This was identified as a Type M7 bodkin arrowhead, likely 12th or 13th century. The arrowhead was conserved at the Metals Department, Conservation Centre, Liverpool. Radiocarbon dates the skeleton as most likely 1280AD – 1320AD AND 1350AD – 1390AD which is in agreement with the probable age range for the arrowhead. Osteological examinations estimated that SK535 was an adult male with an age at death of 35-39 years of age and a stature of 1.68m. The only pathology observed was a well healed fracture of the right distal ulna. The individual represented by SK535 could have been wounded by an arrow carrying the Type M7 bodkin arrowhead, possibly during the English-Welsh border skirmishes during this period.

Chapter 1

Introduction

1.1 Skeleton 535

Skeleton 535 (SK535) was excavated on 29th March 2011 from a medieval cemetery at Poulton, Cheshire, England (www.poultonproject.org). The grave containing SK535 was a single burial situated on the north side of the chapel (Appendix 1). The skeleton was buried in an east-west orientation, with the head facing west. During the excavation an unusual burial position was noted relative to other excavated skeletons at Poulton. Most skeletons of this period are presented with their arms extended, semi-flexed or flexed by their sides (Sullivan, 2004), which is also true of Poulton. However, the right arm of SK535 was flexed at the elbow with the antebrachium crossing the thorax, while the left arm was in a typical extended position. During the removal of the surrounding soil, what appeared to be a metal object was discovered within the thorax under the right arm. Preliminary examinations of the object, including radiographic analysis, indicated that it was likely to be a Type M7 Bodkin arrowhead (Jessop, 1996). It was orientated with the tip of the arrowhead superior in the thorax and measured 14cm long. On removal, it broke into two segments likely due to its delicate, corroded condition. This is the second arrowhead to be found at Poulton but only the first of this type and the first to be found *in situ* within a skeleton [*].

*** A third arrowhead was subsequently found on 2nd September 2013 located within the lower thorax of Skeleton 719 (SK719) at Poulton. This skeleton had a similar arm position to SK535, only with the left arm crossing the thorax. The arrowhead was located under the right radius and has been determined to be a Broad head MP1, dated to be 14th century.**

1.2 Aims and Objectives

The aims of this research regarding SK535 are: to study and measure SK535 to identify what type of individual it was, using radiocarbon (^{14}C), and to characterise and conserve the arrowhead found within the thorax. Interpretations of SK535 will then be placed within the historical context of medieval Poulton. The following tests were used.

- Radiocarbon dating was determined off site by Beta Analytic, Miami, USA, funded by the Poulton Research Project (www.poultonproject.org). The extraction of the sample for dating was undertaken at Liverpool John Moores University.
- Conservation of the arrowhead was carried out in conjunction with the Conservation Centre, Liverpool, under the supervision of Steve Newman, Head of Metal Conservation for National Museums Liverpool.
- Examination and comparisons with other bodkin arrowheads housed at the Potteries Museum & Art Gallery, Stoke.
- Examination and comparisons with other arrowheads housed at the Royal Armouries, Leeds.
- Consultation with leading longbow expert Robert Hardy CBE, regarding the type of arrowhead.
- Age at death, sex, stature and any skeletal abnormalities (e.g. taphonomical, ante and post-mortem pathologies) were documented, analysed and interpreted for SK535.
- Scanning Electron Microscope (SEM) analysis was carried out on the arrowhead; which allowed identification of the elemental composition of the arrowhead.
- Unusual features found on the arrowhead during the conservation process were examined with the appropriate tests carried out.
- Historical information about Poulton was obtained from archaeological records regarding the time surrounding the death of SK535.

This study hopes to provide further insights of medieval life and death at Poulton archaeological site.

Chapter 2

The Poulton Research Project

2.1 The History of Poulton

Chapel House farm is located in the rural village of Poulton six miles south of Chester, west Cheshire. This multi period archaeological site lays on the north-eastern border of Wales, overlooking the old Pulford Brook, a small stream that runs into the river Dee and marks the border with Wales.

The earliest documentary evidence for Poulton is found in the Domesday book (1086).Original entry:

> "*Ricardvs pincerna ten de comPontone. Eduintenuit. 7 lib ho fuit. Ibiihida geld.Trae.v.car.In dniosunt.iii.car. 7 vi. bouar. 7pposit 7 iii.bord.cu.ii.car.Ibi.viii.ac pti.T.R.E. ualb.xl. sol. 7 posttntd. Modo.iiii. lib"* (Morgan, 1978)

Translation:

> 'Richard Pincerna holds Poulton from the Earl Eadwine held it and he was a free man. There is one taxable hide there. There is land for 5 ploughs. In demesne there are 3 ploughs and 6 ploughmen; a reeve and 3 smallholders with 2 ploughs. There are 8 acres of meadow. In the time of King Edward the Confessor it was worth 40 shillings; later the same. Now worth £4.'

A charter of 1153 then confirms the foundation of the Cistercian Abbey of Poulton. Many endowments of land were made to the abbey which became the richest Cistercian estate in Cheshire. However, by 1483 all the monastic lands had been leased out to a local family, the Manleys. The Manleys, in turn, developed an existing small, single cell, chapel (of Late Anglo-Saxon origin) into a fully developed church adding a chancel and tower (the chancel being used as a private burial area for the Manleys (Emery *et al,* 1995). The last known activity on the site took place during the siege of Chester during the English Civil War (1645-1646) (Emery, 2000).

2.2 Aims of the Poulton Research Project

The original aim of the Poulton Research Project was to locate and investigate the lost Cistercian Abbey of Poulton.

In 1995, the owners of Chapel House Farm invited a team of archaeologists to investigate one of their fields (Chapel field) where some medieval artefacts and fragmented human remains had been found. Geophysical surveys (resistivity) of the area were undertaken and revealed the outline of what appeared to be a building. During the period 1995 to 2012, a medieval chapel (AD 1000-1600) was uncovered and excavated along with its attendant cemetery which contains, to date, over 700 skeletons and a considerable amount of disarticulated bones. Many of the burials are thought to date from the 13^{th} – 14^{th} centuries, the last attested burial took place in 1598 (Emery, 2000).

Little is known of the chapel's early history. However, recent research of the ceramics from the earliest phase of the chapel, suggests that it was established sometime in the early 10^{th} century, nearly 250 years before the foundation of Poulton abbey. However, the site of the abbey at Poulton and its burial ground still remains elusive.

Figure 1: Map of medieval religious houses in Cheshire, after *CWArch.Service* (Emery *et al* 1995).

During the medieval period, the site was owned by numerous families. In the years before the Norman Conquest, Earl Eadwine owned the manors, however; he seems to have lost his control after the conquest. The manors are then listed as owned by a Robert Pincerna who also owned the nearby estate of 'Calvintone' (Emery *et al,* 1995). He donated part of Poulton to William, abbot of Combermere, Poulton, Stanlow and Vale Royal (Fig.1). It is thought that Poulton abbey was founded between 1147 and 1153 as a daughter house to Combermere (Emery *et al,* 1995).

In 1146, Earl Ranulph II the Earl of Chester, was captured by King Stephen, of England. While captured, the Boutellier (i.e. butler) Robert Pincera, responsible for the Earl's household, granted half of the manor at Poulton to the Cistercian monks, in return for the building of an abbey and prayers for the safe return of the captured Earl (Emery *et al*, 1995).

During this time the Welsh took advantage of the Earl's capture to ravage the hinterland of Chester. In 1307, a new English king was crowned, Edward II, son of Edward I. Edward II was by no means as fearful a warrior as his father; he had also inherited debts and legacies from the previous wars. Edward II, in time, won over the Welsh and slowly incorporated English law and rules into Wales. However, after the death of Edward II in 1327 the Welsh began to revolt against the English again. At this time England had fallen into crisis leading to this rebellion lasting for 10 years (Emery *et al,* 1995).

By the end of the 14^{th} century, it is estimated that the Cistercian monks had acquired over 3,000 acres of land through donations and endowments (Emery *et al*, 1995). Although the monks had long translated to the new monastic foundation of Dieulacres (Staffordshire), some remained to look after their large estates administered from the grange and chapel at Poulton.

A lack of man power resulted in the monks leasing Poulton chapel and land to the Manley family in 1487. The estate was leased to John Manley a local Cheshire man and his family in 1493 and then passed to his son Nicholas in 1504. During their time living at Poulton they created a private family chapel, they added to the chapel by building an eastern chancel and a tower to the west of the original building which was a single cell building. When Nicholas Manley died in 1520, he left a will stating that he wanted to be buried in the chapel (Emery *et al,*1995).

With the dissolution of the monasteries by King Henry VIII (1536-39), the monastic estates at Poulton were divided up between the Grosvenor and the Manley families. In 1538 the monastery was closed. The remainder of the land was granted to Sir John Cotton in 1544, who sold part of the manor to Thomas Grosvenor. The Manley family continued to live at Poulton Hall until they sold the entire estate to Richard Grosvenor during the reign of Elizabeth I (1558-1603) or early James I (1603-1625) (Emery *et al,* 1995). In 1601 ownership of the Poulton estates passed entirely into the hands of the Grosvenor of Eaton. The Grosvenor family own this land today (Emery, 2000).

One of the last historical events to have taken place at Poulton Hall was the English Civil War (1642-1651). During this time parliamentary troops were kept in the barracks in the surrounding villages of Farndon, Aldford, Dodleston and Eccleston. Letters from the parliamentary commander Sir William Brereton dated within a month of surrender refer to Poulton requesting a need to guard Poulton green and the water sides by Poulton Hall. This was probably due to a royalist outpost being a few kilometres upstream. During the English Civil War Poulton chapel was used as a lookout point. The chapel overlooks the countryside and so was a good advantage point for the soldiers to see the advancing Welsh. The tower was also a strong structure so could be used as a good defence against attack (Emery *et al,* 1995). By 1718, it was recorded that there was nothing left of the chapel after it being demolished (Emery *et al,* 1995).

2.3 Investigation of site

A major focus of investigation at the site has been the remains of the medieval chapel and surrounding graveyard (Fig. 2). From the beginning of the project in 1995 to date, over 700 human skeletons have been excavated along with large quantities of disarticulated bone. The skeletons recovered thus far, likely represent only a small proportion of the total number of burials because much of the chapel site has yet to be excavated.

Burial locations are relevant to the two phases of the chapel. The grid shows fewer single burials in the north than that of the west and south (Fig. 2). This suggests an area that was used exclusively for higher status burials. Most burials are laid out in an east-west orientation, head facing west, thus being consistent with Christian burials. There are, however, a few buried in an easterly direction. Possible explanations for this are head to toe packing for multiple burials, limited space, carelessness or deliberate ill treatment (Burrell, Carpenter 2013). This is unusual but has been known to happen at other medieval sites (Daniell, 1998).

There appears to be no evidence of coffin burials at the site, although it is known that the soil at Poulton does not favour the preservation of wood, (Burrell, Carpenter, 2013). The grave cuts also suggest that coffin burials were not used; they are exactly the right fit for a body and would leave no room for a wooden coffin. Many pins have been found in and around some of the skeletons indicating that shroud burials may have taken place (Burrell, Carpenter, 2013)

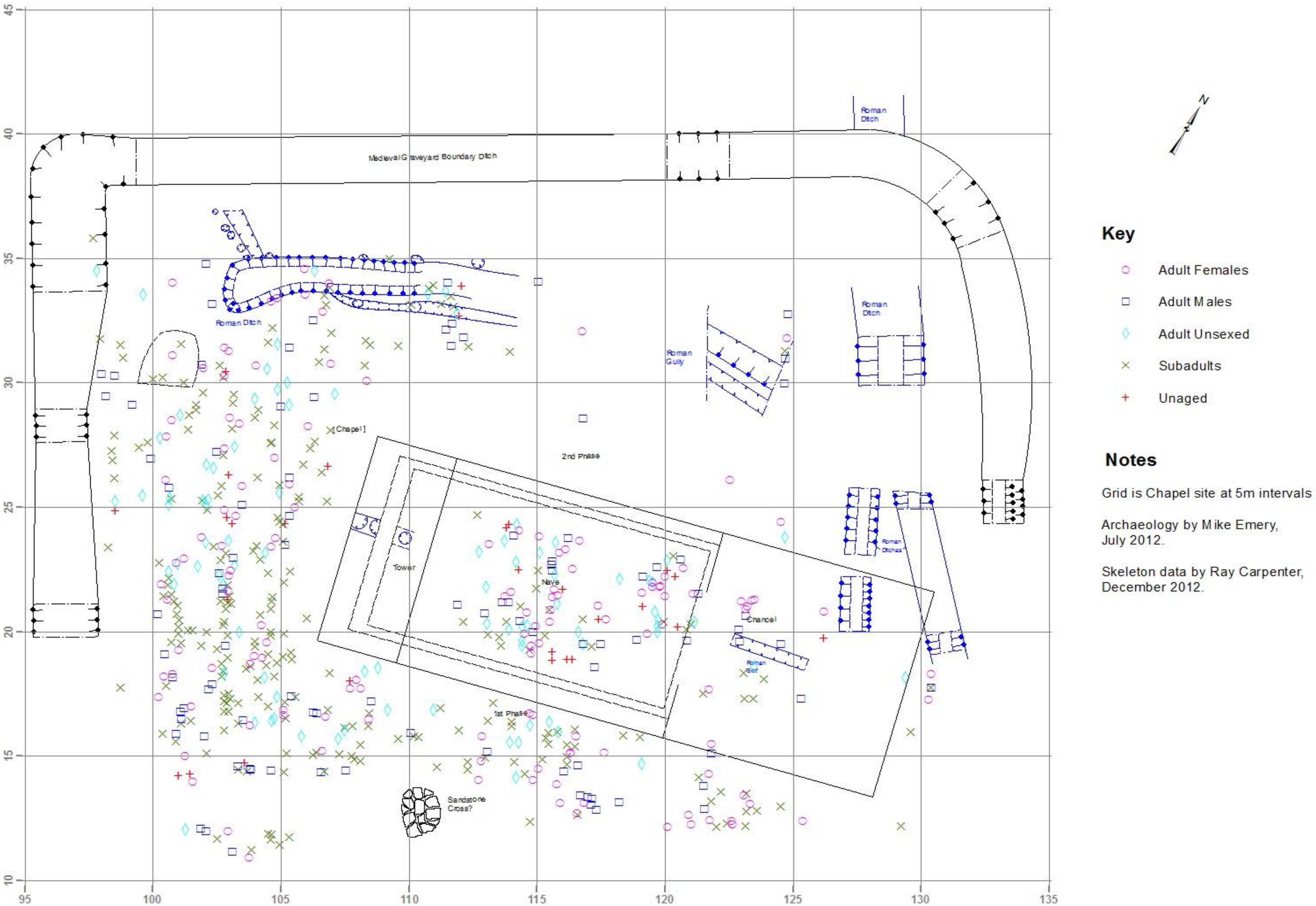


Figure 2: Location and organisation of burials at Poulton archaeological site (Burrell, Carpenter, 2013).

Chapter 3

Excavation of SK535

3.1 Excavation

Skeleton 535 (SK535) was situated within the graveyard outside the area known as phase II (Fig. 2). There are two phases within the chapel site, Phase I is located within the chapel walls and Phase II is outside the chapel walls. SK535 was a single burial orientated east-west in an extended supine position (Fig. 3a), depicting a traditional Christian burial (Daniell, 1998). SK535 did not have the usual arm positions of other burials excavated at Poulton. The right arm was flexed at the elbow with the antebrachium crossing the thorax, the left arm in a normal extended position at the side (Fig. 3b). This burial position is thought to be unique of the 700+ skeletons excavated at Poulton*.

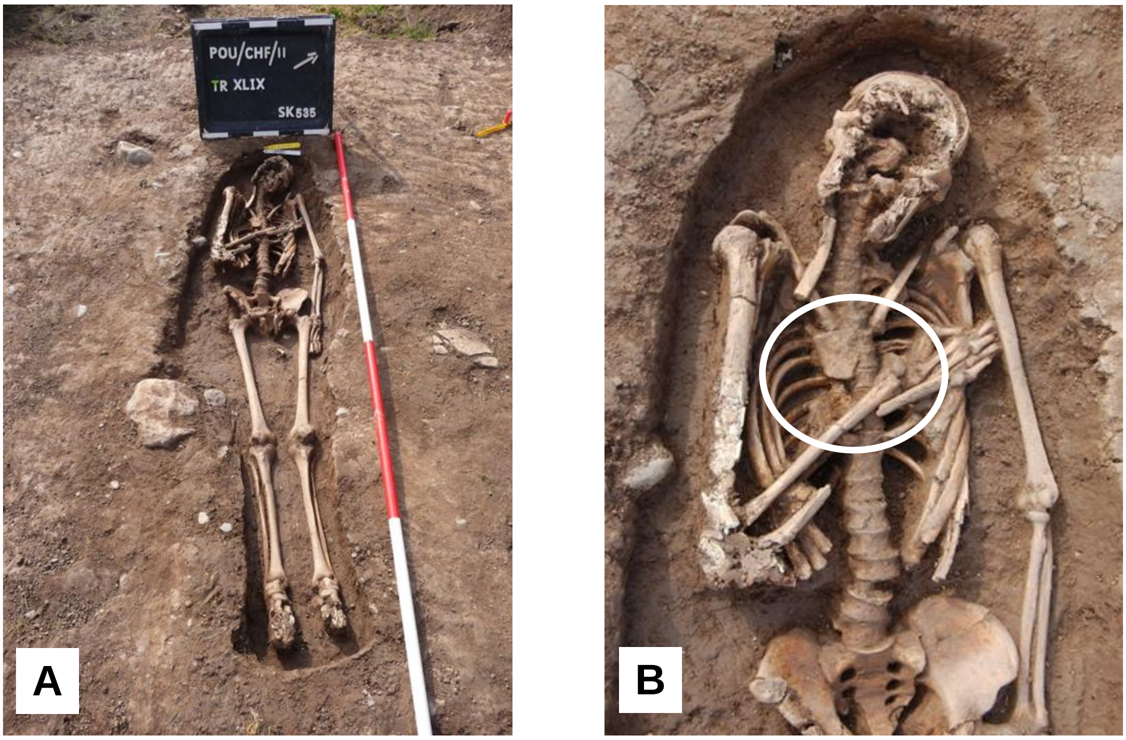


Figure 3: SK535 *in situ* at Poulton before excavation (A) with a unique arm position, with right arm overlying the arrowhead as indicated by the white circle (B).

