Combining forensic anthropological and geological approaches to investigate the preservation of human remains in British archaeological populations and their effects on palaeodemography

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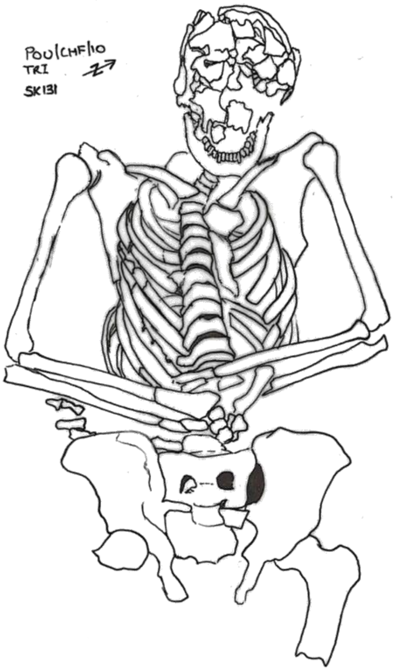

To Albert and Jean Davenport, the most amazing Grandparents who supported my Mum in every way they could and enabled me to have an unforgettable childhood. I hope you are proud, because by showing my Mum she could overcome any obstacle; you made me believe it was possible to chase my dreams.

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To learn about the present, you must look into the past….

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Abstract

Palaeodemographic studies enable the lifespan and health of a population to be studied and subsequent influences deduced from the analysis of biological profiling data. The aim of this research was to produce the demographic profiles for the medieval sites of Poulton Chapel and St Owens, Gloucester. Comparisons with previously published sites would allow a comparison between the demographic profiles from rural and urban populations. Taphonomic and cultural factors have been listed amongst the causes for the lack of material available for osteological analysis, and the subsequent under-representation of certain age within a population. Although commented on in published literature, there has been no research into the degradation of the human skeleton, with many projects focussing only on the soft tissue decomposition rates and factors.

Using a combination of techniques from forensic anthropology and geology, the collections were analysed using traditional palaeodemographic life tables and the sites subjected to geoarchaeological investigation. This enabled not only the preservation of the skeletal remains to be observed under differing burial conditions, but incorporated the use of archaeothanatology to understand the cultural practices undergone during the time of burial.

This PhD thesis found that soil pH was not the biggest influencer on the potential preservation of a skeleton, but the cultural practices behind the burial itself. By combining techniques from forensic anthropology, geoarchaeology and geochemistry, greater insights into the effects of taphonomic and cultural influences on the preservation of human skeletal remains are found. This has enabled the questions into what influences the ability to produce a demographic profile to be answered, which will encourage the use of multidisciplinary studies when investigating cemetery samples.

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1.1. Introduction and rationale for the research

Palaeodemography assesses the changes to archaeological populations to learn about the factors that affect the lifespan and health of a population. An analysis of the literature on palaeodemography revealed that it was more than simply a question of what is a normal demographic. Palaeodemography has been subjected to a number of critiques and controversies, with a multitude of issues affecting the potential for achieving an understanding of the structure of a past population. Many previous studies have been carried out on the issues of underrepresentation of age ranges, with the reasons given as poor excavation, taphonomic conditions or differing burial practices. Few studies have aimed to bring the different elements together to explore what is influencing the preservation and retrieval of human remains. Therefore, this study does not seek to correct or test palaeodemographic modelling processes, but to explore the differences that can affect an analysis during the deposition, excavation and curation stages.

The original aim was to examine one rural (Poulton Chapel, Cheshire) and one urban (St Owens Church, Gloucester) sample from a medieval population, with a later comparative analysis using previously published data from the medieval sites of Wharram Percy, North Yorkshire and St Mary Spital, London (Connell *et al*., 2012; Mays *et al*., 2007 respectively). The sites were selected based on the lack of published literature and research on Poulton Chapel and St Owen's Church, which presented a unique opportunity to learn more about the medieval population and how the differing lifestyles may have affected the demographics at each site. A lack of information on extensively studied rural medieval sites would also help answer the questions as to whether the demographic profiles attained from the study of the Wharram Percy skeletal population were representative of a rural lifestyle.

However, during the assessment of the St Owens material it was discovered that the two excavations carried out on this site contained the skeletal remains of not one, but three cemeteries covering two different time spans. An additional, external osteological contract for an urban site in Chester provided an opportunity to explore the impact taphonomy has on human bone, though demographic analysis was not possible on this sample due to small numbers of skeletons retrieved during excavation (n=20). The addition of Chester Greyfriars brought the total number of cemetery samples included in this thesis to five (Figure 1.1):

1. Poulton Chapel, Cheshire
2. St Owens, Gloucester
3. Southgate Congregational Church, Gloucester
4. Gloucester Infirmary Burial Ground, Gloucester
5. Chester Greyfriars, Chester

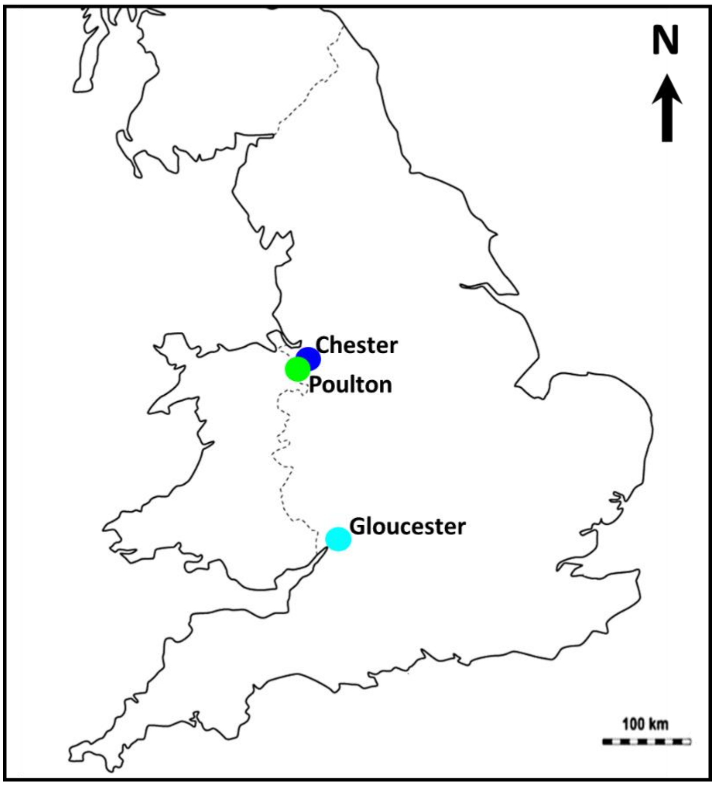

Figure 1.1. The locations of the cemeteries are shown for Poulton Chapel in Cheshire, Chester Greyfriars in Chester and the Southgate Street cemeteries in Gloucester.

Geoarchaeology is the application of geological techniques to archaeological questions. The field has seen significant scientific advances over the last 20 years (Canti and Huisman, 2015), with studies investigating the influence of soil pH on the preservation of bone (Berna *et al.*, 2004; Jans *et al.*, 2004 and Smith *et al.*, 2002). Combining the results of the geoarchaeological investigations at the studied sites with additional geochemical soil testing and the anthropological assessment of the skeletal preservation, will enable the investigator to devise a sample selection protocol for further detailed testing of human remains for methods such as radiocarbon dating, stable isotope testing and ancient DNA to characterise the human populations in detail. Therefore, a multi-disciplinary study into the factors affecting palaeodemographic research is presented in this thesis.

The PhD research presented challenges that required the development of new techniques and protocols for the assessment of fragmentation, and the elemental analysis of human bone. By incorporating techniques from anthropology, geoarchaeology and geochemistry, it enabled investigation of the diagenetic factors on interred human remains and provided an oversight into the potential areas for further testing in both the field and the laboratory.

1.2. Literature Review

> 'Thus the problems lie not with the demographic analysis of complete skeletons but with those of poor condition or which are significantly less complete, and it is in the study of these individuals that the greatest census error is to be expected.'

Lovejoy (1971, p.102)

1.2.1. The issue of palaeodemography

Anthropologists and archaeologists study human remains to learn more about the life history of that individual, the population in which they lived, and in some cases, the circumstances surrounding their death and the deposition of the body. Palaeodemography is the study of ancient human mortality, fertility and migration, and looks at the changes in pre-modern populations to learn about the influences on the lifespan and health of the population from which they originated.

Palaeodemographic studies use the sex and age-at-death estimates derived from skeletal material (Angel, 1969). Based upon these death cohort data, the production of life tables enables the analysis of population dynamics, including survivorship, life expectancy, fertility and mortality rates (Drusini *et al*., 2001; Lovejoy *et al*., 1977; Weiss and Wobst, 1973). Ubelaker (1974) carried out demographic studies on ossuary skeletal samples, using a case study from the Tidewater Potomac to illustrate that a successful palaeodemographic study must meet the following requirements:

1. The researcher must have knowledge of the completeness of the sample.
2. Information regarding the archaeological associations of the skeletons.
3. A determination of the length of time the collection represents.
4. An adequate assessment of sex and age-at-death.
5. A proper selection of demographic methodology.
6. Uniformity of analytical work throughout the procedure

If one or more of these requirements are not met, the palaeodemographic study will be inaccurate and will not produce usable information. Thorough assessment of the available historical and archival information on an archaeological site is necessary to provide an estimate of the period the population represents. Once deduced it should be possible to ascertain the average number of deaths per year for the population, before using a regression formula to determine the minimum size of the population needed to sustain this.