***On 2nd September 2013, Skeleton 719 was excavated and showed the same arm position as SK535 but, with the left arm across the thorax, this too was found to overlie an arrowhead (Appendix 1).**

SK535 was excavated following the guidelines by the Institute of Field Archaeologists (McKinley, Roberts, 1993). Upon removal of the soil from around the right arm, an object was discovered under this arm (Fig. 4a). The object was long and slim, (estimated *in situ* to be about 14cm*)*. The object was carefully removed but broke into two pieces due to its delicate condition (Fig. 4c). Residue left by the object was also lifted. Preliminary examination of the object indicated it was a Type M7 bodkin arrowhead (Jessop, 1996), with the tip of the arrowhead missing. The tip was later found amongst the residue which added a further 2cm onto the length. Thus the overall length of the arrowhead is approximately 16cm long. The arrowhead can be clearly seen resting above the right ribs (4-9) lying against the 9^{th} thoracic vertebra (Fig. 4b). The right arm, which is flexed, lies across the thorax completely covering the object, as if specifically positioned over it.

Figure 4: Location of arrowhead before and after excavation. Arrowhead *in situ* as indicated by white circle (A).Arrowhead *in situ* after excavation of the right arm (B) and arrowhead after excavation (C).

3.2 Burial position

It is well documented that the position of a burial can be a representative of the status of the person when alive (Sullivan, 2004). In Poulton four arm positions are represented; arms by the side, arms by the side with hands inside pelvis, arms folded across the stomach and arms folded across the chest (McLeod, O'Regan, in prep.). SK535 differs from these four arm positions previously recorded.

When analysing burial positions it is important to take into account decomposition movement. During the decomposition process; movement of the body can occur due to chemical and physical process or decay (Gunn, 2009). Grave cuts can also be a good indication of how much movement a skeleton may have undergone. The grave cut for SK535 seemed to be individually tailored to the skeleton making decomposition movement limited.

Once lifted, SK535 was cleaned, bagged and transported to Liverpool John Moores University for detailed analysis.

Chapter 4

Osteological Analysis of SK535

4.1 Condition and preservation

Skeleton 535 (SK535) was examined to determine the condition and preservation of the bones. The bones were dry, lightweight and smooth in texture. SK535 Shows signs of preservation, but there is some post-mortem damage from excavation. Pathological conditions and trauma concerning SK535 were noted after the osteological analysis had been undertaken, (Brickley, Mckinley, 2004) (see section 4.7).

4.2 Minimum number of individuals (MNI)

To determine the minimum numbers of individuals present (MNI) in this assemblage, it was necessary to account for each bone, and sort them according to type and side. Any duplicates, or bones of different age or sex, suggest that more than one individual is present amongst the remains (White, Folkens, 2005). SK535 showed no duplications of any bones therefore, MNI for SK535 indicates one individual.

4.3 Inventory

SK535 was assembled in anatomical position. Each bone, whether complete or fragmented was recorded from the cranium to the feet (Appendix 2). The entire skeleton was examined macroscopically. Any unusual features were photographed and recorded thoroughly for further examination.

SK535 was relatively complete but fragmented. The skull showed the most post-mortem damage, much of which was likely caused during the excavation process. Most of the splanchnocranium, including some of the mandible and all of the maxilla, were missing. Regarding the dentition, only the left lower canine (LC_1) and the upper right first molar (M^1) was present within the remains of skull fragments.

Both scapulae were incomplete, with the acromion processes and scapula plates missing. The clavicles were complete yet the right exhibited a single post-mortem fracture, midway along the shaft. The right anterior surface of the humerus suffered post-mortem damage from the excavation. The left humerus was also fragmented with a post-mortem fracture at the neck. The right radius was damaged from excavation. The left radius displays a post-mortem fracture. The right ulna showed excavation damage and also a healed facture of distal aspect of shaft. The left ulna displays a post mortem fracture of the proximal shaft. Only the 1^{st} and 3^{rd} distal phalanx of the right hand was present. The 1^{st} metacarpal, 2^{nd}, 3rd 4^{th} and 5^{th} intermediate and 1^{st} to 5^{th} distal phalanx of the left hand were absent.

All 7 cervical, 12 thoracic and 5 lumbar vertebrae were present but fragmentary. The 9^{th} thoracic vertebrae showed a red/brown staining on the surface where the arrowhead had laid. All ribs were present except for the 2^{nd} right rib. Ribs present were fragmented.

The *os coxae* and sacrum were present but fragmented. Both femora, tibia and fibula were present with post-mortem fractures along the shaft. The intermediate and distal phalanges of both feet were missing.

Analysis was hindered by the fragmentary condition of SK535. To help, the crania and *os coxae* were reconstructed using B72 Paraloid 60% with acetone to join the fragments together (Fig. 5a, b and c).

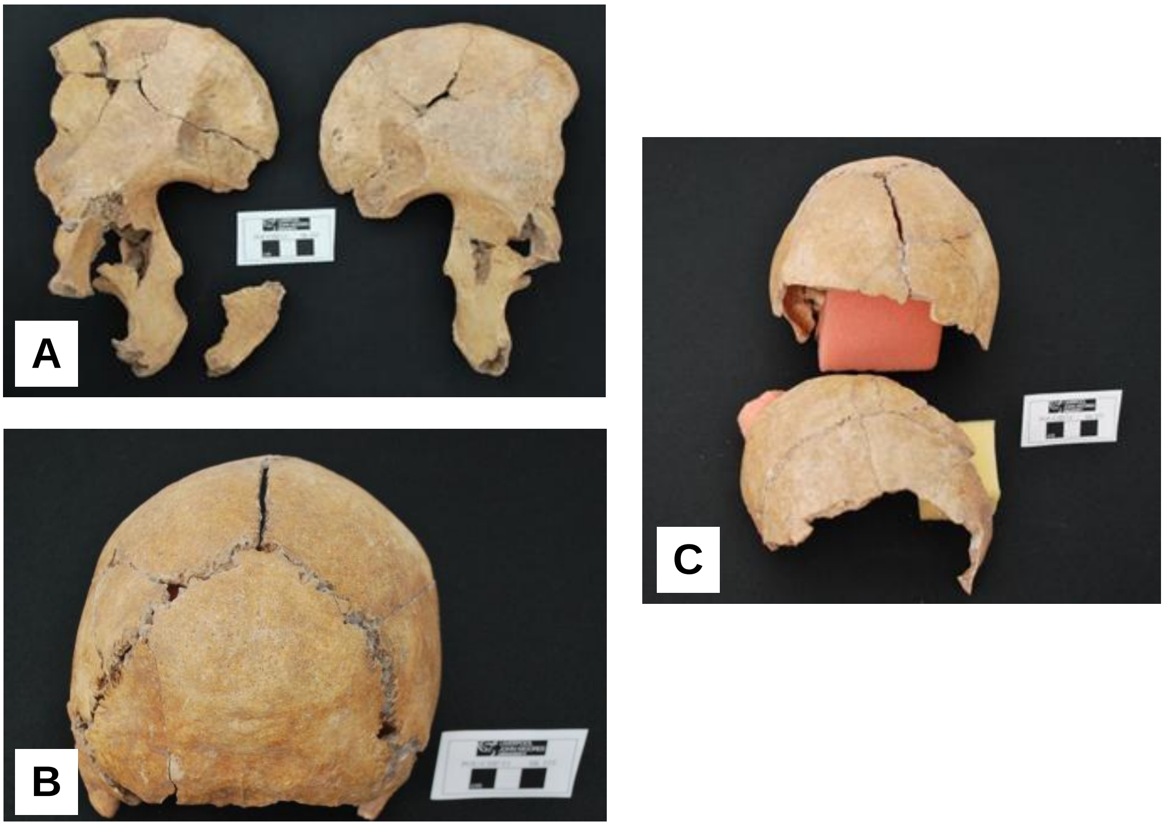


Figure 5: Reconstruction of *Os Coxae* (A). Reconstruction of the posterior portion of Cranium (B) and anterior portion of the cranium (C).

4.4 Sex estimation

Determinations of sex in skeletons are normally the result of the analysis of traits in the skull and the pelvis. In any population, male and female skeletons differ in size and shape but, there are individuals who do not have defined characteristics and therefore do not fall into a definite male or female group. Each attribute is normally scored on a 1 to 5 scale, 1 being mostly female and 5 being mostly male, while those scored as 3 are classed as ambiguous (Buikstra, Uberlaker*,* 1994).

Sex determination of the skull can sometimes be difficult to interpret due to idiosyncratic variation (Meindl, Lovejoy, 1985). Males normally have a larger and more robust skull in comparison to females, who tend to be more gracile although this varies among the modern human (White, Folkens 2005). There are five key sex indicators of the skull that typically survive in archaeological and forensic contexts; the nuchal crest, the mastoid processes, the mental eminence, the supra-orbital margin and the supra-orbital ridge. The skull of SK535 was badly fragmented due to post-mortem taphonomic damage, mostly likely resulting from the excavation process. The only visible traits were the mastoid processes and nuchial crest, using (Buikstra, Uberlaker ,1994) they were scored a 4, suggesting a male.

Sex determination of the *os coxae* is estimated from the following traits, the greater sciatic notch, the sub-pubic angle, the ventral arc, the sub-pubic concavity and the ischiopubic ramus ridge. Only two traits of SK535 *os coxae* were available for analysis, the greater sciatic notch and the sub pubic angle. The left and right greater sciatic notches were scored as a 4, resulting in a strong male trait (Buikstra, Uberlaker, 1994). The subpubic angle, a trait from the Phenice Method (Phenice, 1969) was scored as a 4, a strong male trait. The Phenice method has been reported to be 96 – 100% accurate (White, Folkens, 2005*).*

After the reconstruction of the cranium and *os coxae*, these traits were re assessed. The traits of the *os coxae* and cranium produced the same results as stated above.

Results for the cranium and pelvic indicators of sex are present in Table 1. Overall the best estimation of sex for SK535 is male.

Os Coxae	**Traits**	**Left Side**	**Right Side**	**Sex Estimation**
Ilium	Greater Sciatic Notch	Fairly narrow	Fairly narrow	Male
Pubis	Sub-pubic angle	N/A	Sharp narrow	Male

Table 1: Sex estimation results for SK535 using the Phenice technique and Buikstra (1994).

Sex for SK535 was also quantitatively assessed by size of the femoral head the radial head and the humeral head using Stewart's technique (Stewart, 1979). The results obtained from these measurements show an overall sex estimate of indeterminate (Table 2). Given the indeterminate quantitative assessment, but consensus agreement among qualitative traits, it is likely that SK535 was male.

Bone	**Left Side (mm)**	**Sex Estimation**	**Right Side mm)**	**Sex Estimation**
Femur	43.02	Female	43.73	Indeterminate
Humerus	45.61	Indeterminate	45.50	Indeterminate
Radius	23.17	Indeterminate	22.71	Indeterminate

Table 2: Sex estimation results for SK535 using Stewart's (1979) method.

The overall assessment of sex determination for SK535 based on the traits described is male.

4.5 Age at death estimation

Estimation of age at death involves observing morphological features in the skeletal remains, comparing the information with changes recorded for recent populations of known age, and then estimating any sources of variability likely to exist between the prehistoric and the recent population, furnishing the documented data (White, Folkens, 2005).

Methods to determine age at death of a human skeleton are based on the attributes of the skull, such as dentition and the fusion of the spheno-occipital synchondrosis (Powell, 2005), due to the measured rates that bones fuse and teeth develop. The pelvis is another good indicator of age especially, the pubic symphyseal surface and the auricular surface of the ilium as an age range to 60+years can be made.

Formative and degenerative changes can be determined across the skeleton. Formative changes occur during growth development such as tooth eruption and epiphyseal union. Degenerative changes such as dental wear and osteoarthritis result as the process of ageing and normally follow as soon as formative changes have finished.

Due to the badly fragmented stated of the skull and pelvis of SK535 it was difficult to estimate age at death.

Os Coxae	**Left Side**	**Age Estimation**	**Right Side**	**Age Estimation**
Auricular Surface	Phase 4	35-38 years	Phase 4	35-38 years
Pubic Symphysis	N/A	N/A	Phase VII	35-39 years

Table 3: Age at death estimation results for SK535.

Both auricular surfaces were present but fragmented. Using Meindl, Lovejoy method (1985), the auricular surfaces were assessed as a phase 4, giving an age at death of 35-38 years. The right pubic symphyseal surface was assessed as phase VII, giving a likely age at death of 35-39 years (Meindl et al, 1985).

Therefore an overall best estimation of age at death is 35-39 years of age (Table 3).

4.6 Stature estimation

The height (stature) of a human body correlates with limb bone length for all ages, allowing the stature of the human body to be estimated. Regression equations have been derived based on skeletons from different populations.

Before an estimation of stature can be made, the sex of the skeleton, if possible, should be known, because this improves the estimation.

Many researchers have produced different regression equations to estimate stature from limb bone length using different long bones and for different reference populations. The formula used here was for White males (Trotter, 1952 and 1958) given that the Poulton population is medieval British. The results (Table 4) for SK535 produce a mean of 168.5 cm, (5ft 6in).

Bone	Length (cm)	Formula for White Males	Height Estimation (cm)
Femur Left	45.4	2.38 x Fem + 61.41 +/- 3.27	169.46
Femur Right	45.5	2.38 x Fem + 61.41 +/- 3.27	169.70
Fibula Right	35.5	2.68 x Fib + 71.78 +/- 3.29	166.92
Fibula Left	35.9	2.68 x Fib + 71.78 +/- 3.29	167.98

Table 4: Equations for stature estimation of SK535 (Trotter and Gleser, 1952).

4.7 Pathology and trauma

SK535 was macroscopically and microscopically examined for any pathology or trauma on each bone and fragment. No abrasions, erosions, cut or animal marks were evident on any bone surface. Post mortem damage was evident on the splanchnocranium, right femur and proximal ends of the right ulna and right radius. This damage was due to excavation machinery during the excavation process. Pathologies previously seen at Poulton such as fractures, osteoarthritis, schmorls nodes, and cribia were looked for, however, SK535 showed no evidence of these except for a healed fracture, located on the distal aspect of the right ulna, possibly a transverse fracture (Fig. 6a and b). There is evidence of remodelling to this fracture and the surface has returned to its original appearance. A radiograph of the fracture (Fig. 6c) showed no evidence of an active fracture demonstrating that this injury occurred many years before death.

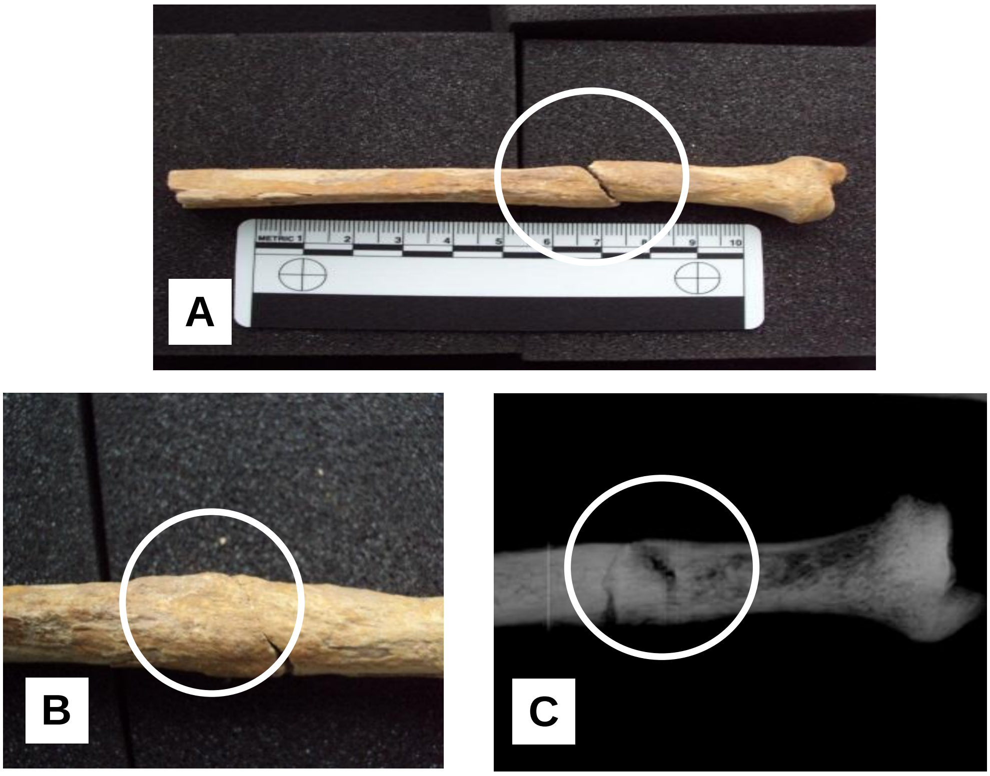


Figure 6: Right ulna showing healed fracture and post mortem fracture (A). Right ulna showing healed fracture and post-mortem fracture (B) and radiograph 100kv showing right ulna (C).

The radial (circumferential) articulation appears to be larger and flatter than that of the left one and the styloid process is irregular in shape (Fig. 7). In contrast the left radial (circumferential) articulator surface display a more expected shape, so the distal articular surface of the right radius is likely remodelled as a result of the well healed fracture.

Figure 7: Right and left ulna showing radial (circumferential) articulation of SK535.

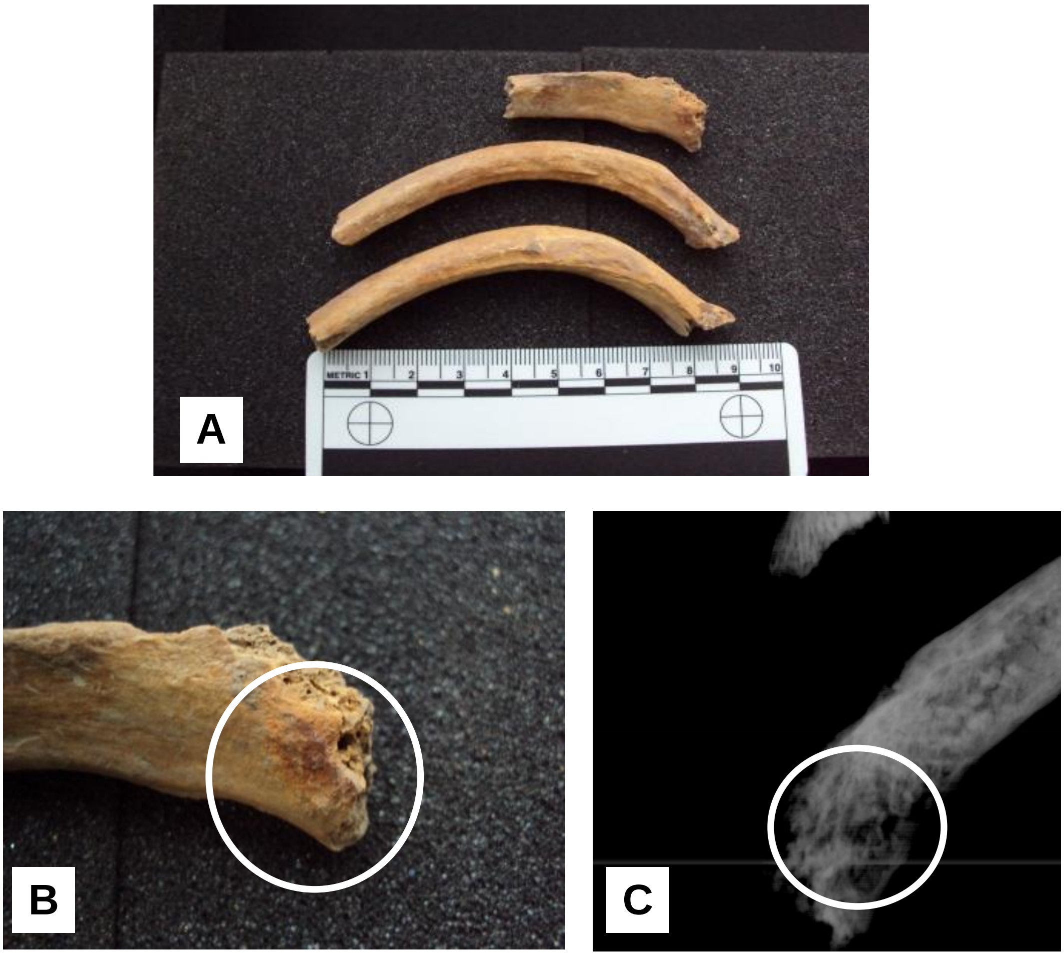


Figure 8: Oxidation staining on right ribs 5, 6 and 7 (A). Right rib, 7th, shows staining on head and neck (B) and radiograph 100kv of right rib, the white circle indicates where the staining should be (C).

A number of the bones within the thorax, sternum, T9 and right ribs (5-7) show a red/brown discoloration on the surface, these bones were located within the vicinity of the arrowhead. These markings are thought to be oxidation staining from the metal of the arrowhead (Fig. 8, 9 and 10).

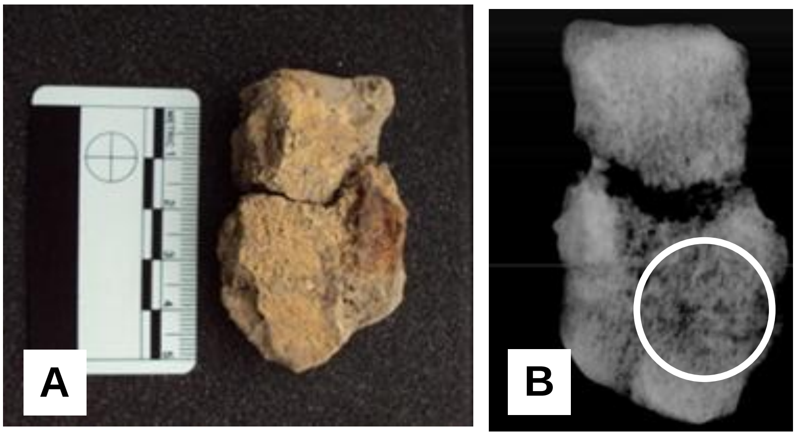


Figure 9: Oxidation staining. Sternum with red/brown staining (A) and radiograph 100kv with white circle indicates area of staining (B).

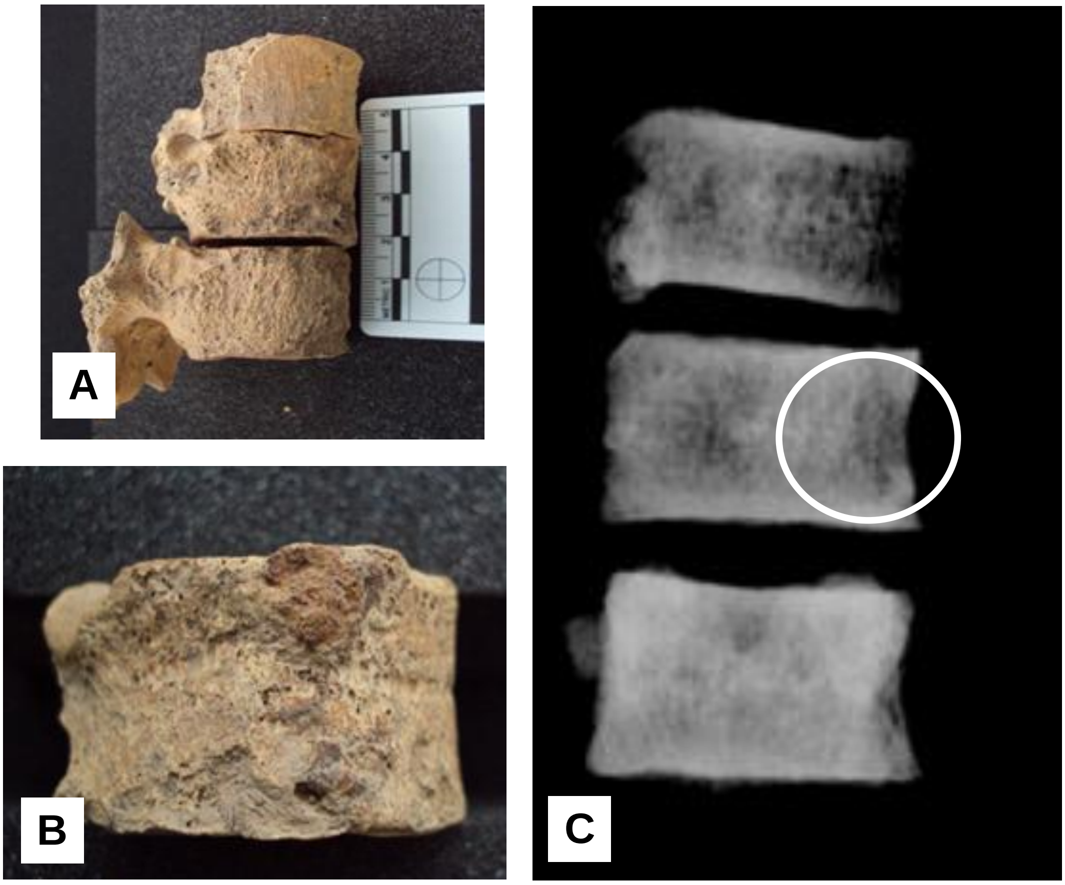


Figure 10: Thoracic vertebrae 8, 9 and 10 showing staining (A). 9th Thoracic vertebra showing red/brown staining on superior anterior border (B) and radiograph 100kv of 9th thoracic vertebrae, white circle indicates area of red/brown staining (C).

The areas of red/brown staining on these bones were radiographed to see if any damage within the bones could be observed. The radiograph showed no signs of trauma or any pathological conditions in the area of the staining. Thus they likely result from corrosion of the metal arrowhead.

Chapter 5

AMS Radiocarbon Dating

5.1 Analysis of SK535

An AMS Radiocardon date was obtained for skeleton 535 (SK535) using the collagen from the upper right first molar (M^1). It was hoped that the results would either prove or disprove that the arrowhead could have been in use during the time that SK535 was living or at the time of his death.

5.2 AMS radiocarbon dating

The root of the M^1 from SK535 was used for this process. Analysis was performed by Beta Analytic (Appendix 3).

There are three principal techniques used to measure ^{14}C content of any given sample, gas proportional counting, liquid scintillation counting, and Accelerator Mass Spectrometer (AMS), used in this case. AMS radiocarbon dating counts the number of ^{14}C atoms that are present in a sample.

Once the sample has been obtained it is converted into a solid graphite form, only a small amount is required for testing. The sample is then placed on to a metal disc, with a reference sample placed on another; these are then placed in the Mass Spectrometry machine.

Advantages to this type of carbon dating are, the sample size required. Only 20 milligrams is needed, this is helpful when dealing with rare material as less is damaged. The disadvantage to this is the expense of the determination machine and rigorous pre-treatment is needed due to a small sample size.

5.3 Materials and methods

Before any testing began moulds and casts were taken of M^1 in order to retain an accurate copy of the tooth. These casts showed the shape and any areas of interest of the tooth that may be of help for future investigations. The sample for ^{14}C was taken from the core of the tooth, so the moulding and casting process did not damage or contaminate the tooth required for testing. President regular body casting mix was used to produce the mould. This is a silicone – based impression used in dentistry. The tooth was encased in the mixture and left to dry. The tooth was then carefully removed leaving the mould behind.

Tiranti Prestia Classic was used to cast the tooth; this is a general purpose casting plaster. 23.5g of plaster was mixed with 15ml of water; this mixture was then poured into the mould and allowed to set. On removal of the mould an exact copy (cast) of the tooth was left behind. To be able to perform these procedures and obtain a good representative copy of the tooth the technique was practised a number of times using a reference collection of modern day population teeth. Once good moulds were being produced casts of both of SK535 teeth, left lower canine (LC_1) and the Upper right first molar (M1) were taken. Although only one was being used for ^{14}C it was decided it would be better to cast both in case they got damaged.

For ^{14}C to be performed the tooth was cut at the Cervicoenamel line (or CEJ junction), allowing for the extraction of the sample. For the cutting of the tooth, a Draper multi-tool kit saw with a Dremel speed clic cutting disc diamond blade was used. However, during practice sessions, sample teeth shattered during this procedure so another technique was sought. A hand held hacksaw with a blade of 152mm x 6.35mm was then purchased and tested, this performed better. Once the tooth had been cut in two the root section was placed in a sterile plastic bag with all reference information detailed. The root was then sent off to Beta Analytic, in Miami, USA for the ^{14}C analysis.

The remaining tooth LC_1 was retained for potential further analysis (e.g. Stable Isotope analysis for paleodiet studies). As there were only two teeth retrieved from SK535 and one has already been used any further testing has to be seriously considered and thought to be of extreme relevance. The results from Beta Analytic showed that the sample was of good quality and preservation, ^{14}C was easily obtained by extracting the collagen from the tooth. Results produced dates of Cal AD 1280 to 1300 (cal BP 670 to 650) and Cal AD 1370 to 1380 (cal BP 580 to 570) to 1 sigma calibration. When quoting results it is customary to state the 2 sigma calibration results, as this gives a 95 % probability compared to 65% from 1 sigma results. The 2 sigma results for SK535 were Cal AD 1280 to 1320 (cal BP 670 to 630) and Cal AD 1350 to 1390 (cal BP 600 to 560). (See Table 5 and Appendix 3). Calibrations of radiocarbon age are used to convert before present (BP) results to calendar years. The differences between the two are due to changes in the heliomagnetic modulation of the galactic cosmic radiation or burning of fossil fuels and testing of nuclear devices of today. The dates obtained are in agreement with the typology of the arrowhead (see Chapter 6). Type M7 bodkin arrowheads were used during the 13th and 14th centuries (Hardy, 1976, Ward Perkins, 1940). This confirms that the individual represented by SK535 lived during the time these arrowheads were in use.

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-20.5:lab. mult=1)

Laboratory number: Beta-337189

Conventional radiocarbon age: 670±30 BP

2 Sigma calibrated results:(95% probability): Cal AD 1280 to 1320 (Cal BP 670 to 630)
and
Cal AD 1350 to 1390 (Cal BP 600 to 560)

Intercept data

Intercept of radiocarbon age with calibration curve: Cal AD 1290 (Cal BP 660)

1 Sigma calibrated results :(68% probability): Cal AD 1280 to 1300 (Cal BP 670 to 650)
Cal AD 1370 to 1380 (Cal BP 580 to 570)

Table 5: Radiocarbon dates for SK535. Results supplied by Beta Analytic Radiocarbon dating.

Chapter 6

Analysis of Arrowhead

6.1 Longbows

Longbows are defined by the British Long Bow Society (www.askarts.co.uk) as "the traditional type with stacked belly, horn nocks and limbs made of wood only, and all surfaces should be convex". The idea of using a longbow whether for sport or as a weapon, is based on a deep seated root of mankind to throw objects and propel items through the air, both defensively and aggressively (Hardy, 1976). It is only over time and by learning what works and what does not that highly sophisticated weapons and tactics have been established. Bows at first were used to hunt game, being able to kill animals while at a safe distance was seen as a great advantage. This was soon employed against the enemy during battles (Fig. 11).

Figure 11: Longbows in use, Taken from 'Longbow' (Hardy, 1976).

All the bows were made of organic material some purely wood and others were composite bows. Due to the organic material these arrows have disappeared and disintegrated over time reducing the amount that can be studied and investigated. The arrowheads of the longbows are the part that can produce a typology. They are associated to a time period and areas of the country that bows were used in and what type they were. This is due to the arrowheads being made of hard wearing substances such as flint, stone and iron which have allowed them to survive the harshest environments for thousands of years unlike the fragile wooden bow (Hardy, 1976).

6.2 History of the Longbow

English longbows were used during the 12th to the 15th century. Bowmen of the early 14th century had to build up strength and the skills required for using such a technical weapon (Bradbury, 1985). Over the years the design and materials for the longbow improved to keep up with the changing armours of the day (Bradbury, 1985). Once it was realised that these weapons could kill or injure and could be used from a safe distance of the intended victims the advantage for the archer was enormous. It is hard to say what the first type of bows were designed like and when they were first used as few have survived.

The father of the military longbow is known as Edward II. It was under his guidance that both the Welsh and the English learnt how to use these great weapons (Hardy, 1976). During the reign of Edward II, the only battalions that contained purely archers came from Gwent and Crickhowell supplying around 800 longbow men in 1277 (Hardy, 1976). It was his tactical organisations of the men with longbows that shocked the French during the fighting of the 100 year war 1340AD to 1420AD.

A 14th century law stated that every male from the age of 7-71 years had to have a longbow and practice with it (Rhodes, Knusel, 2005). Training started early to develop the expertise and technique required. This weapon was dependant on strength of the user and lengthy training (Hardy, 1976). Being an archer was a prestigious job during the medieval period and most of them were well treated, being paid regularly.

In 1369 Edward III issued the following order to sheriffs;

> '*Cause public proclamation to be made that everyone of the said city (London) strong in body, at leisure times on holiday, use in their recreation bows and arrows....and learn and exercise the art of shooting, forbidding all and singular on our behalf that they do not after any manner apply themselves to the throwing of stones, wood, iron, handball, football, bandyball, cambuck, or cock fighting, nor other such like vain plays, which have no profit in them.. Under pain of imprisonment'*
> (Hardy, 1976).

However by 1595, the longbow was slowly going out of favour and on 6th October a request was made from the County of Hertfordshire for longbows to be replaced with muskets. On 26th October 1595 Queen Elizabeth I wrote to her privy council saying all longbows must be converted to muskets amongst all the trained soldiers (Hardy, 1976).

6.3 Construction

The name longbow is representative of the look of the bow. The English Longbow was constructed of wood from the yew tree. Other woods were available, but none as good as yew. Elm was seen as the best secondary timber and was often used by the Welsh (Hardy, 1976). The bow contained elastic sap wood on the outside, or back of the bow, and strong heart wood on the inside or the 'belly' (Rogers, 2011). During construction of the medieval bow the weaker staves were taken from branches of the yew (Hardy, 1976). When the bower thought the wood to be ready, he would shape it into a D shape the depth being of personal taste.

For the fletching the best were goose feathers as described by Roger Ascham (Hardy, 1976). The feathers are stiff and strong which was good for wind (Fig. 12).