Mathematical equations to investigate the pattern of mortality in adult populations have been used since the work of Gompertz in the early 19th century (Meindl and Russell, 1998).

Following World War II there was a shift from using the functional graduations towards life table reference sets (Brass 1971). The reference sets supplemented incomplete demographic data from developing countries, and were based on the basic assumption that governs mathematical principles:

> "A limited number of dimensions of variation exist for the shape of the curve of deaths."
>
> (Meindl and Russell, 1998, p.389).

Four families of mortality profiles were identified from the models created, though the West family reference set is used in anthropological applications most frequently. The palaeodemographic models have been used by anthropologists to examine and explain the processes that may apply to extinct populations (Buikstra and Konigsberg, 1985; Horowitz and Armelagos, 1988; Dumond, 1997 and Sullivan, 1997). Others sought to eliminate certain archaeological populations from palaeodemographic study completely (Howell, 1982; Milner *et al,* 1989 and Paine, 1989), as the survivorship levels of many populations tended to be very low, especially when compared to the West family reference sets. Those undertaking the assessment concluded that the life table analysis must be wrong (Howell, 1982; Milner *et al*, 1989 and Paine, 1989).

The Libben site, Ottowa County, Ohio, dates from the 8th to 11th centuries and was subject to a palaeodemographic study, which was published in the 1970s (Lovejoy, 1977). A well-preserved sample, with 1289 of the 1327 skeletons recovered included in the life-table, was analysed with a view to understanding more about the population and historical events that affected the mortality rates of the population (Howell, 1982). Some of the current methods used for ageing skeletal remains have derived from methods originally tested on the Libben population (Lovejoy, 1985; Lovejoy *et al*, 1985a; 1985b), along with the justification for carrying out multifactorial studies to increase accuracy when assessing the biological profile of human skeletal remains (Bedford *et al*, 1993; Mensforth and Lovejoy, 1985).

When publishing the data, Lovejoy (1977, p.291) it was claimed that it was "the largest and most comprehensively censused North American prehistoric cemetery", drawing comparisons between the demographic results obtained from the life tables and those of ethnographic censuses (Chamberlain, 2006). However, the analysis drew criticism due to the low infant and high adult mortality profile (Howell, 1982; Coale and Demeny, 1983). A comparison was carried out between the Libben mortality distribution and the West model mortality profile produced by Coale and Demeny (1983), which had a similar life expectancy at birth of 20 years (Chamberlain, 2006). There were marked differences between the profiles, with the Coale and Demeny profile showing an increase in death in the 0-4 year range, a reduced adult mortality between 25 and 45 years and gradual decline in individuals surviving past 60 years, rather than the abrupt cut off that occurred in the Libben life table. Lovejoy (1977) responded to the comments, denying that there was under-representation of the non-adult population and that there were no issues with the estimation of age in the adult population. Lovejoy's (1977) argument was that the non-adult population could not be under-represented due to the excellent rates of preservation and thorough excavation of the site. Adult age estimation was carried out using a multivariate approach, with seven age indicators used in the assessment, leaving little doubt to the accuracy of the ages reported. Lovejoy (1977, p.293) proposed that it was the modern populations that showed abnormal demographics due to "the selective influence of a battery of novel pathogens", which led to increased risks in early childhood resulting in a reduced adult mortality level.

Investigations into the possible cause of this discrepancy were undertaken by Brass (1971), who investigated populations that had a very high adult mortality rate in an attempt to understand what else could be influencing the results. Brass (1971) found that there were factors, both social and environmental that could lead to deviations from the expected model, although the resultant demographic analysis did not show this. It appeared that individuals under the age of 10 years and those over 60 years were not represented fully using this method, leading to discrepancies in the life table model (Meindl and Russell, 1998). It had been noted that while the Libben demographic pattern was not see in extant populations, but regularly observed in skeletal demographic analyses (Howell, 1982). When modelling a hypothetical population to simulate the living population that would have resulted in the demographic profile observed with the Libben population, it was clear that there would have been a very high proportion of dependent non-adults, with many orphaned due to the high mortality observed among young adults. Families would have been limited to two generations, with few non-adults having surviving grandparents. The pressures of providing for so many children in a population would result in a significantly heavy workload for the adult population. Howell (1982) concluded that the life table might have been distorted by differential preservation and inaccurate age estimation from the skeletal remains.

Later, stable population theory provided a practical means to show the relationship between the age distributions of a cemetery with a mortality profile (Bennett, 1973; Weiss and Wobst, 1973 and Moore *et al* 1975). By using stable population theory, the new demographic profiles were more of a continuum of solutions, with each point on the table providing both mortality and fertility levels, rather than a single demographic profile. Other papers put forward alternative life tables that offered some flexibility (Weiss and Wobst, 1973), although it was the production of hazard tables by Gage (1988; 1989; 1990) that enabled the demographer the option of smoothing the life table data. Wood *et al* (1992) introduced the concept of hazard functions, enabling the demographer to model the demographic structure as a continuous function, rather than a series of values. They were useful when exact ages of death are known, due to ensuring the maximum amount of information is gained from the analysis (Chamberlain, 2006). However due to archaeological populations rarely providing information on the exact age at death, it had limited use for many palaeodemographers.

Recent palaeodemographic studies have used probability models, or Bayesian statistics, using known data and unknown data (Gelman *et al*, 1995). Lewis and Gowland (2007) carried out a study comparing the mortality profiles of the non-adults from four medieval sites (two rural and two urban), using both standard regression methods from long bone age estimation, and a Bayesian method. While the regression formula produced a peak in age at 38 weeks, the Bayesian method produced a broad range of ages, which was more representative of a *'natural'* demographic profile. However, it was noted that the overall mortality profiles did not differ significantly from each other.

In 1982, Bocquet-Appel and Masset published a paper consisting of a series of critiques regarding the currently available methods for age estimation and the reliability of life table parameters. It was followed up by a series of papers from many authors providing evidence both for and against the claims. Buikstra and Konigsberg (1985) reviewed the paper and in doing so compiled a list of the weaknesses put forward by Boucquet-Appel and Masset (1982), which are paraphrased here:

1. Profiles seem to reflect those of the reference populations, is the methodology really informing on the mortality structure or is it biased?
2. The standards used for age estimation methods do not evenly represent all age categories and therefore are likely to be biased in the estimates given
3. Many standards do not account for older age groups; therefore, analysis could result in incorrectly assigning an individual to the wrong age category.
4. The currently available methods for estimating age at death are not profiles
5. No single technique to assess age will not account for the variation present within or between populations. By standardising the methodology, any significant variances in the profiles will not be identified.

The criticism of palaeodemography was met with disagreements in the points raised and in the methodologies carried out by Boucquet-Appel and Massett (1982). One such paper was the published in 1985 by Buikstra and Konisberg, who not only addressed each of the points raised, but also identified the flaws in the initial paper and carried out an assessment of 26 life tables compiled from North American skeletal samples to support their argument.

There have been questions into what the demographic life tables actually represent, with many believing that rather than the mortality of a population, it indicates population growth and fertility (Buikstra *et al*, 1986; Johansson and Horowitz, 1986 and Milner *et al*, 1989). A high proportion of non-adult individuals excavated from a cemetery would result in a low life expectancy at birth, indicating a thriving, growing population (Larsen, 2002). Whereas populations with a low proportion of non-adult burials would produce a high life expectancy at birth, possibly indicating a population in decline.

Lovejoy (1971) had previously stated that without taking into account the variability within a population and the additional variability brought in through migration into the population, it is not possible to make a reliable judgement on the population demographics. Later demographic papers also noted that there are several potential sources of error when investigating demography (Meindl and Russell, 1998). Aside from the issues noted with age at death estimation techniques, there were problems raised with burial practices, truncation due to later burials, excavator experience, the completeness of the excavation and taphonomic interference.

Cemetery populations

The treatment of the living within societies can vary with age, population pressures and illness, though there are times when this may not be represented in cemetery samples. The treatment of the dead only varying in very specific circumstances, although the variation will depend on the population and their cultural beliefs, practices and superstitions. Funerary rites have been used to express the identity of the deceased, with certain practices highlighting a particular age group or profession (Stoodley, 1999; Buckberry and Hadley, 2007). By excluding particular groups of individuals from burial within the cemetery, or by interring particular demographic groups in burial structures such as a family mausoleum, the demographic reconstruction of the overall population will be affected (Bello *et al*, 2006). Many papers attribute the differences in mortality profiles to the under-representation of age or sex groups, however, it should be noted that this is not a concern to all demographers, with those excavating sites in the eastern United States claiming the impact was overstated (Masset, 1973, Walker *et al*, 1988 and Jackes, 1992).

Under-representation of non-adults

The limited number of recovered infant burials is a frequent problem (Angel, 1969; Weiss and Wobst, 1973), with many palaeodemographers assuming the number of recovered burials is representative of the non-adult population due to the lack of understanding regarding infant burial practices at the site (Moore *et al*, 1975). Under-representation of non-adult age classes can result in a major potential source of bias when undertaking a demographic analysis, a problem that is often encountered when assessing skeletal populations (Chamberlain, 2006). It is suggested that low non-adult representation within a population where cemeteries are expected to contain the representatives of all age ranges within a community, is due to the vulnerability of the non-adult remains. The fragility of the non-adult remains will increase the influence of taphonomic factors, with the size of the bones and poor mineralisation due to incomplete development making them particularly susceptible. Mensforth (1990, p.90) summarises the issues seen in non-adult under-representation:

> "Selective cultural biases and mortuary practices at the time of death, differential postmortem preservation, selective recovery and curation practices, and variation in the degree to which age can accurately be inferred from fragmentary skeletal remains all increase the vulnerability of skeletal series to sampling errors."

Put into simpler terms, when infants are subjected to different burial practises and interred in locations separate to those of the adults, it will have a significant impact on the demographic profile, leading to bias in the overall estimation and mortality profile of the population.

Infanticide is a topic rarely covered when discussing the under-representation of non-adults in the demographic record. However, many situations may preclude this issue, such as short inter-birth intervals, the difficulties and cost of transporting infants long distances, the need to limit family size and the preference for male births who were seen to be of greater value as providers or combatants (Divale and Harris, 1976 and Scrimshaw, 1984). Saunders and Hoppa (1993) notes that infant deaths through infanticide were rarely buried in the cemetery as they were not baptised and therefore could not be buried on consecrated ground, leading to questions as to how the demographer would be able to note such events as occurring. It would be difficult to account for infanticide through those lost due to short inter-birth intervals or limitations on family size. Therefore, given that for many cemeteries the determination of sex in non-adults does not take place due to financial constraints, the demographer would need to look to the adult population.

There are also many studies noting that concentrations of neonatal and infant remains are also a possibility at medieval sites, following on from the Anglo-Saxon practice more commonly referred to as eaves drip burials (Boddington, 1987; Craig-Atkins, 2014; Hadley and Kemer, 2014). The burial practise was named after the identification of clusters of infant burials close to the foundations of the church in early medieval cemeteries (Boddington, 1996; Crawford, 1999; Craig-Atkins, 2014; Hadley and Kemer, 2014). The phenomenon has been reported at Raunds Furnells (n=25), Pontefract (n=18), Cherry Hinton (n=33), Thwing (n=25) and Spofforth (neonates, *n*=9), although the list of sites reporting the clustering of neonates and infants is much longer (Craig-Atkins, 2014). All burials are found within 1.5-2m of the building foundations, with the exception of the burial cluster at Thwing, which was centred on a posthole. Possible explanations for the eaves-drip burials include posthumous baptism provided by the water dripping from the eaves of the church onto the burial, or the space close to the church only providing room for infant and neonatal burials in heavily populated cemeteries (Boddington, 1996; Crawford, 1999; Craig-Atkins, 2014; Hadley and Kemer, 2014).

One study in the literature compared the mortality rates of infants across Medieval, Georgian and Victorian times to determine the impact of industrialisation on demographics (Lewis and Gowland, 2007). However, it was suggested that the material from the rural medieval population used in this study might not have been representative of the population due to the high rates of infant mortality when compared to other sites. With few rural sites to compare to, it demonstrated a clear need for other sites to undergo palaeodemographic analysis to ascertain what is 'normal' for rural populations.

Under-representation of the old and infirm

Evidence suggests that many societies would occasionally kill the old and infirm (Meindl and Russell, 1998). However, unlike infants who may be buried outside of the cemetery, the old and infirm were very rarely treated differently from the rest of the adult population. Excavation of a leper hospital at St Bartholomew in Oxford, England, recovered 12 skeletons when widening the A1065 road at South Acre uncovered the graves (Wells, 1967). The mechanical excavator had truncated the feet and in some cases, the lower limbs of skeletons, with others being in a very poor state of preservation and seven of the burials displayed signs of leprosy. Since the initial discovery, a further 19 burials have been listed as from the same site by the Archaeology Data Service, an online resource for researchers working with medieval monastic populations. The second excavation brought the total number of individuals recovered from the site to 31, represented by 11 females, 12 males, three adults of indeterminate sex, three non-adults and one unaged individual. Although there was no sex bias identified at this site, there was an underrepresentation of non-adult individuals present, which would cause a significant bias in a demographic profile.

There should be consideration of the demographics of the people who would be buried within a hospital cemetery. Members of the community that were from higher status backgrounds would most likely bury their dead in their preferred cemetery rather than the hospital. Hospital cemeteries only contain individuals who had not recovered from an injury or illness, rather than the local community. Bodies that had not been claimed, and those who travelling through the town or city at the time of becoming ill, will also make up a portion of the hospital cemetery population, which was often managed by the local authority. The type of hospital that served the cemetery will also need to be taken into account; a women's hospital would mean a sex bias in the cemetery profile. Likewise, an infirmary or hospital serving an army would likely have a bias towards males. In either case, those that were interred there were the poorer members of the community, whose family were not able to afford the costs of a funeral in their local church, or for transport of the remains to a local cemetery.

Sex bias within cemeteries

There are many religious houses that only allow single sex members, which would in turn provide a biased demographic. Religious houses believed that having members of both sexes in such closed quarters would lead to distractions from the simplistic lifestyles of those that had devoted their lives to God. Although the lay community would be comprised of both males and females, there would be very strict access rules for each of the sexes as to the locations they could access. Chapels and cemeteries would often be located away from the religious houses, often with separate burial cemeteries for members of the religious order. An example of this would be the medieval Dominican Friary, Oxford Blackfriars, which recovered 83 individuals from a range of locations in the friary grounds (Lambrick and Woods, 1976). Of those that could be sexed (n=63), the majority were males (n=53), with only 10 female burials identified. A small number of non-adults were also recovered (n=9). A number of sites that housed infirmaries that would serve the local community, which may account for the presence of females in a male monastic order. However, without further analysis into the daily workings of the sites, it is not possible to confirm this as the reason for the presence of females.

An under-representation of adult females could indicate a preference for male children given that ‘normal’ population demographics suggest that there should be a relatively equal number of individuals represented for both sexes. However, if the cemetery population in question spans a long period of time (i.e. several hundred years), the demographer would also have to consider whether this was an ongoing or traditional practice that occurred throughout the lifespan of the cemetery, or whether it was limited to a specific event in time. Additionally, an under-representation of female deaths may also be due to the location of the burials in the cemetery, excavation constraints, or the impact of a battle occurring nearby. Due to the difficulty in investigating the practice of infanticide, Meindl and Russell (1998) recommend that the issue be removed from the calculation of life expectancy at birth, which would better represent the mortality conditions.

Researcher knowledge

The level of knowledge and expertise of those carrying out excavations will play a role in the retrieval of non-adult remains. Poor knowledge of developmental skeletal anatomy can lead to bones being missed or lost during excavation, causing the loss of infant remains or limiting the possibility of age estimation. Commingled skeletons present issues with bones not being correctly identified and smaller burial plots may be missed completely, further contributing to the issues (Moore *et al*, 1975).

Incomplete excavations

The size of the cemetery population will influence the resultant demographic profile, if a site is only partially excavated, it will have a bearing on the results obtained. Partial excavation of a cemetery has been noted in studies (Barclay *et al*., 1976; Bermúdez de Castro and Nicolás, 1997; Gowland and Chamberlain, 2005 and Howell, 1986) however, there is little information as to the minimum sample size required for a demographic analysis. Lawrence Owens (Owens, 1998) carried out an analysis of the skeletal material excavated at Poulton Chapel, one of the sites presented in this PhD thesis, during the 1996-1997 seasons (34 articulated burials and associated disarticulated material, bringing the total estimated MNI for the study to 85 individuals). The study gave a preliminary insight into the Poulton Medieval population; however, the small sample size was not representative of the population as a whole due to under-representation of female and infant remains. One issue raised by Chamberlain (2006) was that no literary evidence exists for the number of individuals interred at a cemetery when assessing most archaeological populations. Therefore, the demographer can never really be sure that the sample is complete, even after completely excavating a site, as there is no way to check the number of burials excavated tallies with the number of interred at a site.

Cemetery lifespan

The life table is created from the overall cemetery sample, though this usually involves grouping the biological profiles of individuals that may have died generations apart. Although the archaeologist may have carefully excavated the burials and compiled a Harris matrix detailing which burial truncated which, the analysis is based on estimation and interpretation, and therefore may not provide an accurate overview of which burials represent each timeframe. Expensive radiocarbon dating can assist in providing information on time since death, although the date ranges can often span decades. Where funding for radiocarbon dating is available, the skeletons selected may not be representative of the full date range of the site. Sample selection is critical to the analysis. By selecting the burials that are deepest, the archaeologist is not guaranteed that the results will give the date range of the earliest interred. Nor will the shallowest burial result in a date giving the latest interred at the site. Therefore, using several approaches to gain as much information as possible to aid in an interpretation of timescales should be standard practice across excavations. Approaches can be in the form of historical records, literature, radiocarbon dating and the Harris matrix compiled during excavation, but even then, the accuracy of the demographic life table will still be questionable. Without the original burial records detailing the date of death for each individual, it is not possible to fully, and accurately recreate the demographics of multiple timespans from the skeletal remains alone. Therefore, the demographer must interpret the results accordingly dependent on the analysis undertaken.