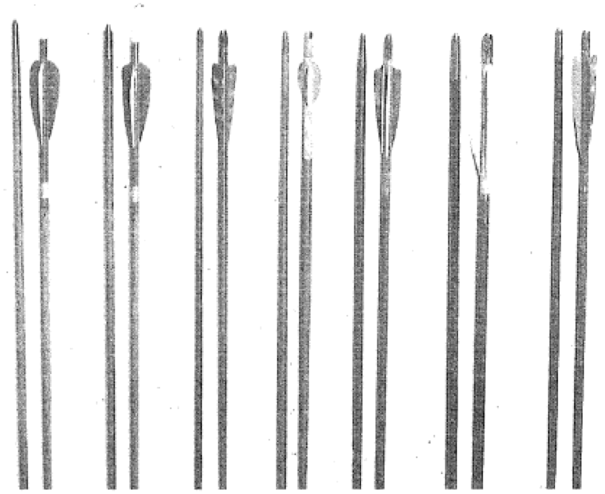


Figure 12: A selection of arrows. Taken from 'Longbow' by Hardy (Hardy, 1976).

It has been thought by many including (Strickland, Hardy, 2005) and (Bradbury, 1985), that ancient long bows did not exist. However evidence of long bows from the 14th and 15th centuries have been found on the Mary Rose shipwreck (Strickland, 2005, and Bell *et al,* 2009). The Mary Rose is a ship from the Tudor period that was built in 1510. It was in service until its sinking during a battle against the French at Portsmouth, England in 1545. In 1836 the site of the shipwreck was discovered by divers, and on 11th October 1982, the Mary Rose was raised and is now situated in the Mary Rose Museum, Portsmouth Historic Dockyard (Christopher, 2012).

6.4 Size

Estimating the bow size is difficult due to the lack of bows remaining. The largest amount of longbows and those in the best condition to be found were from the Mary Rose shipwreck. These have been measured to be around 6-7ft tall. This indicates that most of the bows would have been taller than the bowman who used them (Rogers, 2011). Due to the great size of the longbows they were drawn to the ear with three fingers not the normal two fingers used with smaller bows. Draw weights of the longbow were in the region of 100 to 180lb (Hardy, 1976). A draw weight is the weight held momentarily by the archer when he has drawn back the arrow to its full length before he loses it (Strickland, Hardy, 2005). During a battle an English military longbow archer could use between 60-70 arrows (Hardy, 1976).

6.5 Arrowheads

There have been many different types of arrowheads used throughout the years. By the end of 13th century, the barbed broad arrowhead that had been commonly used had gone out of favour in battle, except for the use against cavalry to injure or kill the horses (Bradbury, 1985).

The arrowhead found *in situ* with skeleton 535 (SK535) has been identified as a M7. The name M7 stands for the type of arrowhead M meaning Military and 7 standing for the date. There are 1-10 different military arrowhead types (Jessop, 1996). Classification was obtained on the size of the arrowhead, shape and cross sectional shape of the shaft. According to Jessop, the Type M7 has a short circular socket which narrows into a very long, thin point with a diamond cross section. The dimensions, length and width can be seen in Table 6.

Size	Shape	Cross sectional shape
140 -200mm Length 8-12mm Width	Short circular socket Very long and thin	Diamond

Table 6: Dimensions of a Type M7 Bodkin as specified by Oliver Jessop (1996).

Arrowheads namely the bodkin Type 7 or 8 (Ward Perkins, 1940) were designed to penetrate armour. These had an average weight of 0.35 – 0.71 oz (10 – 20gm) depending upon their length (Hardy, 1976). The design of these arrowheads allowed low wind resistance and the ability to wound even without fully penetrating the armour. The points of these arrowheads make them less likely to bounce off the armour. This type of arrowhead could achieve ranges of up to 300 yards with the smaller headed arrows (Hardy, 1976). The heavier the arrowhead and the increase in size reduce the distance the arrowhead travelled.

6.6 Armour

The Type M7 bodkin was developed in answer to the increasing use of defensive armour, (Ward Perkins, 1940). The bodkin was about 16 cm long and very slim and its appearance corresponded with the arrival of chain mail or ("Ring Maille"). This arrowhead could penetrate through the small rings of the mail armour, entering the body and killing the individual. Chain mail covered the head, chest, abdomen, thighs and shoulders, covering what it was considered to be the vital organs of the body. Worn under this chain mail was a padded lining, reducing the impact to the body (Mitchell, *et al,* 2006). Mail was also effective against sword blows, converting fatal wounds to less severe wounds where survival was more likely (Mitchell, *et al,* 2006).

Tests have shown that bodkins were capable of piercing even the plate armour of the 14th and early 15th century (Bradbury, 1995). The square, round or triangular cross section of the arrowhead allowed it to exert as much force as possible on the smallest area of armour so as to achieve maximum penetration (Delrue, 2007).The resistance of penetration of armour depends upon the strength, toughness, ductility and thickness of the material (Strickland, Hardy, 2005). It is difficult to produce a specific date for the arrowhead discovered at Poulton by only using its type as very few have been found over the years that have been accurately dated (Rogers, 2011).

6.7 The Type M7 Bodkin arrowheads

The arrowhead was compared with those in The London Museum Catalogue (Ward Perkins, 1940) and determined to be a Type 7 bodkin. Our arrowhead fitted into all the categories, size, and shape as described by Ward Perkins (1940). The Type M7 bodkin is quite a rare find. The Museum of London, the British Museum and the Tower of London possessed no information on this type of arrowhead.

Two bodkin type arrowheads are housed at the Royal Armouries, Leeds. Thom Richardson, Keeper of Armour & Oriental Collections examined radiographs of the Type M7 bodkin arrowhead and thought it was a very early bodkin arrowhead. The bodkin arrowheads housed at the Royal Armouries were much smaller. Arrowheads stored at the Royal Armouries were recovered from the River Thames in London and were late 14th century to 15th century.

The leading expert on the English longbow, Mr Robert Hardy was consulted in terms of the type of arrowhead. Mr Hardy confirmed that it was a Type M7 bodkin and the estimated period of its use was the 13th century, which corresponds with the radiocarbon dates obtained for SK535.

Figure 13: Type M7 Bodkin arrowheads from Stafford Castle, housed at the Potteries Museum & Art Gallery Stoke-on-Trent.

Mr Hardy recommended visiting the Potteries Museum & Art Gallery, Stoke-on-Trent, Staffordshire. Ms Klemperer, Principle Collections Officer at the museum, permitted examination of the arrowheads housed in the Potteries Museum, some of which were very similar (see Fig.13) Ms Klemperer agreed that this type of bodkin, Type M7 is quite rare.

The arrowheads in Ms Klemperer's possession were from Stafford Castle. They had not been conserved but were in a much better condition that our one, with far less corrosion product on them. They were also complete. These arrowheads had previously been examined by Simon Stanley longbow expert and dated to no later than the 13th century. These arrowheads have not undergone any chemical analysis like ours but are thought to be made of iron.

Chapter 7

Conservation of the Arrowhead

7.1 Conservation of the Metal Arrowhead

After the excavation of SK535 the arrowhead was placed in a plastic container without silica gel and remained in sealed storage at Poulton archaeological site for a number of weeks.

The arrowhead was then later sent to Manchester University's X-ray imaging facility where it underwent Computed Tomography (CT), producing a video from 3000 2D radiographic images. This is a 3D non-destructive technique producing images that allowed the outer iron corrosion products and soil from the hidden underlying metal and corrosion structure to be visualised. During the CT procedure the arrowhead was kept in the plastic container and was never directly handled. During the months following the CT the arrowhead was not worked on. It was stored at the Poulton archaeological site where it remained in the plastic container. Temperature and humidity during this period were not controlled.

In summer 2012, the arrowhead was initially examined by Steve Newman, Head of Metals Conservation for National Museums Liverpool. It was noted that the metal composition was most probably an iron alloy and appeared to contain a few large cracks along the surface although it was not evident how deep these cracks were, without further investigation. The arrowhead appeared to be completely covered in a layer of mixed soil and corrosion products with hardly any of the original surface visible, except at the ends. Before conservation can take place radiographs and if possible micro-CT scans should be taken as a record to indicate the area where the original surface may have been and any additional features of interest that could be worked towards during the removal of the outer soil layers. The results for these scans amongst other techniques were used for recording the condition of the arrowhead prior to and during the conservation process.

Packing of the arrowhead was improved securing its parts in Plastazote foam and placing it in an airtight plastic container containing silica gel, to help with the drying out process and reduce any cracking or further damage to the arrowhead from ongoing corrosion. It remained in storage at Liverpool John Moores University (LJMU) for a further 8 months, until it was possible for the conservation process to begin.

At the beginning of the investigative conservation process, important questions were considered regarding the aim and extent of the treatment and how we would determine:

- What type or types of metal were present?
- What type of corrosion products were present and to what extent?
- What methods would be used to determine whether other associated materials or structures were also preserved in physical or pseudomorphic form, (a mineral having the outward appearance of another mineral that it has replaced by chemical reaction or a hollow retaining the shape and sometimes surface texture of a material lost through chemical reaction)?
- And what would be the best way to conserve the arrowhead, whilst minimising further damage?

7.2 Metals

Metals are made of crystals known as grains (Cronyn, 2004). The physical properties of metals are affected by the size and shape of these crystals but also by the material incorporated in them. There are two types of metals, pure metal which contains only one type of metal and alloy metals which contain elements of different metals. Alloy metals which contain many different elements can lead to the metal taking on certain characteristics of the compounds contained within. For example if a brittle compound is contained within, this can produce a metal which is brittle. As well as this, metals can also contain other elements such as slag. Slag is a type of glass that is formed during the smelting process from the siliceous material found in most ores (Cronyn, 2004). Slag can be found either within the grains or on the boundaries of them. During the working of the metal the slag becomes elongated in the direction that the metal is being worked. This in turn can affect the properties of the metal.

By studying the structure of the grains and phases within the metal it can be possible to understand the history of the metal and the working process and the properties contained within. However, if the artefact has been reheated or deformed since its manufacture which can occur after excavation, then some of this information may be lost (Cronyn, 2004).

Iron made from primitive solid state smelting will contain a lot of slag from the iron ore that is contained in its pores. When hammering takes place this mixture a glassy and crystalline fayalite is squeezed out (Cronyn, 2004). However, in wrought iron and steel a certain amount of this remains and can be drawn out in stringers along the line of the working, known as slag stringers (Cronyn, 2004). The approximate date for the first widespread use of iron was 1000 – B.C (Selwyn, 2004).

7.3 Corrosion

Deterioration of a metal is usually brought about by chemical changes rather than physical damage (Selwyn, 2004). These chemical changes relate to inorganic and biological organisms that are present in the environment, leading to corrosion (a chemical change in the metal). Corrosion is almost always electrochemical. It occurs when two or more electrochemical reactions taken place on a metal surface, resulting in the metal changing from a metallic state to a non-metallic state (Selwyn, 2004). Some metals known as base metals are more likely to corrode than those known as noble metals. Metals most commonly found from archaeological sites can be graded in reactivity (Table 7).

Zinc	**Iron**	**Tin**	**Lead**	**Copper**	**Silver**	**Gold**
Most Base	→					**Most noble**

Table 7: Reactivity table (Cronyn, 2004).

There are two types of corrosion dry and aqueous. Dry corrosion in archaeological artefacts is less important as moisture is contained in the atmosphere; this type of corrosion usually leads to the metal becoming tarnished and dull. Aqueous corrosion involving moisture is much more common; however, the process of this type of corrosion is not a simple one but involves electrochemical corrosion, leading to oxidisation (Selwyn, 2004). During this process two situations can occur. Active corrosion and passive corrosion. Active corrosion is where the metal produces soluble products that move away from the metal and into the surrounding environment (Cronyn, 2004). Active corrosion, when it occurs on iron produces bright orange spots on the object; “Weeping” or “Sweating” may be seen. Weeping takes the form of yellow, brown or orange droplets on the surface when the relative humidity is high; when the relative humidity decreases it leaves desiccated blisters and bubbles on the iron surface.

Passivation is where the metal produces solid products which attach to the surface of the artefact and prevent further corrosion attack.

If iron has been subjected to a moist oxygenated environment the corrosion process usually begins with the loss of metal from the surface. The corrosion then continues moving down the metal parallel to the surface (Fig. 14). This shows how an iron artefact corrodes and how the original surface can be preserved under a sequence of corrosion layers.

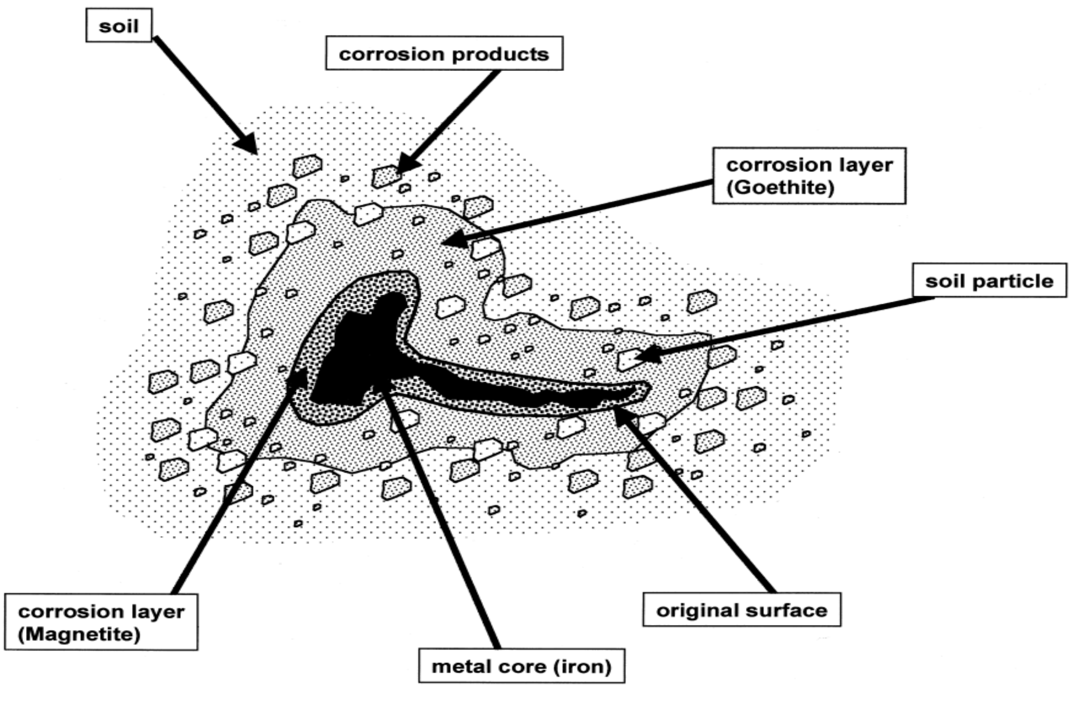


Figure 14: Schematic cross-section of an archaeological iron artefact Gerwin, Baumhauer, (2000).

Figure 15: Active corrosion on the middle section of the arrowhead.

Active corrosion can be seen on the middle piece of the arrowhead (Fig. 15). This section was revealed during the conservation process.

7.4 Examination

It is important to give the artefact a close visual examination before any conservation can begin to get an overall picture of any damage or areas of interest. If any corrosion crusts are seen it is important to identify if they contain any organic pseudomorphs (Cronyn, 2004), often indicated by particular changes in colour or texture. If they are identified further tests should be carried out to establish if the organic material is part of the iron object or associated with it or, whether it is from the surrounding environment.

Radiograph examination is a must. Corrosion layers and especially corrosion crusts can change the look of the object in plain sight. An X-ray will show the underlying shape of the object and any areas that may be damaged, allowing for better analysis of the object and often having an influence on the methods used to treat it. However, a radiograph can only reproduce a two dimensional view of the artefact and in most cases to clearly identify the structure of the item radiograph from more than one angle or a cross sectional image is required. The best way to achieve this is either by CT scan or by cleaning. Analysis through a CT scan is quick and non-destructive although can be expensive. Cleaning the artefact can be a destructive process and is time consuming.

7.5 Conservation Process

When cleaning artefacts and removing any corrosion products, care must be taken not to lose any of the original surface. In the past metallic artefacts where commonly cleaned with chemicals or by electrolysis (Selwyn, 2004). This often led to removal of the entire corrosion product to reveal the metal below. However, in doing this, evidence contained in the corrosion product layers and the surface below was usually lost. This could include original surface and any associated organic material. This process could also lead to an attack from the chemicals used on the newly exposed metal, allowing further damage to the surface metal.

As the Type M7 bodkin arrowhead has been buried for hundreds of years it will have reached a state of equilibrium. Removing it from this environment will change this state and can lead to further corrosion. This process can be halted by immediately removing any water from the environment. This can be easily achieved using passive techniques such as desiccation (e.g. using silica gel). This technique is an extreme one; it can lead to the corrosion crust shrinking which can in turn impede washing processes if used later on (Cronyn, 2004).

The arrowhead was eventually placed in an air-tight container with silica gel; however this did not happen immediately possibly leading to further damage through corrosion. This process of desiccation does not mimic the equilibrium of the burial environment in which the arrowhead was stable in but, removes one of the main factors that leads to corrosion, water.

7.6 Features of Interest of Type M7 Bodkin

To help with the orientation of the arrowhead and its features, from now on it will be described in three pieces (Fig. 16a, b and c). Piece one – the base with the socket (the shaft end of the arrowhead) (Fig. 16a), piece two – the middle section (Fig. 16b) and piece three –the tip (Fig. 16c).

When starting the conservation treatment it was decided that a dry conservation process would be the best way to proceed due to the delicate condition of the arrowhead especially when investigating the presence of pseudomorphic structures within the corrosion and soil layers.