Further complications can arise when dealing with large older sites due to the high rate of truncation from the continual use of the space over a long period. The truncation of a burial is where the skeleton is cut by a later event (for example, an interment or construction), and is frequently observed in medieval cemeteries. Truncation can lead to the displacement of the skeletal elements and the bones scattered over a wide area and therefore recorded as disarticulated material. Truncation of a single individual by multiple burials can complicate the burial record, with the need for keeping complete records and a continual Harris matrix the only way to interpret the burial evidence provided by the skeletal remains. Secondary, or bundle burials, placed in the grave with articulated remains, could indicate an effort to return the skeletal remains of a member of the community back to a common place of burial (Meindl and Russell, 1998). An alternative interpretation of this however is that the remains were disturbed during a later internment, and placed back in carefully prior to the refilling of the grave.

1.2.2. Anthropological assessment of human skeletal remains

The human skeleton can provide information on biological characteristics such as age, sex and stature, along with information about health and lifestyle through pathology, dietary analysis and musculo-skeletal markers (Larsen, 2002). By assessing the diet and nutrition of an individual, along with assessing the literature for the availability of foodstuffs, disease epidemics and living conditions within the timescales of the population in question, it is possible to gain an insight into the lifestyle of a population. This insight can enable the demographer to infer the reasons behind periods of poor health and model the structure of a society.

Bocquet-Appel and Masset (1982) questioned whether a demographic analysis could be carried out on an archaeological population when there was so much variability in aging methodologies. In 1985, it was followed up with a further paper, which stated:

> "…the estimation method for the age at death is biased, and that there are contradictions between the demographic data collected on living populations with an archaic pattern of mortality, and data collected on skeletal populations"
>
> (Bocquet-Appel and Masset, 1985, p.107)

However, the issue of variability in aging methodologies has been defended in other publications, due to palaeodemographic analysis and age estimation techniques improving in recent years (Jackes, 2000; Meindl and Russell, 1998 and Milner *et al*, 2000).

Adult sex determination

The assessment of sex in adult human skeletal remains uses methods that are either morphological or metric in nature, primarily distinguishing between the sexes by the degree of dimorphism present. Sexual dimorphism has been noted in the pelvis (Phenice, 1969; Stewart, 1979a; 1979b), cranium and mandible (Krogman, 1955; Buikstra and Ubelaker, 1994). The use of metric measurements provides further support to the determination of sex, with a brief overview of each area given in this section.

Pelvic sex determination: The pelvis has long been noted as the most reliable skeletal element for sex determination, (Acsádi and Nemeskéri, 1970; Krogman and Işcan, 1986; Phenice, 1969, Stewart, 1979a; 1979b) due to the differences in pelvic function between the sexes. Although both males and females are subject to the same locomotion and weight bearing pressures from being bipedal, females have the added selective pressure of pregnancy and childbirth. It is due to this added pressure that the female pelvis has adapted to ensure the successful delivery of young, increasing the sexual dimorphism of the pelvic girdle (Garvin, 2012). The changes in the positioning of the sacrum led to a wider greater sciatic notch, one of the traits used by Bruzek (2002) for the determination of sex. Bruzek's (2002) method used five main traits, the greater sciatic notch, preauricular sulcus, the composite arch, the inferior pelvis, and the ischiopubic proportions, with high correct classification rates noted when the traits were used together. The technique most often used by anthropologists is based on the changes to the ischiopubic ramus (Phenice, 1969). It uses three specific features for sex determination; the ventral arc, the subpubic concavity and the medial aspect of the ischiopubic ramus, with Phenice (1969) noting that although there may occasionally be some traits that are ambiguous, there will always be one which clearly indicates sex. PhD research was recently carried out by Samuel Rennie at Liverpool John Moores University, which compared over 1100 individuals from eight populations (including Poulton Chapel and St Owens, which are presented in this thesis), to determine if multivariate analysis could be used for unknown individuals given that other methods struggle with between population variation. Using eight morphological sex determination features from the pelvis, and scoring each one through a combination of seriation and statistical methods, Rennie (pers. comm., 2017) was able to determine that the techniques could be used when geographic or temporal origin was not known.

Cranial sex determination: Cranial traits were first studied by Broca (1875), with several notable studies since detailing the sexual dimorphism present in the human population (Krogman, 1955; Acşadi and Nemeskéri, 1970; Buikstra and Ubelaker, 1994). The most commonly used method by anthropologists is the scoring system given in the 'Standards for Data Collection from Human Skeletal Remains' (Buikstra and Ubelaker, 1994). Consisting of five traits (glabella/supra orbital ridge, supraorbital margin, nuchal crest, mastoid processes and mental eminence), each of which is drawn to represent five stages of dimorphism in the cranium. The cranial traits range from very feminine to very masculine, with the three scores in the middle representing a shift from one end of the scale to the other. Cranial sex determination has been noted to have a high degree of accuracy in many cases, although some studies have found the interobserver scores were low, due to the degree of subjectivity introduced by comparing traits to drawings (Walker, 2008; Walrath *et al*, 2004). As with other methods discussed however, there is a degree of variation between populations (Walker, 2008), which requires further investigation, especially given that there are currently no population specific standards to use (Garvin, 2012).

Metric sex determination: The use of metric sex determination is governed by sexual dimorphism, in that within humans, males are more robust/larger than females (Garvin, 2012. The measurements taken from long bone lengths, articular surface dimensions and cranial size can be used to distinguish between males and females within a given population as part of univariate or multivariate analyses. The parameters for sex determination can vary between populations, therefore, when assessing the sex of unknown adults, it is preferred to have an understanding of the likely population the individual has come from (Garvin, 2012). There have been many studies assessing the use of skeletal elements for sex determination, with Meindl and Russell (1998) listing a number of papers for use in this area. However, in this thesis, the humeral head and femoral bicondylar breadth (Stewart, 1979), femoral head (Pearson, 1917-1919), radial head (Berrizbeitia, 1989) and the glenoid cavity of the scapula (Dwight, 1984) have been used. Due to the long bones being subject to environmental stress (Meindl and Russell, 1998), the metric measurements formed part of a multivariate analysis alongside the non-metric analysis.

Non-adult sex determination

The assessment of sex in non-adults is not accurate when based on a macroscopic assessment of the skeletal framework, due to the unfused elements used in adult sex determination, and a lack of sexually dimorphic indicators (Schueur and Black, 2000). Previous attempts at developing methods for non-adult sex estimation have met with criticism due to population specificity or lack of repeatability. Advances in the determination of sex using DNA using the sex chromosomes has enabled the possibility of obtaining a more complete biological profile (Kaestle, 1995; Stone, 2000). However, the technique is dependent on the availability of a well-preserved bone or tooth. DNA testing is expensive and for large sites containing several hundred non-adults, it is not feasible to carry out destructive testing.

Adult age estimation

Once the process of skeletal development is complete, aging becomes subject to genetics and environmental influences. As these factors start to influence the age estimation, the variation between skeletons of similar ages starts to increase, requiring the use of multivariate age analyses to minimise the impact of the variation (Krogman 1962, Acsádi and Nemeskéri 1970, Lovejoy *et al* 1985a). The age ranges assigned to a skeleton will increase from the small margins that can be assigned to non-adults, to at least five year and where necessary, even more.

Macroscopic age estimation for the pubic symphysis has been used primarily for young and middle-aged adults, due to the lack of change in the morphology of the pubic symphysis in older age groups (Todd 1920, 1921; Brooks 1955; Hanihara and Suzuki 1978, Brooks and Suchey, 1990). However, many other age estimation techniques also give low, top end age estimates when compared with longevity of the modern population for the same reason, suggesting that age estimation should use a combination of methods, with consideration given to the possibility of carrying out a seriation of the skeletons for each available aging method (Lovejoy *et al,* 1985a). Using a multi-variate approach will help to minimise the inaccuracy of skeletal aging due to human variation and maximise the information available for estimating biological age (Meindl *et al*, 1983; Acsidi and Nemeskeri, 1970).

Late Epiphyseal Union: Although majority of the skeleton has completely fused by adulthood, the anterior iliac crest and medial end of the clavicle fuse during early adulthood. Webb and Suchey (1985) studied a modern sample of known age individuals (605M/254F) in the largest study of its kind at the time of publication. The observations of the epiphyseal union of the anterior iliac crest and medial clavicle showed that female age ranges were slightly broader than those for the males, but there was little difference between the timings of the union (1-2 years). There was also little ancestral variation in the results, with only the American black females having greater variability in the age distribution.

Cranial suture closure: Age estimation through cranial suture closure has had a controversial past, with many in the 1950s finding it too variable in its estimations and therefore problematic to use, especially for forensic casework (Singer 1953, Brooks 1955, McKern & Stewart 1957). The belief was, at the time that the field of anthropology was developing at such a rate that new and more accurate methods would soon be available to use. This belief in development of techniques led to many people abandoning the method completely, however as no new methods came forward, they got a second chance. Cranial suture closure used in conjunction with other age estimation methods helped to narrow down age and as such, should not be used a sole indicator of age. The resurgence of the technique led other anthropologists to study the sutures and develop new techniques, with Acsádi and Nemeskéri (1970) presenting a method for use on young and middle adults whose cranial sutures were still actively fusing at the time of death. Later developments saw the development of techniques that used endocranial and ectocranial closure, a range of sutures and scoring systems (Meindl and Lovejoy 1985, Masset 1989). One of the ectocranial methods put forward by Meindl and Lovejoy (1985) seemed to offer a solution to some of the issues of extreme age assessment, although Lovejoy *et al* (1985a) warns that the error margin can increase significantly after 50 years of age. The studies carried out on the techniques put forward by Masset (1989) and Saunders *et al* (1992) found both techniques to have a very poor performance rate, with the method by Meindl and Lovejoy (1985) being used more frequently.

Pubis symphysis: The most studied age indicator used is the pubic symphyseal face, and is an excellent indicator of age in young and middle age adults. The first technique devised to use this region of the adult skeleton for age estimation was devised by Todd (1920; 1921), who described the age related changes present and assigned the stages of epiphyseal fusion and subsequent degenerative changes. This method of assigning the development and degeneration to categories became the basis for many later age estimation techniques (McKern and Stewart 1957, Gilbert and McKern 1973). It was also used in the condensed forms of the technique described in later publications (Meindl *et al,* 1985b, Suchey *et al,* 1986; Brooks and Suchey, 1990). When used in palaeodemographic models the technique becomes inaccurate after the age of about 40 years (Hanihara and Suzuki 1978; Meindl *et al* 1985b; Lovejoy *et al,* 1995; 1997), due to the epiphyseal fusion of the ventral rampart having completed at this point. Degeneration of the pubic symphyseal face is more variable and can be affected by environmental stress, pathology and pregnancy (Saunders *et al*, 1992), making the technique less valuable in older individuals. When assessing archaeological populations, it has also be noted that the pubis is less durable than the auricular surface, with the element frequently damaged by taphonomic processes (Pfeiffer 1986, Waldron 1987a).

Auricular surface: The auricular surface of the ilium forms one-half of the sacro-iliac joint and was assessed for degenerative changes by Lovejoy *et al* (1985), with the resultant technique demonstrating that it was possible to observe changes into the sixth decade of life (Lovejoy *et al*, 1995; 1997). The method involves the examination of the auricular surface, with changes recorded for the apex and retro-auricular surface, along with the levels of porosity, granularity, densification, transverse organisation and striations. By scoring the level of degeneration in relation to each of these changes, it is possible to assign an age category to the individual. By having several aspects of change to assess, the technique itself becomes a multi-variate analysis (Lovejoy *et al,* 1985b; Meindl and Lovejoy 1989). The technique requires knowledge of the anatomy of this region and full understanding of the changes that can occur, with some studies criticising the technique due to high interobserver error rates or inability to replicate the results (Rogers, 1990; Jackes, 1992). The method fit with Howell's (1976) uniformitarian assumption, which states that both living and extinct populations age at similar rates, making the technique suitable for palaeodemographic studies (Konigsberg and Frankenberg, 1992). Assessments carried out to whether the method could be used to predict the older aged individuals, with the results showing considerable improvement over the pubic symphysis age estimations (Meindl *et al*, 1990; Saunder *et al*, 1992; Bedford *et al*, 1993).

Sternal rib ends: The use of the costochondral joints to estimate adult age has been suggested since 1957 in a paper by McKern and Stewart. However, it was not until 1984 that a method for age estimation using the fourth rib was put forward by Işcan *et al* (1985a; b), with the method also giving information in sex related changes in the area. The method records the rate of change from a billowing surface in the sternal end of the ribs in young adults, to an irregular and more concave surface due to remodelling as age increases. The method put forward by Işcan has been accepted as a valuable tool in the estimation of adult age due to its very low bias prior to 50 years of age (Saunders *et al* 1992, Russell *et al* 1993, Dudar *et al* 1993). However, it should be noted that, as with the pubic symphysis, the ribs can be influenced by taphonomic change during decomposition and as the cortical bone layer is very thin, the sternal rib ends do not survive well in hostile conditions.

Dental attrition: Meindl and Russell's (1998, p.386) list dental wear as:

> '….one of the most reliable methods of estimating adult age, as long as the assumption of uniform rates of attrition in the population can be reasonably met'

There have been numerous studies on the rate of attrition in adult dentition, a method that was first devised for age estimation in the late 1950s by Murphy (1959). However, its origins are much earlier; with a five level system for scoring the rate of wear on the occlusal surface of the dentition developed by Broca (1879), which was further developed in other studies (see Lovejoy, 1985 for an extensive list). Broca's (1879) scale allowed for the rapid recording of dental wear patterns, but was limited by the amount of detail that could be gained from an assessment. The method devised by Murphy (1959) allowed a more detailed analysis, however each tooth cusp was scored individually, considerably increasing the amount of time needed for an assessment. Molnar's (1971) method enabled the detailed assessment of the occlusal wear on the dentition; however, its difficult application (Lunt, 1978) and lack of applicability for age estimation prevented its use for this purpose (Lovejoy, 1985). The method put forward by Lovejoy (1985), allowed for assessment of the entire dentition using a ten-stage system for the mandible and nine stages for the maxilla. The technique (Lovejoy, 1985) allowed for a rapid and detailed assessment, based on the study of a hunter-gatherer population from the Libben, Ottowa County, Ohio. Although there has been success in applying this technique to other populations with similar lifestyles, there are cases where the amount of wear on the occlusal surface of the dentition has been considerably higher (Mensforth, 1990; Meindl *et al*, 1998). The difference in lifestyles violates *the 'assumption of uniform rates of attrition'* (Meindl and Russell, 1998), suggesting that caution is needed when using this technique to ensure that the age assessment carried out for the individuals from a population is not biased. Dental attrition is not only a product of mastication, but can be increased considerably in occupations where individuals use teeth as tools (Irish and Turner, 1987; Erdal, 2007), or for holding items for long periods of time (Caffell and Clark, 2011). The differences in the dental attrition between foraging and agricultural populations were reported by Smith and Knight (1984), and should be considered when looking at the dentition from many different populations.

Non-adult age estimation

When assessing the age of non-adult skeletons, there are three categories of age estimation methods to consider which were dental development and eruption, epiphyseal ossification and fusion, and metric measurements. Seriation is recommended where possible to account for any population specific variation and to minimise observer error (Meindl and Russell, 1998). Any attempt at age estimation should aim to use all available methods in the assessment to limit bias and error. An overview of each of the three categories is given to provide background information on the methods used in the research presented in this thesis.

Dental development and eruption: When working with non-adult archaeological skeletal remains, the most reliable methods for age at death estimations are derived from dental development studies (AlQahtani *et al*., 2010; Cardoso, 2006; Ubelaker, 1999). Dental development is one indicator of skeletal maturity that is well documented. For any individual, development of the dentition is a continuous process that begins during embryonic life and continues until late adolescence (AlQahtani *et al*., 2010; Demirjian *et al*., 1973; Moorrees *et al*., 1963a, b; Massler and Schour, 1941; Ubelaker, 1987; 1999). This process progresses through usually two overlapping stages of development; that is, the deciduous dentition followed by the permanent dentition.

Lewis and Garn (1960) argued that calcification rates in teeth are only minimally affected by environmental conditions (i.e., epigenetic factors). Gorlin *et al.,* (1964) agreed, suggesting that dental development stages are less affected by variation in nutrition and endocrine status. However, Cameron and Demerath (2002) suggested that epigenetic factors could introduce some variability during 'critical periods' of growth. Nevertheless, the pattern of dental development is recognisable across all populations and proceeds at a reasonable and predictable rate in both modern and archaeological contexts (Stull *et al*., 2014). Therefore, dental development is one of the most accepted methods for assessing developmental age, as well as its transformation into a chronological age estimate.

Sometimes, however, the non-adult dentition is incomplete or missing, but other skeletal elements are preserved and can be used to assess developmental age.

There are studies that have presented the developmental stages of human dentition, using the whole dentition and documenting the development of selected teeth, or composite scoring to predict dental age (Moorrees *et al* 1963a; 1963b; Ubelaker 1989; Demirjian *et al* 1973, Demirjian and Levesque 1980; Gustafson and Koch, 1974). The accuracy of the dental age estimation has been subjected to testing between populations (El-Nofely and Işcan, 1989), with the results showing that while there is a difference in the development rates, on average this is less than a year. The similarity in development rates support the conclusion that dental development is resistant to environmental conditions, nutrition and endocrine status (Lewis and Garn, 1960; Gorlin *et al,* 1964; Meindl and Russell, 1988). The accuracy of dental aging was studied in modern populations that do not routinely keep birth records, known as non-counting cultures, with the accuracy of the estimation provided through examination of the teeth more reliable than the mother's ability to remember the actual date of birth (Townsend and Hammel, 1990).

Epiphyseal ossification and fusion: The ossification of the epiphyses, and subsequent fusion, can provide an estimation of age-at-death to support the dental assessment, or in cases where the teeth are not recovered, to indicate possible age. However, the skeletal elements, in particular, the long bones can be subject to environmental stress, causing the under-estimation of age due to retarded growth (Johnston and Zimmer, 1989; Meindl and Russell, 1998). The consideration of ossification during an age assessment enables the anthropologist to identify the developmental stage of the bones from the time of its appearance at the centre of ossification through to fusion, with the most comprehensive work carried out by Scheuer and Black (2000). The work carried out by Schueur and Black (2000) expands on the studies by Fazekas and Kósa (English translation, 1978), who documented the skeletal development of 136 fetal individuals, ranging in age from 12-40 weeks gestation. By including the ossification and fusion rates of the entire non-adult skeleton, rather than the long bones covered in many previous studies, the accuracy of age estimation is increased (Stewart, 1979; Krogman and Işcan, 1986; Ubelaker, 1989).