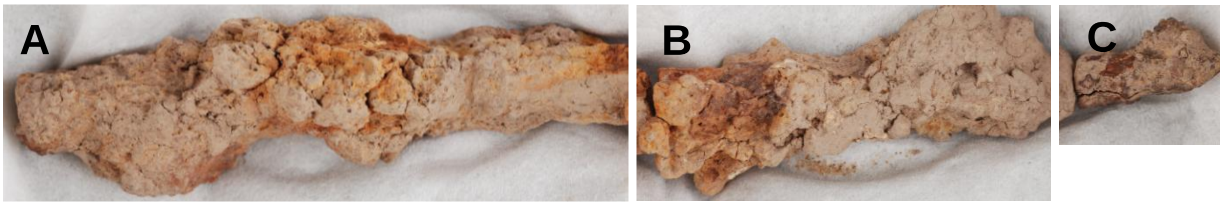


Figure 16: Three pieces of the arrowhead, base (A), middle section (B) and the tip (C).

Photographs of the arrowhead where taken using, a digital SLR camera and some of these were used to make large and highly detailed composite images. This was undertaken to show any features of interest that would require further investigation and further analysis to be carried out prior to the conservation process. It would also provide a reference to show the initial appearance of the arrowhead before any conservation took place. Measurements were taken of the entire arrowhead including the length and shape of all three pieces combined. The shape of the arrowhead was obtained by looking at the cross section of the end of piece two (Table 8). Measurements taken must be treated with care due to the deformation of the artefact that may not reflect the original dimensions of the arrowhead. These measurements fall within the parameters of a Type M7 bodkin arrowhead as described by London Museum Catalogue, Ward Perkins (1940).

Measurements	Units
Length	16cm
Shape	Diamond (Cross-section)

Table 8: Type M7 Bodkin Measurements and shape before conservation.

An initial look at the surface of the arrowhead showed a red/brown mass on Piece one (Fig. 17) its appearance is different to the rest of the arrowhead (covered in a pale brown/buff covered soil) and at first we considered whether this might be of organic origin; In Cronyn's "The Elements of Archaeological Conservation" (2004) a similar appearance can be seen and is described as a bulky red/brown mass. This appearance is that of a typical iron find that has been excavated from damp aerated sites. Sand and or stones may have become incorporated within the mass.

Figure 17: Red/Brown Mass on piece one. White circle indicates mass.

Another appearance that has been seen on the arrowhead during microscopic examination is that of a stringy appearance within the corrosion product, Cronyn (2004) identifies these as slag stringers when they become exposed, giving an appearance of wood, (as previously mentioned in section 7.2).

Micro CT images of the arrowhead were performed at the University of Liverpool, Institute of aging and chronic disease by Russ Savage. This imaging technique was used as a record should any structural deterioration of the arrowhead occur during the conservation process. It would also facilitate future 3D printing of the arrowhead.

7.7 Conservation of Type M7 Bodkin

Dry mechanical conservation treatments began on the two ends of piece two; this was carried out using a Dynascope stereo viewer microscope at a range of 6 to 40X magnification. The two ends were carefully scraped removing surface debris with a scalpel using a fine no. 15 blade. As the treatment developed some small amounts of a mixture of de-ionised water and industrial methylated spirit (I.M.S) 50/50 concentration, was applied using a small cotton wool swab tip and a very small short bristled paint brush to remove soil from around certain structures. This process allowed any excess dust particles and soil to be softened and removed without causing too much damage to the underlying layers, the I.M.S helping the water to evaporate. By removing the soil from these two end pieces we gained a better indication as to what the underlying structure were like, and whether this technique would work on the entire arrowhead. An eye was kept out for changes in the microstructure and colour of the soil and corrosion products, particularly relating to mineralised organic remains. Once the overlaying soil was removed in these test areas you could see the remaining, denser, corrosion products that were closer to the original surface underneath and showing something more like its original shape. This proved that some of the original shape and structure was still present. It was decided to take photomicrographs of the arrowhead, to provide a record in case other sections of the arrowhead deteriorated as well. Photomicrographs were taken of the arrowhead in 5mm steps over the four sides of the three pieces. These were then combined and a 2D photomicrographic image produced by alignment and merging as a composite using Adobe Photoshop CS5 (Fig. 18a, b, c and d).

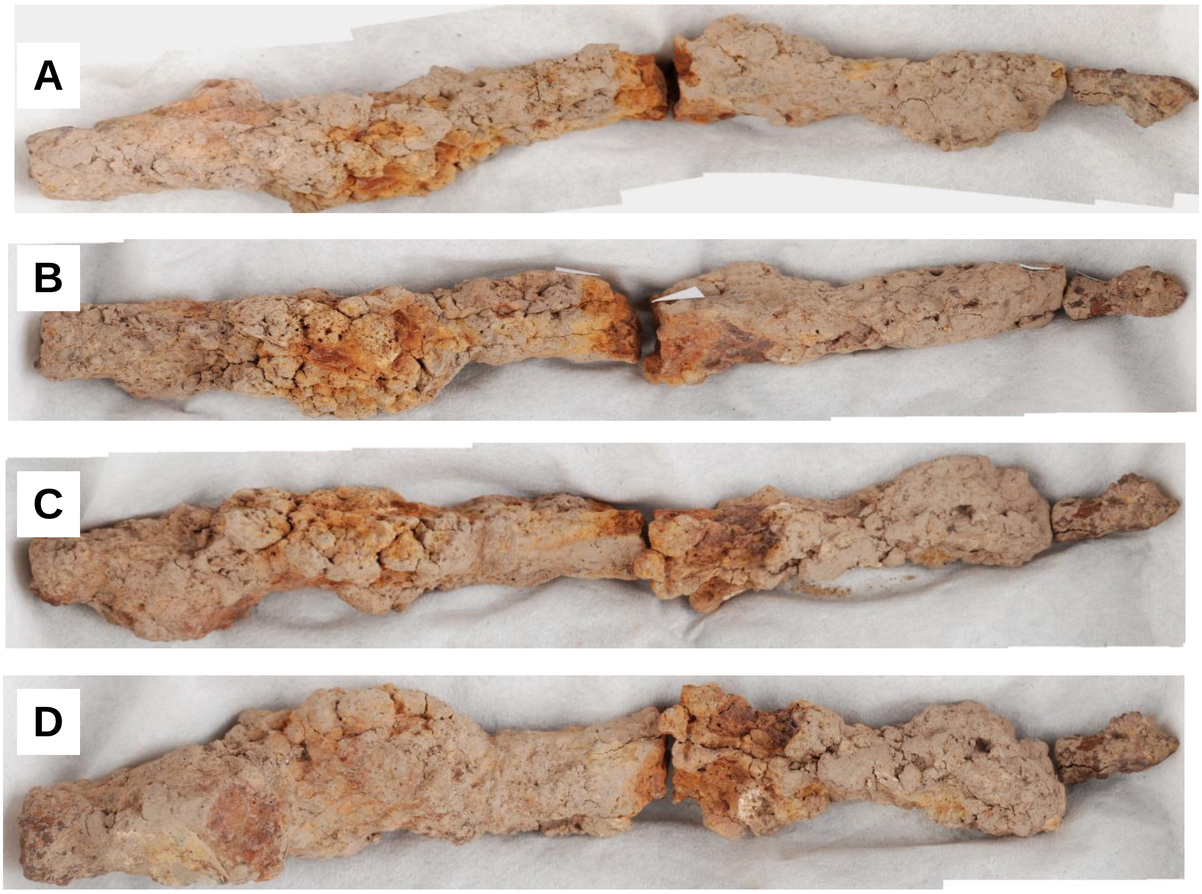


Figure 18: Side 1 (A), side 2 (B), side 3 (C) and side 4 (D).

It was decided to use SEM EDX as an elemental chemical analysis method. As well as being able to see surface morphology and specific areas of interest, this would also give an elemental breakdown of certain structures on the arrowhead. Before this could go ahead a test was carried out on the arrowhead to see how well it would withstand the very high vacuums within the SEM vacuum chamber. Piece one and two of the arrowhead were placed in a separate conservation treatment moderate high vacuum chamber, and exposed to increased vacuum in steps over an hour. Although not as high a vacuum as the SEM chamber, this chamber being usually used for vacuum impregnation treatments, could still achieve high vacuums comparable to the first stage of two used by the SEM. Our concerns were whether the vacuum of the chamber might result in some loss of outer corrosion layers of the arrowhead or at the worst large scale fragmentation. The test was carried out in the Metals Conservation workshop at the Conservation Centre in a General Electric portable steel vacuum chamber under 28 inches Mercury vacuum pressure. The results of this test fortunately showed that vacuum to this level had no obvious physical effects on the arrowhead and tests could continue.

The first SEM used was in the Conservation Centre NML, and was operated by Dr Siobhan Watts, Conservation Scientific Officer. Imaging results from this older machine were interesting but did not provide enough clarity to easily examine surface features. A second SEM machine became available at LJMU, and arrangements were made for imaging and EDX analysis on this more modern model.

The FEI Quanta 200 SEM – Low Vacuum SEM, has a variable high vacuum and low vacuum setting. The higher the vacuum the better and more precise the images produced are, although with some risk of damage to some materials. Initially the arrowhead was placed under the high vacuum but the correct pressure could not be reached due to water vapour still being detected, most probably emitted from the arrowhead. To reduce the amount of damage the low vacuum setting was then chosen and viewed at 20KV. Each area was viewed for 100 seconds. The images obtained through this method were very clear. It was only areas of interest such as the Red/Brown corrosion mass, holes on the surface and anything of an unusual appearance seen under the optical microscopes that were examined. Professor George Sharples Reader in Microbiology and Director of Electron Microscopy was present during this examination, as was Paul Gibbons, SEM technician at LJMU.

On viewing the surface a number of areas of interest were seen, such as what looked like a fibre but could possibly have been slag stringers previously mentioned. When zooming in to get a closer look and directing the detector (Oxford Instruments INCA Xact Dry Detector) at an angle of 30^{o} and a working distance of 10mm into the appropriate place, these pieces would move and often jump from one area to another as well as often disappearing altogether. This may have been due to the vacuum, or charging of pieces of debris by the SEM electron beam, known as ionisation excitation. This can happen when using this type of machine and dealing with loose items unfixed and inadequately earthed within the chamber. Items usually examined in the SEM machine are coated to help against the charging; however this was not done with the arrowhead as we did not want to cause any further damage to the object, as manual conservation was to continue. Unfortunately this happened on at least three occasions and these areas of interest were lost. There was also a problem with charging of the areas under observation; this was due to the electrons becoming charged when they were directed into an area on the metal surface. This is a common downside to SEM analysis. Charging of areas leads to some of the pictures becoming bright and the images being unclear.

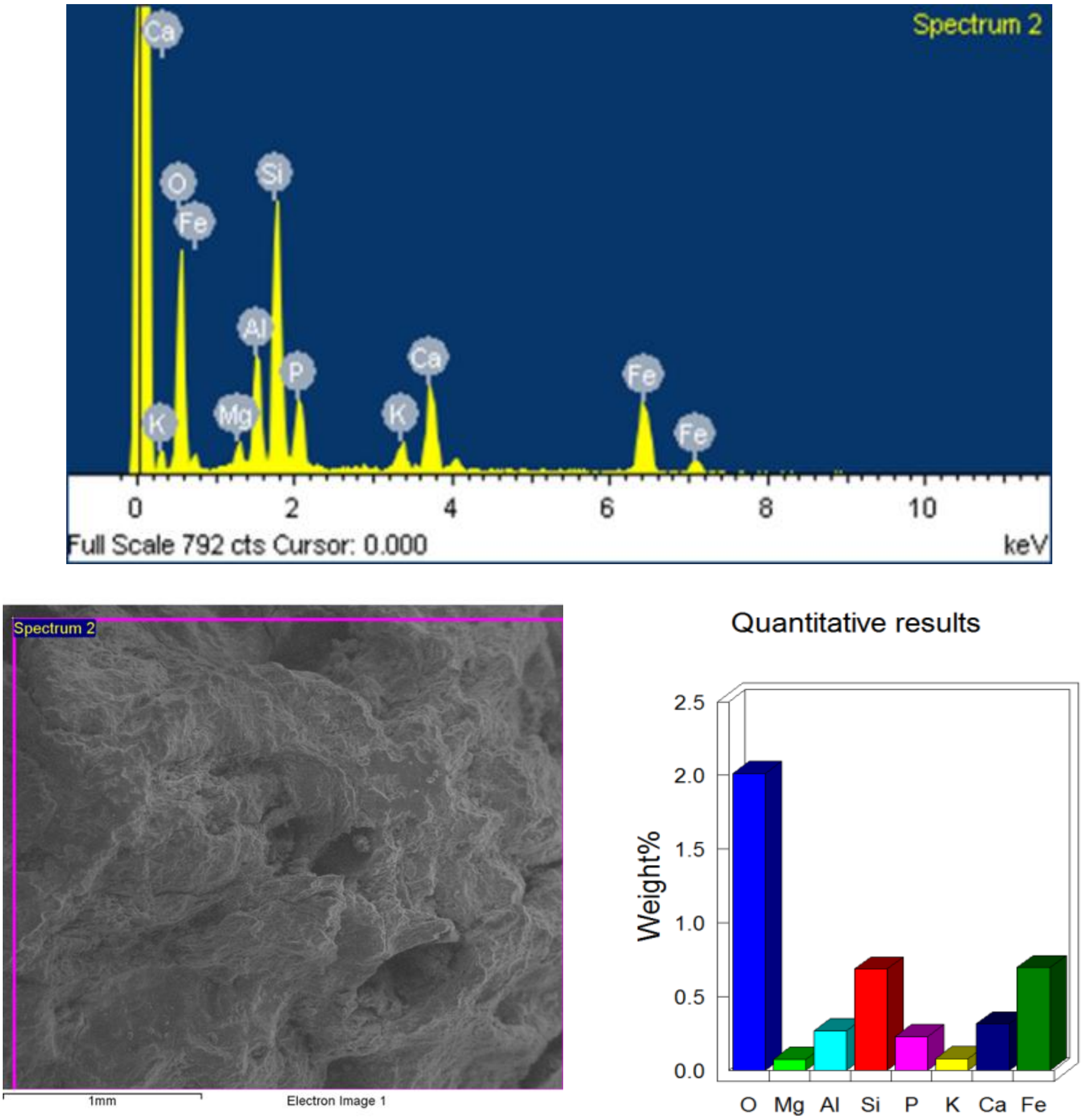


Figure 19: Surface image and elemental analysis for the Red/brown mass located on section 2 of the arrowhead.

The pictures and elemental readings carried out on the red/brown mass showed no unusual features that could have been of organic composition (Fig. 19). Both Paul Gibbons and Professor Sharples could not see anything other than what they knew to be normal surface structure of soil. The chemical analysis revealed elemental components that were normal for soil products with Si, Ca, Mg, and Al all common in soil and can be found in some corrosion products. However, mineralised organics may show most of the same elements as the soil. It is possible that corrosion products might by their voluminous nature overwhelm data from other elements. The results matched those obtained from other 13th century arrowheads that have been analysed (Ashkenazi *et al* 2013). These arrowheads were excavated from Crusader Castle of Arsuf, Israel. They were also highly corroded and showed cracks which travelled along residual contour lines of the arrowheads like ours. SEM results of these arrowheads also revealed an extensive presence of Fe and O and other elements of Si, C, Ca and Al like our results.

The holes seen on the surface of the arrowhead under the microscope were also examined (Fig. 20a and b). It was first thought that these might have contained hairs or fibres that may have come from clothing or animals that came into contact with the arrowhead previously, although when measured they appeared to be larger than the diameter of a hair fibre. Under examination no conclusive evidence for this theory could be found. The chemical analysis did not show up anything other than normal corrosion and soil elements. These may be the empty spaces left behind from Weeping or Sweating as previously mentioned in section 7.3. They could also be from roots or small fibres that were present in the soil at one time during burial. No bone or decomposed mineralised tissue was evident from the SEM images.

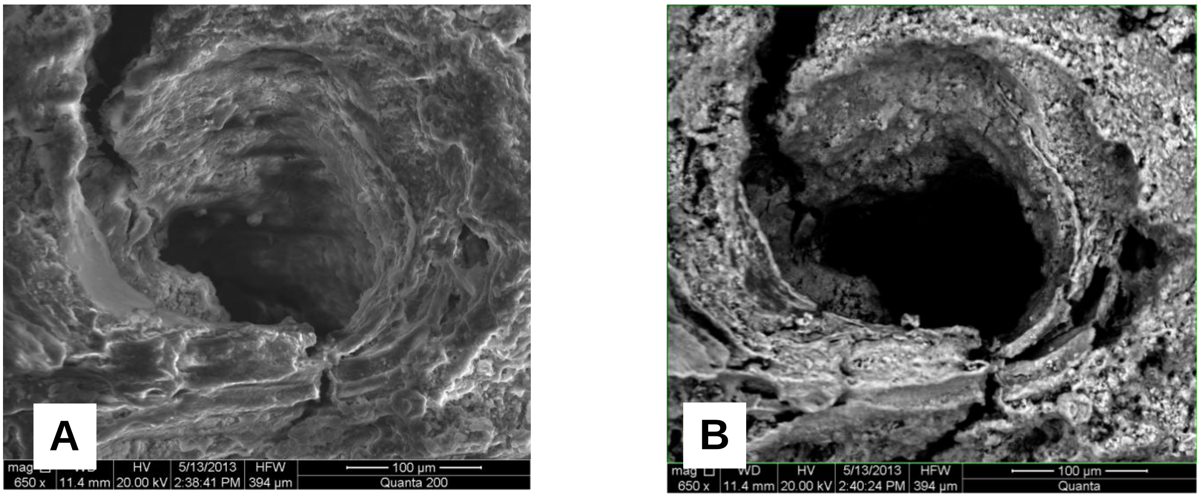


Figure 20: Hole located in the soil/Corrosion layer of the arrowhead, SEM at magnification of x 650 (A) and SEM image using backscatter at magnification of x 650 (B).