Metric measurements: Age at death is often estimated from long bone lengths due to the simple methodology and frequent use of this material in numerous studies both from modern data with known age (Hoffman, 1979; and Maresh, 1970) and archaeological data with estimated ages (Primeau *et al*., 2012; Rissech *et al*., 2008). Long bones also form by endochondral ossification, with the diaphysis developing from the primary centre of ossification. Therefore, diaphyseal lengths can be used to assess developmental age. Relative to the remaining postcranial skeleton, the humeral and femoral diaphyses are commonly recovered from archaeological contexts due to their robust nature. Although the use of metric measurements has the same issue with under-estimation of age due to growth interruption, it is still a valuable tool when estimation the age of incomplete remains. Thorough analysis of the material, including radiographs to assess whether stress related pathologies are present, should enable the anthropologist to provide a justified age estimation and limit the impact of bias (Wood *et al*, 1992).

Diet and nutrition

Dietary analysis using carbon and nitrogen isotopes can give an indication of poor diet and nutrition, or an excessively rich diet, which can lead to a number of pathological conditions, such as gout or diffuse idiopathic skeletal hyperostosis (Aufderheide and Rodríguez-Martin, 1998). The historical literature gives information on of periods of unrest or violence, which would increase the demands on the population. For instance, at the parish of St Owens in Gloucester, the siege in 1643 led to many losing their homes due to the clearing and firing of all grounds outside the city walls (Herbert, 1988). This movement of the population would have led to many losing possessions and income from businesses, the destruction of crops and farmland, and the increased risk of infection for those now being confined to close living quarters in the city. Poor sanitation would have led to increased bacterial levels and therefore risk of infection. Space would have to be shared with livestock, which would have been kept alive to prolong the length of time the city could survive during the siege before the townsfolk began to starve.

Poor nutrition can lead to increased levels of stress and infectious disease, which often leave their mark on the skeleton, enabling the palaeodemographer to understand the increase in at-risk age groups during specific life stages. Conditions such as *cribra orbitalia* and enamel hypoplasia (linear or pitting) have been linked to periods of nutritional or environmental stress within an individual’s lifespan, which may be evident on the skeletal remains as an injury or illness (Roberts and Manchester, 2010).

1.2.3. Decomposition processes

To understand the factors affecting the demographic analysis, as well as the biological attributes of the skeletal framework, the extrinsic conditions of the deposition or burial site need to be addressed. In order to do this, the stages of decomposition need to be understood and taken into account.

The stages of decomposition

The aim of forensic taphonomy is to establish post-mortem interval, determine the cause and manner of death, locate clandestine burials and identify the deceased (Haglund and Sorg, 1996; Sorg and Haglund, 2001). It involves the understanding of the deposition site, the changes made to that site when the deposit is added and how the site will affect the decomposition of that deposit. With a range of taphonomic research facilities looking at the decomposition of human remains in the USA (n=6), Australia and Amsterdam, and animal substitute decomposition centres in the UK, the understanding of the decomposition processes is increasing. However, forensic taphonomy research most often deals with the decomposition processes surrounding the soft tissue rather than the osseous remains, most likely due to the timescales required for experimental studies on bone.

To aid in consistency across the field of forensic taphonomy, as suggested by Payne (1965), the process of decomposition is listed as comprising of six main stages: fresh, bloated, active decay, advanced decay, dry and remains. The decomposing remains can affect the surrounding soil and vegetation, initially causing the death of plant life in the area surrounding the burial due to the large quantities of decomposition fluids and the smothering of underlying plants (Towne, 2000). This phenomenon has been termed the Cadaver Decomposition Island (CDI). If the burial is placed on flat ground that has a low water table and is relatively sheltered, then the formation of a CDI in the immediate area will occur. If the body is placed on a slope, the water table sits relatively close to the surface, or the burial is in open ground and subjected to the elements, the CDI is likely to trail away from the body as the leachate plume drifts. This process causes a change to the soil chemistry and biology, enabling these changes to be detectable in soil samples taken during the search for clandestine burials, or when collecting evidence from crime scenes.

Fresh: Following death, the internal aerobic microorganisms in the body deplete the surrounding tissues of oxygen, causing the onset of autolysis (Gill-King, 1997). The removal of the oxygen produces the optimal conditions for anaerobic microorganisms who work to convert lipids, proteins and carbohydrates into gases and organic acids. At this point the body, microorganisms in the soil and ovipositing flies form the CDI.

Bloating: This is the start of putrefaction, which is characterised by the bloating of the cadaver, a colour change to the skin, and a distinctive odour. As the fluids and gases build up in the body, the cadaveric openings (such as, the nose, mouth and anus) provide a path for escape, enabling them to flow into the soil. The integrity of the skin is compromised by both the feeding activity of the maggots and the bloating cause by the build-up of gases within the body. This stage continues until the body ruptures due to the internal pressure, releasing both decompositional fluids and gases trapped within, and allowing oxygen back into the body, allowing aerobic microorganisms to begin the process of decay. The CDI now contains the developing maggot masses and decomposition fluids as they leak from the cadaveric openings.

Active: The active decay stage is the most active in terms of visitors to the cadaver. With an influx of insects and scavengers feeding on the remains, the remains can be quickly stripped of soft tissue. Insect and scavenger activity can represent the largest loss of mass during the decomposition process. However, like the other stages, there are many factors affecting the length of this stage and the time taken to get there. The time of year, temperature, climate, exposure to moisture, oxygen, and deposition site can all influence the rate and process of decomposition. How long it takes insects to arrive at the cadaver will also have an impact on scavenger activity, with early onset of insect activity limiting the available food supply (DeVault *et al*, 2004). Dependent on the time of year will also influence the arrival and succession or organisms visiting the cadaver, with winter months restricting insect activity (Putman, 1983).

The active decay stage also provides the largest contribution to the developing leachate plume, which formed through the loss of decomposition fluids from the cadaver. The small islands that formed during the previous stage often form a single CDI at this point, which will be evident in the death of the surrounding vegetation that can continue for at least 3 months depending on the initial mass of the cadaver (Carter and Tibbett, 2008). As the maggot masses migrate away from the cadaver, the process moves into advanced decay.

Advanced decay: As the cadaver moves into the advanced stage, the abdominal cavity will cave in due to the loss of fluids and the extensive maggot activity in this area. Bone exposure in areas of moist decomposition will be observable and if there is sufficient moisture, there may be adipocere formation. In dry environments, the tissues may begin to mummify, either partially or fully. There have also been cases where there has been differential decomposition, leading to a combination of skeletonised and mummified remains. The CDI during advanced decomposition comprises of soils with high carbon, nitrogen and nutrient content and a raised pH (Vass *et al*, 1992; Towne, 2000; Carter, 2002).

Dry: During this stage, only the skeleton, cartilaginous material and other materials such as hair and nails remain. The process now occurs at a much slower rate than before, although there is still some dependence on microbial activity. There is not much information on the CDI at this stage, most likely due to the transition between these stages not being very clear, with many publications mentioning a dry stage but then not commenting on it.

Remains: This stage is complete skeletonisation, the cartilaginous tissue no longer remains, and the bones may be starting to break down due to the surrounding burial environment. Skeletal breakdown could be due to bleaching by the sun if the remains lie on the surface, or exfoliation from soils or other abrasive substances in contact with the bones. The shift into the remains stage is thought to occur when noticeably increased plant growth occurs around the CDI, due to the nutrient rich environment created by the process of decomposition.

Much of the research on decomposition has been carried out in the initial stages of the process, most often eliminating the dry and remains stages, with research on grave soils focusing specifically in this area. The gap in knowledge is most likely due to burials being located after the initial stages of decomposition are complete, which has resulted in a lack of understanding regarding the specific mechanisms that affect the CDI when moving from one stage to the next.

1.2.4. Factors affecting decomposition

The majority of work on the rate of decomposition reported in the literature compares those deposited above the ground and those buried within the ground. The body of an individual in a temperate zone can be completely skeletonised within 1-2 years. However, burial in soil can significantly slow down this process, with the time taken to skeletonisation being decades. The rate of bone deterioration can also differ significantly depending on the site of deposition, with skeletal remains discovered centuries after burial at some sites.

Placing a body in an open area, which leaves it exposed to the elements and scavengers will increase the rate of decomposition. Alterations to the body following death, through cultural or religious burial practices (such as mummification, burning, placing the body in a cave, or burial below the ground), will provide differing rates of preservation on the skeleton (Griffin, 1982; Duday and Masset, 1987; Crubezy *et al*., 1990; Binant, 1991; Castex *et al*., 1996; Masset, 1997; Bello *et al*, 2001; 2006).

It is important to note the environmental conditions of the site undergoing excavation and the condition of any coffins housing the skeletal remains. Careful assessment of the burial matrix enables the archaeologist to take the correct measures when unsealing what looks like an intact burial. Decomposition in a coffin can be affected by the place of deposition; those buried in a vault will decompose at a faster rate than those interred in the soil. The rate of decomposition of a coffin burial in the soil will be dependent on the depth of the burial, soil chemistry, height of the water table, and permeability of the ground.

Skeletal evidence of coffin internment can be provided by the differential preservation of the skeleton, causing excessive erosion to the bones with a thin cortical bone layer, or in the contact with the base of the coffin. Many of these areas are quickly exposed following the loss of soft tissue, as the decompositional fluid will sit in the bottom of the coffin increasing the rate of microbial activity in this area. The loss of surrounding tissue leaves the underlying skeletal framework unprotected and therefore subject to taphonomic influence. Information regarding the placement of the skeleton during interment can be inferred from the skeletal remains, as those elements in the base of the coffin or casket will display a higher rate of erosion.

Coffins made from metal (such as iron or lead) can significantly delay the process of decomposition, resulting in burials that took place nearly 150 years ago being perfectly preserved upon excavation. One example is an iron coffin burial discovered in San

Francisco in May 2016, which contained the perfectly preserved body of a girl holding a rose. The girl was identified as Edith Howard Cook who died aged two years, ten months, on October 13th 1876 of undernourishment. Her burial took place two days after her death at the Old Fellows Cemetery, which was in use from 1866-1905. In 1933, the clearance of the cemetery began, with all burials moved to the Greenlawn Cemetery in Colma, however it appears some burials were missed (KUTV, 2017).

Iron coffins were used mainly in the USA, in the late 19th century as a means to enable the viewing of the deceased prior to burial (Little *et al*. 1992; Owsley and Mann 1992). However, there are occasions where the closing of the coffin has not completed the seal, leaving the body vulnerable to the entry of air, water, bacteria and mould (Owsley and Compton, 1997). The type of coffin should be taken into consideration when determining the impact taphonomy has had on the skeletal remains, with wood, lead or iron coffins, as well as stone or metal sarcophagi all providing different burial environments (Bello, 2001). Although iron coffins were not typically used in the UK, the use of wooden and lead coffins has been common in British history, with the issues that affect decomposition of the body in iron coffins being mostly similar to those of lead coffin burials. There has been little published literature on decomposition rates in coffins and osseous remains. Therefore, the process documented by Owsley and Compton (1997) is detailed here to offer insight into the taphonomic changes the body may undergo during decomposition in an iron coffin environment.

The burial of a coffin into the soil will slow down the rate of decomposition more than that of an internment in a vault or crypt, with the type of soil, depth of burial and hydrology affecting the rate of decomposition further still. A correctly sealed coffin can significantly slow down the rate of decomposition, with embalming extending this process even more. If air and/or water manages to get into an incorrectly sealed or damaged coffin, the normal decomposition process will begin, with the inclusion of mould due to the moisture present. Fungal and mould growth can be encouraged by the dark and damp environment in the coffin, with the staining left by its presence remaining on the bones long after the coffin itself has disappeared (Berryman *et al*, 1996). The bone of coffin-interred individuals will be darker in colour than those buried directly into the soil, with the bone a dark brown in lead coffins, and almost black in iron coffins. The cause of the discoloration is unknown, but Owsley and Compton (1997) theorise that it could be due to the leaching of elements within a metal-based coffin.

Periodic wet and dry conditions in a coffin burial can be present due to the decompositional fluids and fluctuating water tables, leading to the outer layer of cortical bone flaking. This phenomenon occurs when the outer cortical bone surface is subjected to wet conditions prior to the inner, deeper layers of cortical bone. Conversely, the surface will dry at a faster rate than the inner layers too, causing the bone to expand and contract, which leads to flaking of the surface along the natural lines of cleavage provided by the lamellar bone (Berryman *et al*, 1996). Other evidence of coffin burial includes the presence of mould or fungal growth, preservation of hair or skin, differential decomposition, and fracture of the cribiform plate. Even in cases where the coffin appears to be intact, there can be significant decomposition, with the remains being reduced to a skeleton, with only patches of leathery skin and hair remaining.

Embalming can further affect the process by delaying the onset and altering the pattern of decomposition in the body. The upper body tends to decompose more rapidly than the appendages in natural burials, whereas it is the appendages that tend to decompose quicker in embalmed burials (Bass, 1995). The difference in decomposition patterns are due to the embalming fluid dispersal pattern and the techniques being used to pump the fluid around the body. The appendages are more difficult to embalm than the head and thorax, resulting in lower quantities of the fluid reaching these areas and leaving them more likely to decompose at a faster rate. Conversely, as the head and thorax become saturated with the fluid, the brain can often dehydrate in a dry coffin environment, becoming a solid dark mass enclosed within the cranial vault.

Those that are placed in crypts or vaults can undergo mummification or putrefaction, depending on the season and adequate ventilation being present (Madea and Kernbach-Wighton, 2017). Mummification occurs as the water in the body evaporates due to continual airflow and a lack of moisture in the surrounding environment. The skin becomes leathery in appearance, dry and hard, with the body held in the position it was placed in during the burial ritual. If the individual died and subsequently discovered in a mummified state, then the body position can provide information about the individual’s final hours. The process can take several weeks before it is detectable, although the process will begin a few days following death, given that the body is placed in a warm, dry and well-ventilated area, free from humidity (Madea and Kernbach-Wighton, 2017).

1.2.5. Taphonomy – extrinsic factors

Taphonomic analysis covers both the ability of the bone to resist diagenesis (intrinsic factors) and the environmental influence exerted on the bone (extrinsic factors), both of which determine the ability of the bone to survive long term (Manifold, 2013). In a study on French cemeteries, Bello and colleagues (2006) suggested that human remains were more damaged under stronger taphonomic pressures, leading to the conclusion that bones that have a low bone mineral content and high percentage of cancellous bone are more affected than others are. Bone preservation is a complex issue and should be treated with caution when trying to establish if, and to what degree, it influences the skeletal remains of non-adults. It is important factor in both archaeological and forensic contexts, where many post-depositional factors are active.

It is not as simple as considering the extrinsic factors as separate from the intrinsic, it is the interplay between the two that determine the preservation rate of the osseous material. The porosity of the bone can be an important factor to consider when assessing the impact of groundwater intrusion to a grave. There are three hydrological environments to consider with groundwater: diffusive, recharge and flow (Millard, 1993). Diffusive environments have limited water movement, this could be due to waterlogging or where soil are not permanently saturated (Manifold, 2013). Recharge is a continual process of wetting and drying cycles, which can increase the porosity of osseous material, and flow is affected by seasonal factors and rainfall (Hedges and Millard, 1995). In environments where there is little water movement and high concentrations of calcium and phosphorous, bone can be well preserved and survive for long periods. However, if water movement is increased, it can lead to greater dissolution caused by the weakening of the protein-mineral bonding, which leads to increased porosity and subsequently the breakdown of bone (Von Endt and Ortner, 1984; Nielsen-Marsh and Hedges, 2000)

Soils

Post-mortem physical and chemical deterioration caused by burial practise, soil characteristics, water table height and permeability of the soil, climate, weather patterns and the depth of the burial are all extrinsic factors that play a role in the decomposition of skeletal material. With the noted vulnerability of non-adult skeletal remains, hostile conditions will increase the risk of demographic bias due to the under-representation (Gordon and Buikstra, 1981; Walker *et al*., 1988; Walker, 1995; Mensforth, 1990; Mays, 1998; Stojanowski *et al*., 2002; Nagaoka and Hirata, 2007).

Soil is classified as clay, silt, sand and gravel, depending on the particle size present, and comprise of a mix of organic matter, minerals, water and air (Janaway, 1996). Gordon and Buikstra (1981) reported that the biggest influencing factor on the preservation of bone is soil pH, with poorer preservation noted in acidic or strongly alkaline soils and good preservation in soils with a neutral or slightly alkaline pH. The particle size can also influence the preservation of skeletal remains, with those in locations with a high sand or gravel content also being poorly preserved, especially if coupled with an acidic pH (Henderson, 1987; Waldron, 1987b; Janaway, 1996). Henderson (1987) states that the speed of decomposition can be increased in light porous soils, whilst dense clay will inhibit decomposition. Burial depth is also a factor with deeper burials being less well preserved due to waterlogged clay (Henderson, 1987).

Walker *et al* (1988) noted that the number of recovered non-adult skeletons was far lower than the expected number at one of the sites he studied, with just two out of eleven expected burials recovered. The poor preservation of the remains was attributed to the presence of sandy soil in the cemetery, which had an acidic pH. Acidic profiles can contribute to the weakening of the protein mineral bond, increasing the diagenesis rate of the skeletal remains (Walker *et al*, 1988). When compared to the excavations at a second site with higher rates of preservation it was noted that the non-adults and the elderly were the least well preserved, though no details of the soil conditions were provided (Walker *et al*, 1988).

Bone consists of organic and inorganic components, which are preserved at opposing pH levels (Mays 1998). Acidic soils will cause the loss of hydroxyapatite, or the inorganic portion of the bone, leaving the organic collagen exposed to other taphonomic variables due to the loss of the protein-mineral bond. If there is sufficient water movement in the soil, this will then breakdown the organic portion of the bone. Soils with a neutral or alkaline pH provide better rates of preservation, although as soil pH is not the only contributing factor to the diagenesis of the osseous material, there have been cases where high rates of poor preservation have occurred here too (Henderson, 1987; Locock *et al*, 1992; Ferllini, 2007).