Once all these tests had been completed and photographic evidence had been taken, the manual conservation continued. Using the same equipment and techniques as before the surface debris was gradually removed allowing the underlying metal surface to be visible. This surface revealed was not the original surface as this has been at least partially lost due to corrosion and build-up of dense dark-brown nodular outer layers of iron corrosion products. The surface visible was dark brown corrosion product layer and has fortunately helped to keep most of the original shape of the arrowhead. During the removal a white fibre was seen on piece 2 from base to tip, as can be seen in (Fig. 21). This was imbedded in the soil with a soil lump having to be removed before the fibre could be collected. This fibre was placed in a sealed sample tube. The fibre is currently being forensically tested at LJMU's Forensic Department to obtain its chemical composition so we can hopefully identify the fibre.

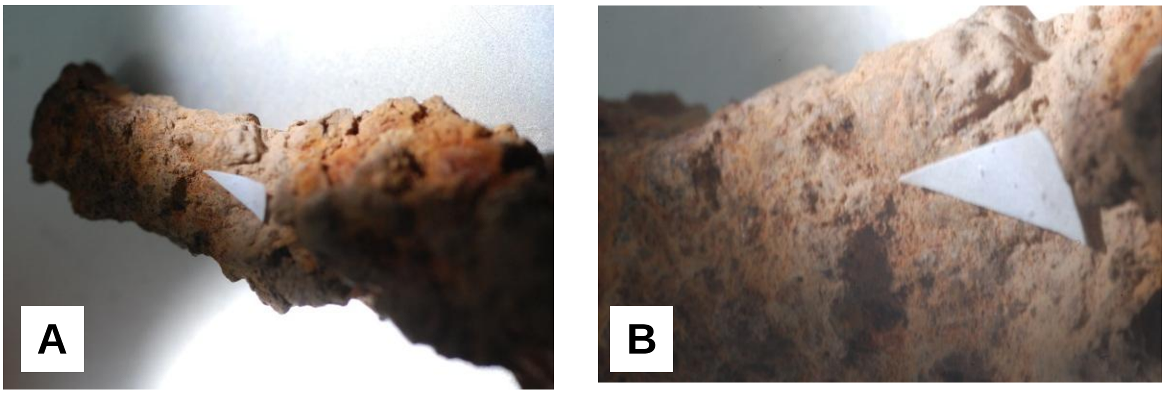


Figure 21: Showing the area that the fibre was found on piece 1 of the arrowhead (A) and close up (B).

During removal of the surface soil its appearance in a number of areas seemed slightly greasy (Fig. 22). It is still unclear why this is the case, could it be stringing and weeping that was previously mentioned? Samples of this soil have been taken for future analysis as have samples of the brown/red mass and soil removed from the areas of all three pieces of the arrow head. This will be kept for any future analysis that may be undertaken.

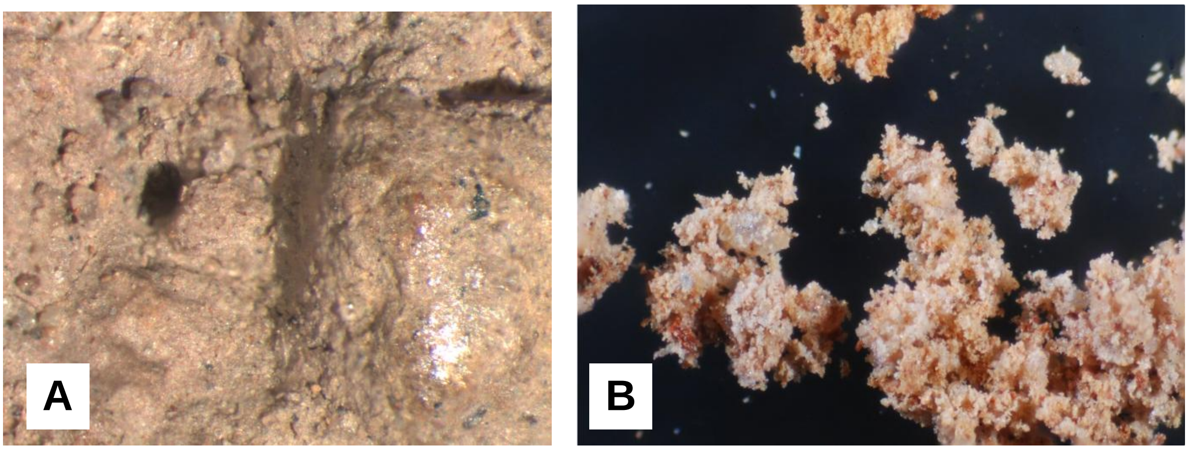


Figure 22: Greasy appearance of the surface (A). Greasy appearance of the soil (B).

Cracks which can be seen on the CT scans taken of the arrowhead became visible once the soil and some corrosion products had been removed. Some of these cracks were very deep. This cracking could have been a result of the corrosion process which travelled along the residual contour lines (Ashkenazi *et al* 2013). It could also have happened since the arrowhead was excavated. The arrowhead was not stored properly for a number of months and if some original metal remained in a few areas, as can possibly be seen in radiographs of the arrowhead, (Appendix 4), then corrosion could have continued, causing some of these cracks. It could also be down to the handling of the arrowhead throughout the conservation process. The greatest risk from too much handling is fragmentation due to the stresses from handling delicate, brittle mineralised elements.

These cracks have made the object fragile. This has reduced the amount of work that could be achieved on these areas of the arrowhead. Removal of the soil and corrosion products around these areas, were not as successful as the rest of the arrowhead. This can especially be seen on the third piece, the tip. This has three parallel cracks radiating from the centre, all of which extend from the tip to tail (Fig. 23).

Figure 23: Showing one of the parallel cracks.

Once all conservation had been achieved it was decided by the Poulton archaeological site team, lead Mike Emery that the arrowhead should remain in three distinct sections and not be (reversibly) adhered together (Fig. 24a, b, c and d).

Figure 24: The conserved arrowhead, side 1 (A), side 2 (B), side 3 (C) and side 4 (D).

It should be noted that any further handling of the arrowhead should be kept to a minimum to reduce further damage. Plastazote foam cut to the exact shape of the parts should help support the arrowhead and minimise stresses. It should also be kept in an environment that will reduce any further corrosion taking place. This can be achieved by placing in a sealed container with silica gel to reduce the relative humidity around the arrowhead to 15% or below.

Chapter 8

Discussion

8.1 Biological profile of SK535

Human remains from archaeological sites are a unique source of data on the environmental, economic and social factors of the site (Walker, 2001). This investigation was undertaken to try and find the identity and cause of death of the individual represented by skeleton 535 (SK535) which will contribute to a better understanding of Poulton archaeological site and the medieval period.

SK535, excavated on 29th March 2011, was identified using standard age-at-death and sexing techniques. Results showed that SK535 was a male, aged 35-39 years at death and had an estimated height of 168.5cm. No significant pathologies were noted, other than a healed fracture of the right distal ulna. There is no evidence in the bones that suggest injuries caused by the arrowhead, other than its presence in the thorax.

Fractures are common and are often observed in archaeological skeletal material. They represent physically traumatic events in an individual's life that resulted in broken bones (Judd, Roberts, 1999). Fractures heal at different rates depending on the bone element, type and severity of the fracture, if infection was absent or present and access to treatment (Roberts, 2005). The appearance of the right ulna showed it is well healed and well aligned. Remodelling has occurred with restoration of the normal architecture of the bone, showing its normal appearance (Lovell, 1997). The only visible deformity of that bone is the left circumferential articulation which is larger and flatter than that of the right one, perhaps suggesting that an injury did take place and damaged the natural growth process. There is no apparent fracture marks shown on the radiograph suggesting this fracture happened many years previous to death (Lovell, 1997).

This type of injury has been shown in many studies to be one of the most prevalent bones to fracture in late medieval populations (Judd, Roberts,1999). Fractures found in other medieval populations such as St Andrew, Fishergate in York, St Nicholas shambles, London and Blackfriars and Ipswich Suffolk, show that a right distal fracture of the ulna is one of the most commonly fractured bones (Djuric *et al* 2006). Fractures of the ulna are quite common and normally occur due to the strains and stresses placed on bones through physical activity and fighting (Judd, Roberts, 1999), or from direct force being applied such as in defensive wounds (Arnander, Newman 2006). However, other studies, such as (Slaus, 1994) argue that an injury such as this was in all probability not the result of violence and most likely caused by a fall. These types of fractures are more commonly seen in men (Grauer, Roberts 1996) and more common in the 40-59 years of age bracket (Djonic, *et al* 2006). During medieval times men were responsible for heavier labour, including working in the fields, ploughing, transporting, tree felling and herding (Judd, Roberts, 1999), all of which could lead to falls and injuries to the forearms. Fractures to long bones in the urban medieval populations were less frequent to that of rural populations during the medieval period (Grauer, Roberts 1996).

Grauer Roberts (1996) showed that all the fractures observed were well healed which like SK535 indicate they occurred years prior to death. It is possible that the fracture occurred during childhood, given that little evidence of the fracture is visible on the radiograph. Well-remodelled fractures of long bones can pass undetected during radiographic investigation making the determination of fracture type difficult (Arnander, 2006). This could explain the appearance on the shaft surface, swollen, discoloured, and flaky in comparison to the rest of the shaft. Fractures in modern population children show less comminution, rapid union and a tendency for deformity to be corrected by growth (Thomas, *et al* 1975). This could be the same for the medieval population children.

The fracture of the right distal ulna of SK535 is not severe and displays a good union of the bones. This raises the question as to the ulna being treated once broken or if the break was only minor. It has been noted in other medieval populations, such as those from St-Helen-on-the-wall, Yorkshire, England, that ulna deformity in this type of break is rare, and that maybe the radius served as a splint for the broken ulna (Grauer, Roberts, 1996).

8.2 Arrowhead

This was the first arrowhead found within skeletal remains at Poulton. One other arrowhead was previously found but it was not associated with any human remains (Emery, 2000).

The bodkin arrowhead was identified as a Type M7 bodkin using its length and the shape of its cross section by comparison with, the London Museum Catalogue (Ward Peskins, 1940) and the revisions proposed by Jessop (1996). Type M7 bodkins were used during the 12th and 13th century. This military type of arrowhead was used against humans whereas broad head arrowheads were primarily used against animals.

Although likely it cannot be definitively demonstrated that the arrowhead was actually within the thorax of the cadaver represented by SK535 at the time of his death. Mitchell *et al.,* (2006) reported skeletons excavated at Garrison of Vadumlocob Castle, Galilee, Israel, with arrowheads embedded within their bones, which definitively demonstrated death associated with the arrow wound (Mitchell *et al*., 2006). Arrow wounds were very common during the 13th and 14th centuries, and it was widely known that a 2 inch arrow wound located in the thorax could lead to death within 15 minutes due to massive bleeding or injury to vital organs. However, with good medical care a 4 inch or complete penetration of muscle could be survived, even if temporary incapacitation was inflicted (Strickland, Hardy 2005). Records show during this period doctors had guidelines on how to deal with such injuries. It was advised that any arrowheads found *in situ* that could not be removed without causing further injury or the patient crying should be left alone (Strickland, Hardy, 2005). Attempting to extract an arrowhead was extremely dangerous. Survival rate from arrow injuries improved with time with 191 people in an Indian war sample from 1860’s to 1870’s surviving their wounds (Milner, 2005).

The English are thought to have often smeared the tip of the arrowheads with poison. However Sir John Smith refuted these ideas and said it was the rust on the arrows that caused the infections (Strickland, Hardy, 2005). Arrows found on the Mary Rose shipwreck go some way to show favour with the idea of poison. Tests revealed a copper based compound used to protect the fletching and to help firm the glue used to fix them on arrow shafts (Strickland, Hardy, 2005), possible copper sulphate. This may have exacerbated a wound and lead to further infection and ultimately death. Bodkin type arrowheads that were used in Africa from rockshelter at de Hangen, have been shown to contain poison on the tips, these arrowheads dates from 1600 – 1860A.D (Clark, 1975).

8.3 Theories surrounding the death of SK535

This bodkin arrowhead was recovered under the right arm and resting on the right ribs in close proximity to the vertebrae and sternum (Fig. 4). Mitchell *et al.,* (2006) questioned whether an arrowhead could be found next to or under a skeleton as a result of the soldier falling onto the arrowhead as they died and then buried were they fell (Mitchell, *et al,* 2006). This is unlikely in the case of SK535 because he was found in a grave showing all the signs of a Christian burial. SK535 has been specifically put there it was not the place where he fell and died.

Evidence of arrow wounds on battlefields within England is small due to a lack of systematic excavation of major battlefields during the medieval period. Those bodies located on assumed battle fields in mass graves with wounds are often common soldiers, without significant armour. Thus it is difficult to know if they were actually included in the fighting or were just bystanders. High ranking soldiers with the luxury of armour were often removed from the battlefields for a more fitting burial.

SK535 was possibly wounded with a Type M7 Bodkin arrowhead that injured him in the thorax, most probably entering through the costal cartilage by the ribs on the right side of his body. The arrowhead either pierced a vital organ in that area such as the major blood vessels or the liver, leading to excessive bleeding and potentially death. By entering the costal cartilage no markings would be found on any of the bones in that area and during decomposition any evidence would have been erased. It is highly likely that the injury would have been bound to stop bleeding, either by members of his community or a doctor. After death a Christian burial took place, showing he was a person of some respectability.

The death of SK535 likely happened during skirmishes between the English and Welsh during the 14th Century. During this period skirmishes were happening between the two over the acquisition of land (Davies, 1991). During this time Poulton chapel was used as a lookout point for the English. The chapel overlooks the country side and the river Dee making it a good advantage point for the soldiers to see the advancing Welsh. The tower situated at Poulton was also a solid structure so could be used as a good defence against attack (Emery, *et al* 1995).

All of the information above could go some way to show why SK535 is the only skeleton at Poulton so far to be found with an arrowhead. The arrowhead could have penetrated through the thorax; indicating that at the time of death no armour was being worn. The arrowhead could have hit either a major organ or became embedded within the soft tissue; it may have been advised by surgeons of this time to leave it *in situ* to lessen the damage to the patient. Binding the arm could have been seen as a way of protecting the wound or stopping any bleeding. Bleeding out or hitting a major organ would have meant a quick death. The lack of armour could suggest that he was not in battle at the time of death

A second theory could suggest that SK535 died from an unknown cause and was buried with a longbow. It is well written that during the medieval time those who had a profession were often buried with a symbol of that profession. Bow makers at this time were known to be buried with a longbow and arrowhead or soldiers with their weapon (Daniell, 1998). This could have happened to SK535 who was buried in a single grave to reflect a professional person and was buried with a longbow positioned under his arm. The wood from the bow would have deteriorated over the years due to soil conditions (Burrell, Carpenter, 2013) resulting in only the arrowhead surviving.

8.4 "Arrowman 2"?

In August 2013, another skeleton, skeleton 719 (SK719) was excavated from Poulton archaeological site also exhibiting an arrowhead located in the lower thorax. SK719 was located on the opposite side of the grave yard to SK535 (Appendix 1). It cannot be determined if the skeleton was buried in a single grave as unfortunately it had been truncated at least 3 or 4 times by other burials. This side of the graveyard is known for containing no single burials. SK719 is not complete and consists of the upper thorax, upper limbs and cranium. There is a mandible which contains many teeth. The arrowhead found within the SK719 was different from that of SK535. It was of the type of a broad head. Using The London Medieval Catalogue it was matched to type MP1, in use during the 14th century; this type was used during wars to injure the enemy and animals. This is a similar type to the first arrowhead found at Poulton although this one was not in conjunction with a skeleton but found within the spoil heap. The new arrowhead found has been photographed and radiographed at Liverpool John Moores University (LJMU). SK719 will also undergo a thorough anthropological examination at LJMU. This will also include detailed examination of the bones surrounding the arrowhead, for any marks which could indicate the arrowhead has struck them. It is also hoped that AMS radiocarbon dating will be carried out using the teeth to establish if the dates tie in with the date of the arrowhead. As this is the second skeleton recovered from Poulton that contains an arrowhead located within it, further investigation is required to hopefully establish more information of what happened at Poulton during the medieval period and how these skeletons died.

Chapter 9

Conclusion

By comparing the results found from anthropological techniques, radiocarbon dating, historical and military records from the medieval period, this study has established a link between the time that SK535 lived and when the arrowhead was in use. From the information obtained it can be shown that it is quite possible for SK535 to have been injured or killed by the arrowhead during the border skirmishes between the English and Welsh around Poulton and the surrounding area at this time. It should also be considered that SK535 had been buried with a longbow and arrowhead. The careful individual burial of SK535 indicates him to be of a higher status than others buried within the graveyard. Due to the lack of injuries within the area where the arrowhead was located, it would appear that the arrowhead penetrated the costal cartilage of the thorax, resulting in serious injury leading to death. It has been shown that the Type M7 bodkin has dimensions that could easily have achieved this. There is also the possibility that SK535 could have died due to an unknown condition and been buried with the longbow and arrowhead an item relating to his profession, either as a soldier or a bow maker (Daniell.1998)

No forensic evidence such as fabric or organic substances were found on the arrowhead, only a small fibre which is being forensically tested. It is not uncommon for there to be a lack of forensic evidence remaining after such a long period of time.

During the research of this study a second skeleton SK719 was excavated also containing an arrowhead, although a different type. The finding of this second skeleton adds to the theory that the people of Poulton or surrounding areas were being injured by arrowheads or being buried with goods. SK535 died from a penetration wound either accidently or deliberately or died from unknown causes and buried with a longbow. The more skeletons found at Poulton with arrowheads should help to prove what was happening during this time in this area.

Bibliography

Arnander,M.W.T., Newman, K.J.H., 2006. Forearm Fractures, *Orthopaedic II Surgery 24*, (12), pp. 426-428.

Ashkenazi, D., Golan, O., Tal, O., 2013. An archaeometallurgical study of 13th century arrowheads and bolts from the crusader castle of arsuf/arsur, *Archaeometry*, (55), pp. 235-257

Bell, L.S., Lee Thorp, J.A., Elkerton, A., 2009. 'The sinking of the Mary Rose Warship: a medieval mystery solved?', *Journal of Archaeological Science,* (36), pp.166-173.

Bradbury, J., 1985. *The Medieval archer*. Boydell press: Suffolk.

Brickley, M., McKinley, J.I., 2004. Guidelines to the Standards for Recording Human Remains. BABAO, Department of Archaeology, University of Southampton and Institute of Field Archaeologists, SHES, University of Reading.

Buikstra, J. E., Ubelaker, D. H., 1994. *Standards for Data Collection from Human Skeletal Remains*. Arkansas Archaeological Survey Research Series, No. 44.

Burrell, C.L., Carpenter, R., 2013. Analysis of Human Skeletal Material from the Poulton Research Project: 1995-,2012. www.poultonproject.org

Christopher, J., 2012. *The Mary Rose Story,* The History Press Limited, Stroud.

Clark, J.D., 1975. Interpretations of Prehistoric Technology from Ancient Egyptian and other sources. Part II: Prehistoric arrow forms in Africa as shown by surviving examples of the traditional arrows of the San Bushmen. *Paleorient*, (3), pp. 127-150.

Cronyn, J.M., 2004. *Elements of Archaeological Conservation*. Routledge: London.

Daniell, C., 1998. *Death and Burial in Medieval England, 1066-1550*. Routledge: London.

Davies, R.R., 1991. *History of Wales. Age of Conquest*, 1063 – 1415. Oxford Paperbacks: Oxford.

Delrue, P., 2007. Trilobate arrowheads at ed-Dur (U.A.E, Emirate of Umm al-Qaiwain). *Arabian Archaeology and Epigraphy,* (18), pp. 239-250.

Djuric, M. P., Roberts, C. A., Rakocevic, Z. B., Djonic, D.D., Lesic, A.R., 2006. Fractures in Late Medieval Skeletal Populations From Serbia,. *American Journal of Physical Anthropology*, (130), pp. 167-178.

Emery, M.M. 2000. *The Poulton Chronicles,* Poulton Archaeology Press: Williamsburg

Emery, M.M., Gibbins, D.J.L., Matthews, K.L., 1995. *The Archaeology of an Ecclesiastical Landscape,* Chester Archaeological Society. Chester City council: Chester.

Gerwin, W., Baumhauer.R., 2000. Corrosion of archaeological metal finds, *Geoderma*, (96), pp. 63-80.

Grauer, A., Roberts, C.A., 1996. 'Paleoepidemiology, healing and possible treatment of trauma in the medieval cemetery population of St Helen- on- the- walls, York, England', *American journal of physical anthropology,* (100), pp. 531-544.

Gunn A, 2011. 2nd edition Essential Forensics Biology; Wiley & Blackwell, West Sussex

Hardy, R., 1976. Longbow. A social and military history: Cambridge.

Jessop, O., 1996. A new artefact typology for the study of medieval arrowheads, *Medieval Archaeology XL*: pp.192-205.

Judd, M.A., Roberts, C.A., 1999. Fracture Trauma in a Medieval British farming Village, *American Journal of Physical Anthropology*, (109), pp. 229-243.

Lovell, N.C., 1997. 'Trauma analysis in paleopathology', *Yearbook of Physical Anthropology*, (40), pp. 139-170.

Mcleod, K. J., O'Regan,H.J., (in prep). Medieval burial practices: An examination of arm positioning within a medieval population from Poulton, Cheshire.

Mckinley, J., Roberts, C., 1993. Excavation and Post-Excavation Treatment of Cremated and Inhumed Human Remains, *Institute of Field Archaeologists*, (13) Meindl, R.S., Lovejoy, C.O., 1985. Ectocranial Suture closure: A revised method for the determination of skeletal age at death based on the lateral anterial sutures. *American Journal of Physical Anthropology*, (68) pp.57-66

Meindl, R.S., Lovejoy, C.O., Mensforth, R.P., 1985. A revised method of age determination using the os pubis, with a review and tests of accuracy of other current methods of pubic symphyseal aging, *American Journal of Physical Anthropology,* (68), pp. 29-45.

Milner, G.M., 2005. Nineteenth-Century arrow wounds and perceptions of Prehistoric Warfare, *American Antiquity* (70), pp. 144-156.

Mitchell, P.D., Nagar,Y., Ellenblum,R., 2006. Weapon Injuries in the 12th Century Crusader Garrison of Vadum Iacob Castle, Galilee, *International Journal of Osteoarchaeology*, (16), pp. 145-155.

Morgan p ed 1978., Domesday book 26: Cheshire including Lancashire Cumbria and North Wales,. Chichester. Phillimore

Phenice, T.W., 1969. 'A newly developed visual method of sexing the os pubis', *American Journal of Physical Anthropology,*(30), pp. 297-301.

Rhodes, J.A., Knusel, C.J., 2005. Activity-Related Skeletal Change in Medieval Humeri: Cross-Sectional and Architectural Alterations, American *Journal of Physical Anthropology,* (128), pp. 536-546.

Rogers, C, J., 2011. 'The development of the longbow in late medieval England and 'technological determinism'. *Journal of Medieval History,* (37), pp. 321-341.

Selwyn, L., 2004. Metals and corrosion. A handbook for the conservation professional: Canada.

Strickland, M., Hardy, R., 2005. *The Great Warbow: a history of the military archer*: New York.

Stewart, T D., 1979. Essential of forensic Anthropology. Springfield, Illinois. C.C. Thomas.

Sullivan, A., 2004. Reconstructing Relationships Among Mortality, Status and Gender at the Medieval Gilbertine Priory of St Andrew, Fishergate, York, *American Journal of Physical Anthropology*, (124), pp. 330-345.

Thomas, E.M., Tuson, K.W.R., Browne, P.S.H., 1975. Fractures of the radius and ulna in children, *Injury: the British Journal of Accident Surgery*, (7), pp. 120-124.

Trotter, M., Gleser, G.C.,1952. 'Estimation of stature from long bones of American Whites and Negros', *American Journal of Physical Anthropology,* (10), pp. 463-514.

Trotter, M., Gleser, G.C., 1958 'A re-evaluation of stature based on measurements of stature taken during life and long bones after death', *American Journal of Physical Anthropology,* (16), pp. 79-123.

Walker, P.L., 2001. A Bioarchaeological Perspective on the History of Violence, *Annual Review of Anthropology*, (30), pp. 573-596.

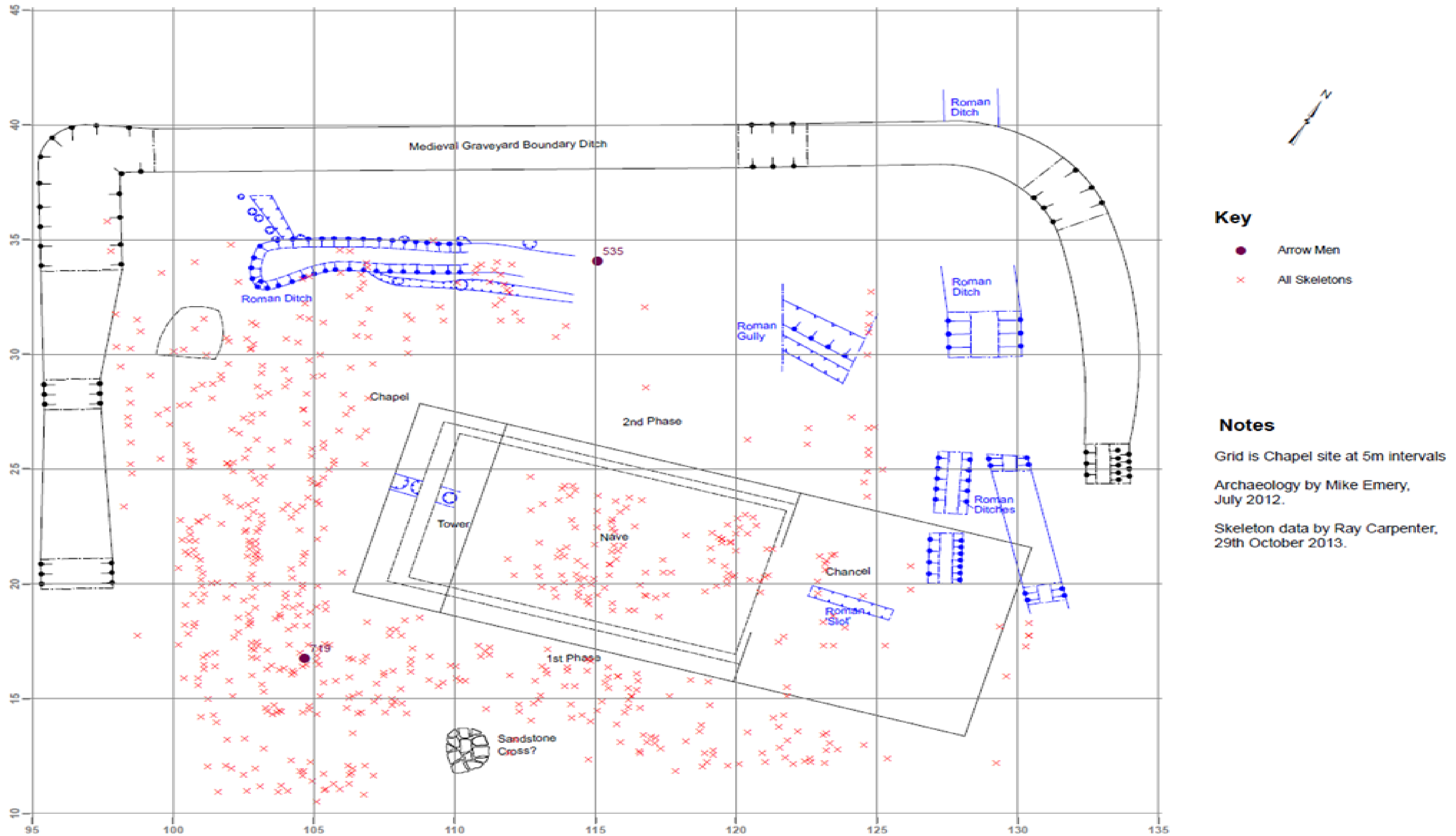
Ward Perkins, J.B., 1940. *London Museum Medieval Catalogue:* London, London Museum.

White, T.D., Folkens, P.A., 2005. *The Human Bone Manual*. Elseiver academic press: Boston.

Appendix List

1. Poulton Map. Showing Locations of SK535 and SK719.
2. Inventory of SK535.
3. AMS Radiocarbon dates.
4. Radiographs of arrowhead.

Appendix 1.



Medieval Graveyard Boundary Ditch
Roman Ditch
Roman Ditch
Roman Ditch
535
Roman Gully
Roman Ditch
Chapel
2nd Phase
Tower
Nave
Chancel
Roman Ditches
Roman Slot
749
1st Phase
Sandstone Cross?
N
Key
Arrow Men
All Skeletons
Notes
Grid is Chapel site at 5m intervals
Archaeology by Mike Emery, July 2012.
Skeleton data by Ray Carpenter, 29th October 2013.

Appendix 2.

Bone	Side	Condition/Pathology notes	Features present	Features absent
Skull	N/A	Fragmented and incomplete. Reconstructed part of cranium (Figure 5)	Left and right parietals, occipital bone, both mastoid processes and part of frontal bone	Remaining bones of skull
Mandible	N/A	Fragmented and incomplete	2 x lateral sides	Remaining bones of mandible
Maxilla	N/A	Absent	Absent	N/A
Hyoid	N/A	Absent	Absent	N/A
Clavicle	Left	Complete	Complete	N/A
Clavicle	Right	Fragmented/Complete	Complete	N/A
Scapula	Left	Fragmented/Incomplete	Acromion, Glenoid fossa, coracoids process, lateral boarder	Remaining aspects of scapula
Scapula	Right	Fragmented/Incomplete	Acromion, Glenoid fossa, lateral boarder	Remaining aspects of scapula
Sternum	Medial	Fragmented/Incomplete	Distal manubrium, proximal corpus sterni	Remaining aspects of sternum
1st Rib	Left	Fragmented/Incomplete	Head, neck, proximal shaft	Distal aspect of ribs
2nd Rib	Left	Fragmented/Incomplete	Head, neck, proximal shaft	Distal aspect of ribs
3rd Rib	Left	Fragmented/Incomplete	Head, neck, proximal shaft	Distal aspect of ribs
4th Rib	Left	Fragmented/Incomplete	Head, neck,	Shaft of ribs
5th Rib	Left	Fragmented/incomplete	Head, neck	Shaft of ribs
6th Rib	Left	Fragmented/Incomplete	Head, neck	Shaft of ribs
7th Rib	Left	Fragmented/Incomplete	Neck, shaft	head
8th Rib	Left	Fragmented/Incomplete	Head, neck, shaft	N/A
9th Rib	Left	Fragmented/Incomplete	Head, neck, shaft	N/A
10th Rib	Left	Fragmented/Incomplete	Shaft	Head, neck
11th Rib	Left	Fragmented/Incomplete	Shaft	Head, neck

Bone	Side	Condition/Pathology notes	Features Present	Features Absent
12th Rib	Left	Fragmented/Incomplete	Head, neck, shaft	N/A
1st Rib	Right	Fragmented/incomplete	Head, neck, shaft	N/A
2nd Rib	Right	Absent	N/A	N/A
3rd Rib	Right	Fragmented/Incomplete	Shaft	Head, Neck
4th Rib	Right	Fragmented/Incomplete	Head, Neck, Shaft	N/A
5th Rib	Right	Fragmented/Incomplete	Head, Neck, Shaft, Oxidation mark on shaft	N/A
6th Rib	Right	Fragmented/Incomplete	Neck, Shaft, Oxidation mark on shaft	Head
7th Rib	Right	Fragmented/Incomplete	Head, neck, shaft, Oxidation mark on head	N/A
8th Rib	Right	Fragmented/Incomplete	Neck, shaft	Head
9th Rib	Right	Fragmented/Incomplete	Neck, Shaft	Head
10th Rib	Right	Fragmented/Incomplete	Head, Neck, Shaft	N/A
11th Rib	Right	Fragmented/Incomplete	Head, Neck, Shaft	N/A
12th Rib	Right	Fragmented/Incomplete	Head, Neck	Shaft
1st Cervical Vertebra	Centrum	Fragmented/Incomplete	Superior/ Inferior articular facets	Spinous process/transverse processes
2nd Cervical Vertebra	Centrum	Complete	N/A	N/A
3rd Cervical Vertebra	Centrum	Complete	N/A	N/A
4th Cervical Vertebra	Centrum	Complete	N/A	N/A
5th Cervical Vertebra	Centrum	Complete	N/A	N/A
6th Cervical Vertebra	Centrum	Fragmented/Incomplete	Superior/Inferior articular facets/spinous process	Transverse processes
7th Cervical Vertebra	Centrum	Fragmented/Incomplete	Body	Superior/Inferior articular facets/ spinous process/Transverse processes

Bone	**Side**	**Condition/Pathology notes**	**Features present**	**Features absent**
1st Thoracic Vertebra	Centrum	Complete	N/A	N/A
2nd Thoracic Vertebra	Centrum	complete	N/A	N/A
3rd Thoracic Vertebra	Centrum	Fragmented/Incomplete	Superior/Inferior articular facets/spinous process/body	Transverse processes
4th Thoracic Vertebra	Centrum	Fragmented/Incomplete	Superior/Inferior articular facets, spinous process, body	Right transverse process
5th Thoracic Vertebra	Centrum	Fragmented/Incomplete	Superior/Inferior articular facets/spinous processes, body	Right transverse process
6th Thoracic Vertebra	Centrum	Fragmented/Incomplete	Superior/Inferior facets, body	Left and right transverse /spinous processes
7th Thoracic Vertebra	Centrum	Fragmented/Incomplete	Superior/Inferior facets/ spinous processes/body	Left and right transverse processes
8th Thoracic Vertebra	Centrum	Fragmented/Incomplete	Superior/Inferior facets, body	Left and right Transverse/ spinous processes
9th Thoracic Vertebra	Centrum	Fragmented/Incomplete	Body	Everything else
10th Thoracic Vertebra	Centrum	Fragmented/Incomplete	Superior/Inferior facets, body	Left and right transverse/ spinous processes
11th Thoracic Vertebra	Centrum	Fragmented/Incomplete	Superior/Inferior facets, spinous processes, body	Left and right Transverse processes
12th Thoracic Vertebra	Centrum	Fragmented/Complete	N/A	N/A
1st Lumbar Vertebra	Centrum	Fragmented/Complete	N/A	N/A
2nd Lumbar Vertebra	Centrum	Fragmented/Incomplete	Superior/Inferior facets, body	Left and right transverse/spinous processes
3rd Lumbar Vertebra	Centrum	Fragmented/Incomplete	Superior/Inferior facets, body, transverse processes	Left and right spinous processes
4th Lumbar Vertebra	Centrum	Fragmented/Incomplete	Superior/Inferior facets, body	Left and right transverse/spinous processes

Bone	Side	Condition/Pathology notes	Features present	Features absent
5th Lumbar Vertebra	Centrum	Fragmented/Incomplete	Superior/Inferior facets, body	Left and right transverse/spinous processes
Humerus	Left	Fragmented/Completed. Post mortem fracture of neck	N/A	N/A
Radius	Left	Fragmented/complete. Post mortem fracture of proximal shaft	N/A	N/A
Ulna	Left	Fragmented/Incomplete. Post mortem fracture of proximal shaft	N/A	N/A
Humerus	Right	Fragmented/complete. Excavation damage to proximal end	N/A	N/A
Radius	Right	Fragmented/Incomplete. Excavation damage to proximal end.	N/A	N/A
Ulna	Right	Fragmented/Incomplete. Excavation damage to proximal end. Healed fracture to distal end	N/A	N/A
Hamate	Left	Present/Complete	N/A	N/A
Capitate	Left	Present/Complete	N/A	N/A
Lunate	Left	Present/Complete	N/A	N/A
Pisiform	Left	Present/Complete	N/A	N/A
Scaphoid	Left	Preset/Complete	N/A	N/A
Trapezium	Left	Present/Complete	N/A	N/A
Trapezoid	Left	Present/Complete	N/A	N/A
Triquetral	Left	Present/Complete	N/A	N/A
1st metacarpal	Left	Present/Complete	N/A	N/A
2nd Metacarpal	Left	Present/Complete	N/A	N/A
3rd Metacarpal	Left	Present/Complete	N/A	N/A
4th Metacarpal	Left	Present/Complete	N/A	N/A
5th Metacarpal	Left	Present/Complete	N/A	N/A

Bone	Side	Condition/Pathology notes	Features Present	Features Absent
1st Proximal Phalanx	Left	Present/Complete	N/A	N/A
2nd Proximal Phalanx	Left	Present/Complete	N/A	N/A
3rd Proximal Phalanx	Left	Present/Complete	N/A	N/A
4th Proximal Phalanx	Left	Present/Complete	N/A	N/A
5th Proximal Phalanx	Left	Present/Complete	N/A	N/A
2nd Intermediate Phalanx	Left	Present/Complete	N/A	N/A
3rd Intermediate Phalanx	Left	Absent	N/A	N/A
4th Intermediate Phalanx	Left	Present/Complete	N/A	N/A
5th Intermediate Phalanx	Left	Present/Complete	N/A	N/A
1st Distal Phalanx	Left	Present/Complete	N/A	N/A
2nd Distal Phalanx	Left	Present/Complete	N/A	N/A
3rd Distal Phalanx	Left	Absent	N/A	N/A
4th Distal Phalanx	Left	Absent	N/A	N/A
5th Distal Phalanx	Left	Absent	N/A	N/A
Hamate	Right	Present/Complete	N/A	N/A
Capitate	Right	Present/Complete	N/A	N/A
Lunate	Right	Absent	N/A	N/A
Pisiform	Right	Absent	N/A	N/A
Scaphoid	Right	Absent	N/A	N/A
Trapezium	Right	Absent	N/A	N/A
Trapezoid	Right	Present/Complete	N/A	N/A

Bone	Side	Condition/Pathology notes	Features Present	Features Absent
Triquetral	Right	Present/Complete	N/A	N/A
1st Metacarpal	Right	Absent	N/A	N/A
2nd Metacarpal	Right	Present/Complete	N/A	N/A
3rd Metacarpal	Right	Present/Complete	N/A	N/A
4th Metacarpal	Right	Fragmented/incomplete	N/A	Distal end
5th Metacarpal	Right	Fragmented/Incomplete	N/A	Distal end
1st Proximal Phalanx	Right	Present/Complete	N/A	N/A
2nd Proximal Phalanx	Right	Present/Complete	N/A	N/A
3rd Proximal Phalanx	Right	Present/Complete	N/A	N/A
4th Proximal Phalanx	Right	Present/Complete	N/A	N/A
5th Proximal Phalanx	Right	Present/Complete	N/A	N/A
2nd Intermediate Phalanx	Right	Absent	N/A	N/A
3rd Intermediate Phalanx	Right	Present/Complete	N/A	N/A
4th Intermediate Phalanx	Right	Absent	N/A	N/A
5th Intermediate Phalanx	Right	Absent	N/A	N/A
1st Distal Phalanx	Right	Absent	N/A	N/A
2nd Distal Phalanx	Right	Absent	N/A	N/A
3rd Distal Phalanx	Right	Absent	N/A	N/A
4th Distal Phalanx	Right	Absent	N/A	N/A
5th Distal Phalanx	Right	Absent	N/A	N/A
Sacrum	Medial	Fragmented/Incomplete	1st,2nd,3rd sacral element. Right/left alas	N/A

Bone	Side	Condition/Pathology notes	Features Present	Features Absent
Ilium	Left	Fragmented/Incomplete	N/A	N/A
Ilium	Right	Fragmented/Complete	N/A	N/A
Ischium	Left	Fragmented/Complete	N/A	N/A
Ischium	Right	Fragmented/Complete	N/A	N/A
Pubis	Left	Absent	N/A	N/A
Pubis	Right	Fragmented/Complete	N/A	N/A
Coccyx	N/A	Fragmented/Complete	N/A	N/A
Femur	Left	Fragmented/Complete. Post mortem shaft fracture	N/A	N/A
Tibia	Left	Fragmented/Complete. Post mortem distal shaft fracture	N/A	N/A
Fibula	Left	Fragmented/Complete. Post mortem proximal shaft fracture	N/A	N/A
Patella	Left	Present/Complete	N/A	N/A
Femur	Right	Fragmented/Complete. Post mortem fracture of distal and proximal shaft	N/A	N/A
Tibia	Right	Fragmented/complete. Post mortem fracture of distal and proximal shaft	N/A	N/A
Fibula	Right	Fragmented/Complete. Post mortem fracture of proximal shaft	N/A	N/A
Patella	Right	Present/Complete	N/A	N/A
Calcaneus	Left	Present/Complete	N/A	N/A
Talus	Left	Present/Complete	N/A	N/A
Navicular	Left	Present/Complete	N/A	N/A
Cuboid	Left	Present/Complete	N/A	N/A
Lateral Cuneiform	Left	Present/Complete	N/A	N/A
Intermediate Cuneiform	Left	Present/Complete	N/A	N/A

Bone	Side	Condition/Pathology notes	Features Present	Features Absent
Medial Cuneiform I	Left	Present/Complete	N/A	N/A
1st Metatarsal	Left	Fragmented/Incomplete	N/A	Distal end
2nd Metatarsal	Left	Fragmented/Incomplete	N/A	Distal end
3rd Metatarsal	Left	Fragmented/Incomplete	N/A	Distal end
4th Metatarsal	Left	Fragmented/Incomplete	N/A	Distal end
5th Metatarsal	Left	Absent	N/A	N/A
1st Proximal Phalanx	Left	Absent	N/A	N/A
2nd Proximal Phalanx	Left	Absent	N/A	N/A
3rd Proximal Phalanx	Left	Absent	N/A	N/A
4th Proximal Phalanx	Left	Absent	N/A	N/A
5th Proximal Phalanx	Left	Absent	N/A	N/A
4th Proximal Phalanx	Left	Absent	N/A	N/A
3rd Intermediate Phalanx	Left	Absent	N/A	N/A
4th Intermediate Phalanx	Left	Absent	N/A	N/A
5th Intermediate Phalanx	Left	Absent	N/A	N/A
1st Distal Phalanx	Left	Absent	N/A	N/A
2nd Distal Phalanx	Left	Absent	N/A	N/A
3rd Distal Phalanx	Left	Absent	N/A	N/A
4th Distal Phalanx	Left	Absent	N/A	N/A
5th Distal Phalanx	Left	Absent	N/A	N/A
Calcaneus	Right	Present/Complete	N/A	N/A

Bone	Side	Condition/Pathology notes	Features Present	Features Absent
Talus	Right	Present/Complete	N/A	N/A
Navicular	Right	Present/Complete	N/A	N/A
Cuboid	Right	Present/Complete	N/A	N/A
Lateral Cuneiform	Right	Present/Complete	N/A	N/A
Intermediate Cuneiform	Right	Present/Complete	N/A	N/A
Medial Cuneiform	Right	Present/Complete	N/A	N/A
1st Metatarsal	Right	Fragmented/Incomplete	N/A	Distal end
2nd Metatarsal	Right	Fragmented/Incomplete	N/A	Distal end
3rd Metatarsal	Right	Fragmented/Incomplete	N/A	Distal end
4th Metatarsal	Right	Fragmented/Incomplete	N/A	Distal end
5th Metatarsal	Right	Fragmented/Incomplete	N/A	Distal end
1st Proximal Phalanx	Right	Absent	N/A	N/A
2nd Proximal Phalanx	Right	Absent	N/A	N/A
3rd Proximal Phalanx	Right	Absent	N/A	N/A
4th Proximal Phalanx	Right	Absent	N/A	N/A
5th Proximal Phalanx	Right	Absent	N/A	N/A
2nd Intermediate Phalanx	Right	Absent	N/A	N/A
3rd Intermediate Phalanx	Right	Absent	N/A	N/A
4th Intermediate Phalanx	Right	Absent	N/A	N/A
5th Intermediate Phalanx	Right	Absent	N/A	N/A
1st Distal Phalanx	Right	Absent	N/A	N/A

Bone	Side	Condition/Pathology notes	Features Present	Features Absent
2rd Distal Phalanx	Right	Absent	N/A	N/A
3rd Distal Phalanx	Right	Absent	N/A	N/A
4th Distal Phalanx	Right	Absent	N/A	N/A
5th Distal Phalanx	Right	Absent	N/A	N/A

Appendix 3.

BETA ANALYTIC INC.
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REPORT OF RADIOCARBON DATING ANALYSES

Dr. James Ohman — Report Date: 12/17/2012

Liverpool John Moores University — Material Received: 12/3/2012

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 337188	270 +/- 30 BP	-20.3 o/oo	350 +/- 30 BP
Beta - 337189	600 +/- 30 BP	-20.5 o/oo	670 +/- 30 BP

Beta - 337188
SAMPLE : Skeleton53Ca
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (tooth): collagen extraction: with alkali
2 SIGMA CALIBRATION : Cal AD 1450 to 1640 (Cal BP 500 to 310)

Beta - 337189
SAMPLE : Skeleton535M
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (tooth): collagen extraction: with alkali
2 SIGMA CALIBRATION : Cal AD 1280 to 1320 (Cal BP 670 to 630) AND Cal AD 1350 to 1390 (Cal BP 600 to 560)

Dates are reported as RCYBP (radiocarbon years before present, "present" = AD 1950). By international convention, the modern reference standard was 95% the 14C activity of the National Institute of Standards and Technology (NIST) Oxalic Acid (SRM 4990C) and calculated using the Libby 14C half-life (5568 years). Quoted errors represent 1 relative standard deviation statistics (68% probability) counting errors based on the combined measurements of the sample, background, and modern reference standards. Measured 13C/12C ratios (delta 13C) were calculated relative to the PDB-1 standard.

The Conventional Radiocarbon Age represents the Measured Radiocarbon Age corrected for isotopic fractionation, calculated using the delta 13C. On rare occasion where the Conventional Radiocarbon Age was calculated using an assumed delta 13C, the ratio and the Conventional Radiocarbon Age will be followed by "*". The Conventional Radiocarbon Age is not calendar calibrated. When available, the Calendar Calibrated result is calculated from the Conventional Radiocarbon Age and is listed as the "Two Sigma Calibrated Result" for each sample.

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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-20.5:lab. mult=1)

Laboratory number: **Beta-337189**

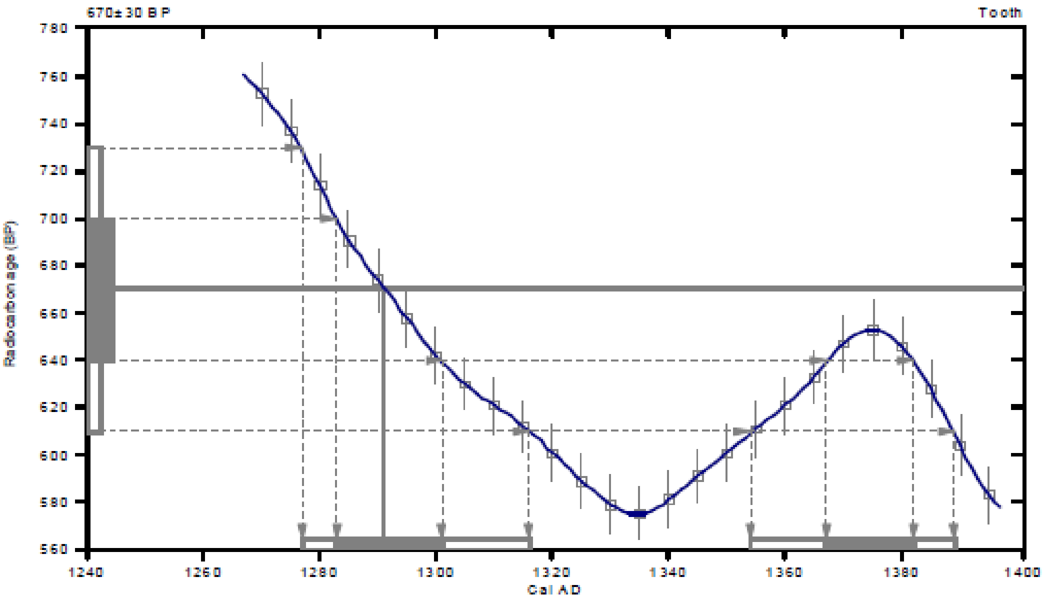
Conventional radiocarbon age: **670±30 BP**

2 Sigma calibrated results: (95% probability) **Cal AD 1280 to 1320 (Cal BP 670 to 630) and Cal AD 1350 to 1390 (Cal BP 600 to 560)**

Intercept data

Intercept of radiocarbon age with calibration curve: Cal AD 1290 (Cal BP 660)

1 Sigma calibrated results: (68% probability) Cal AD 1280 to 1300 (Cal BP 670 to 650) and Cal AD 1370 to 1380 (Cal BP 580 to 570)



References:

Database used

INTCAL09

References to INTCAL09 database

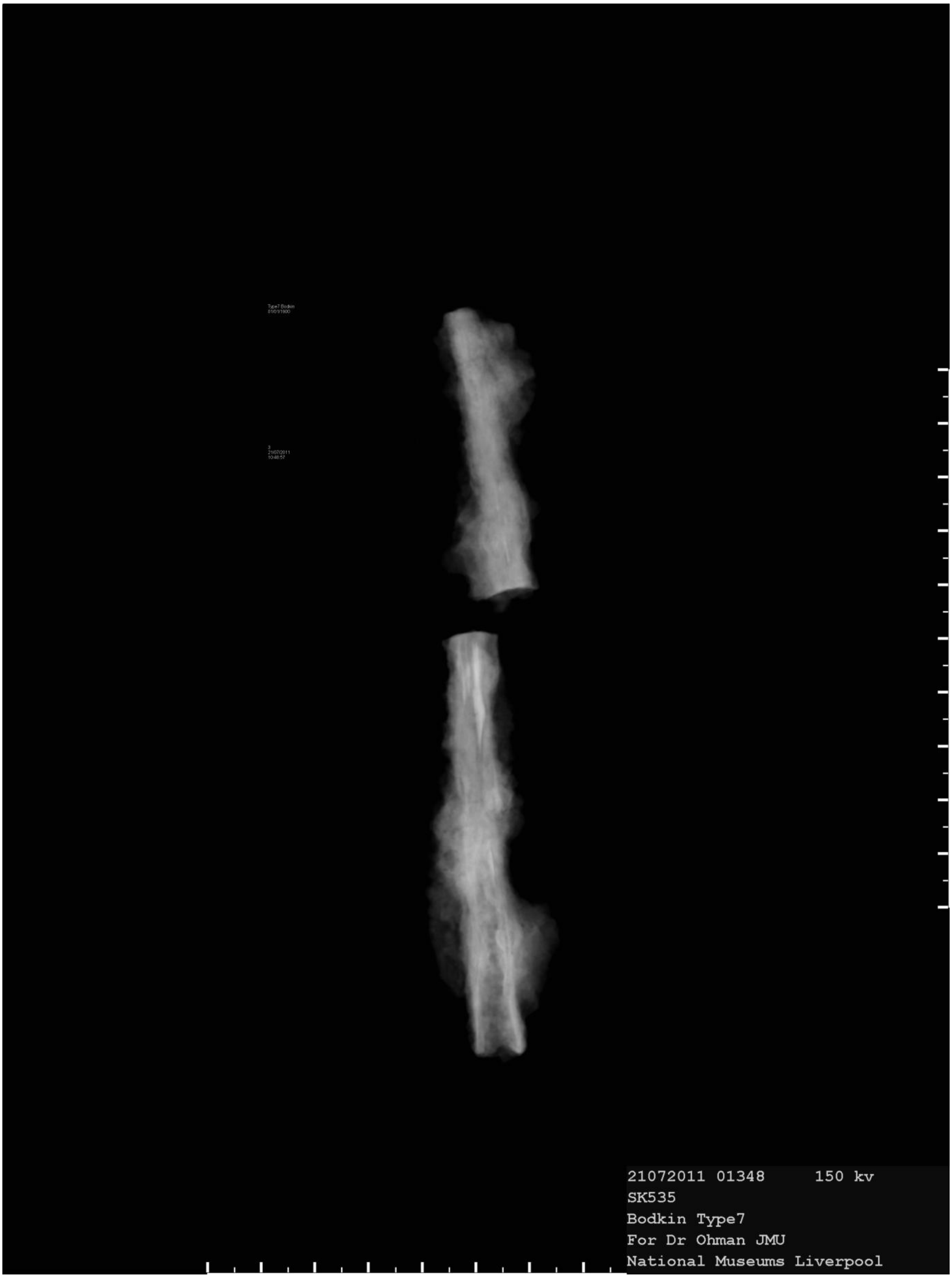
Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):1-244, Oeschger,et.al.,1975,Tellus 27:168-192

Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

Appendix 4.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For Dr Ohman JMU
National Museums Liverpool