However, there have been a number of cases where the soil characteristics and resultant bone preservation do not follow the expected pattern (Henderson, 1987; Waldron, 1987b). Preservation can vary across sites too, with some areas of the cemetery being well preserved, whereas others are badly degraded (Henderson, 1987; Nielsen-Marsh and Hedges, 2000). Despite this huge variation in bone preservation, and the evident need to describe the bone preservation at each site, there is little standardisation in the archaeological literature on the preservation of bone (Garland and Janaway, 1989). The preservation rates can vary from one grave to another and within a single grave, leading to the differential decomposition of a skeleton.

Manifold (2012) informs that the geology of the United Kingdom is complex, so the preservation of bone will differ from one site to another due to the varying types and amounts of soils/rocks in each region. In East Anglia, eastern and southwest England, the calcareous soils are, in general, more alkaline in nature, and can result in mixed preservation levels, although in burials where the soil has a high pH, the remains will be well-preserved (Brothwell 1981; Ferllini 2007). The gravel and chalk areas of southern England consist of well-drained soils with a neutral pH, although again mixed preservation has been noted here (Manifold, 2013). Well-mixed aerated soils are formed through an increase in microbial activity, leading to the breakdown of organic matter and resulting in poor preservation (French, 2003). This breakdown could occur because of the decomposition of the soft tissues as increased microbial activity releases organic acids

(Child, 1995). This leachate may still be present in the soil during excavation, so caution is advised when collecting soil samples from a grave, with controls taken from an area of known natural geology/geology nearby for comparison. A podsol is an infertile acidic soil having an ash-like subsurface layer that underlies coniferous or heath vegetation. The minerals have been leached from the soil, which lends to its grey colouring. These soils occur in high frequency in Scotland and Northern England, with a tendency to be thin, acidic and wet (Manifold, 2013). Although acidic in nature, these soils do not negatively influence osseous preservation (French 2003; Henderson 1987). Peat environments are also highly acidic, yet have yielded burials with excellent rates of preservation due to the lack of microbial activity (French, 2003), examples of which include the Bog bodies of the Bronze Age. There have been disagreements with the claim that pH is the main controlling factor in the preservation of osseous material (Locock *et al*, 1992), especially with the contradictions to that statement presented by many sites in the literature (Manifold, 2013).

Bioturbation

Bioturbation is the intrusion of plant or tree roots, rodent burrowing or worms into the grave causing the disturbance of the burial and providing added pressure to the intrinsic factor for the bone. To gain a greater understanding of the extrinsic factors affecting the bone, histological analysis may be useful in detailing the taphonomic impact. Histological analysis has previously been used to determine age at death (Kerley, 1965; Kerley and Ubelaker, 1978), pathology (Paine and Brenton, 2006a; b) and taphonomic changes to the bone (Garland 1987; Hanson and Buikstra 1987). The disturbance of bone within a grave will scatter the remains throughout a larger area, even with a burial in the soil. Small burrowing animals, worms and roots could displace teeth and other small bones as the pass through the burial, taking these elements outside the grave cut, making complete recovery more challenging for the excavator (Henderson, 1987; Buckberry, 2000).

Burial depth

Differences in burial depth could be due to how individuals are valued in the community, with those under the age of 12 unlikely to be contributing significantly in the home, possibly resulting in shallower burials. Those who are seen to be of more value and importance, such as adults, and in some cases adolescents, may have been buried deeper (Lucy, 1994). From the Anglo-Saxon period onwards, there has been a shift in the number of non-adult burials found in cemeteries, with burial depth noticeably increasing from the medieval period, most likely due to the increased importance on the burial of non-adult remains by the Christian Church (Lucy, 1994).

One theory put forward for the shallow burial depth given for non-adult burials is the difficulty in digging small, narrow graves to the same depth of the much larger adult burials. This behaviour is seen in clandestine burials, where the perpetrator of a crime will dig a shallow grave, as it is more practical than burying a body at greater depths (Vass *et al*, 2008). Although the gravediggers would not have had the same time constraint as an individual carrying out an illicit burial, the difficulty in digging such a small area to a depth in excess of one metre would be challenging. If this is the case, and not considered as a possibility during excavation, then it could be interpreted as a difference in burial rite (Buckberry, 2000). The shallow nature of the burial will not only leave the non-adult vulnerable to scavengers, especially where embalming has not been carried out (Rodriguez, 1997), but also damage by ploughing if the land was used for agriculture after the closure of the cemetery. Machine stripping for the archaeological excavation to take place could also damage, and in some cases, completely remove non-adult burials (Scull, 1997).

Other studies have also noted that the shallow burial depth of non-adults could be possible cause for poor preservation (Manifold, 2013), with it suggested that this was due to them being exposed to a greater range of taphonomic factors (Acsadi and Nemeskëri, 1970). However, some sites have found the opposite, with the shallow burials of non-adults having better preservation than those buried at greater depths (Manifold, 2013). Bello *et al* (2006) also argues against this, reporting cases where there has been differential preservation of non-adults buried at the same depth.

Collection, cleaning and curation

Alongside the potential for missing bones during excavation, the cleaning and curation of bones can also result in the loss of remains (Henderson, 1987; Galloway *et al*, 1997). Frequent loss of loose teeth, hand and foot bones, vertebral bodies and unfused cranial bones occur in the laboratory, which will especially affect the age estimation of non-adult remains. Therefore, the amount of information that can be gained from the skeletal analysis is not only dependent on the preservation state of the remains (Bello *et al*, 2006), but also on the excavation, recovery, cleaning and curation processes that take place following discovery.

The scarcity of previous research on rural medieval populations (1066-1485 AD) has resulted in a dearth of information regarding population demographics from this period. Documented medieval, rural palaeodemographic studies are rare when compared to the extensive information available in the literature for urban sites (Connell *et al*., 2012; Lewis, 2002). The reasons given for this include the lack of archival documentation, under-representation of non-adult material, the poor preservation of the material recovered and poor excavation techniques (Lewis and Gowland, 2007). Furthermore, urban sites are more likely to be disturbed due to continued development in towns and cities, as demand for prime, central locations for businesses continues to increase.

The interpretation of poor preservation is often considered the recovery of incomplete human skeletal remains and recorded as a percentage of the skeleton retrieved. However, it would be better to describe the bone retrieved as well, or poorly preserved, regardless of the percentage of skeleton recovered as factors such as truncation or secondary burial could result in the loss of elements (Bello *et al*, 2006). It would be worth noting that description of well-preserved bone can vary, as there is no standardisation in the methods and description used. For example, the description of a well-preserved skeleton may mean a complete skeleton with *'sound'* cortical bone and no fragmentation for one population, but include truncated remains with preserved metaphysis with sound cortical bone and minimal diaphyseal damage at another site (Bello *et al*, 2006). By using a standard technique for recording the preservation of human remains across all sites, allows comparisons between preservation rates to be assessed.

1.2.5. Taphonomy - intrinsic factors

Gordon and Buikstra (1981) pointed out that when differential preservation is present, and therefore, the loss of skeletal information has occurred, it is not possible to estimate the levels of bias in preservation between age and sex at any given site. Where it is not possible to estimate age or determine sex due to the preservation of the osseous remains due to diagenesis, incomplete excavation and recovery, it limits the value of that site when compiling the demographic profile. The excavation of skeletal remains should give an indication as to the potential of bias occurring by the cursory examination of the burial pit, grave, articulations and cortical surface of the bone. The survival of the teeth and skeletal framework 'is a function of mechanical displacement, soil drainage, and especially pH' (Gordon and Buikstra 1981).

Age

When considering the intrinsic factors placed upon the non-adult remains, aside from the previously discussed issues of size and poor mineralisation, there are many other potential influences to consider when looking at the influence of age on diagenesis (Manifold, 2010; 2012). Non-adults are smaller in size, and the bones unfused, making disarticulation and scattering by scavengers much easier, due to the limited resistance at joints (Waldron, 1987b). The soft tissues will decompose at a faster rate, exposing the skeletal framework, leaving it vulnerable to the elements. The poor mineralisation will result in the skeletal framework being more vulnerable to bioturbation from roots. Areas with thin cortical bone and high levels of trabecular bone are particularly vulnerable, with the ribs, sternum, vertebrae and epiphyses all being particularly affected. Mays (1991) noted that the resistance of soil erosion in the non-adult vertebrae is higher in the lumbar region and lower among the cervical vertebrae. Hand and foot bones are also poorly represented, though this may also be due to the small size and a lack of developmental non-adult anatomical knowledge. Areas with a high quantity of cortical bone are better represented, demonstrating a higher resistance to the extrinsic factors present. It should be noted that although similar patterns have been noted elsewhere, the pattern of preservation would vary from site to site (Waldron, 1987b).

Previous excavations have found that preservation can increase with age. The osseous remains of non-adults tend to be less well represented and well preserved than adults, even when there is a range of preservation shown for non-adults, males and females (Bello *et al*, 2006). It has been suggested that as non-adult remains survive well from some time periods, that this may not be a case of the developing bones having a lower mineral content and therefore more likely to undergo diagenesis at a faster rate (Lucy, 1994). Differences in burial depth, burial type and practice, or location within the cemetery could all lead to differential preservation of the remains and the rate of diagenesis (Lucy, 1994, Crawford, 1999; Buckberry, 2000). The burial rites may have differed from those accorded to adults, which again would imply that they are viewed differently to the adult members of the community (Crawford, 1991; Lucy, 1994). From the Anglo-Saxon period, the number of non-adult remains in burial grounds have increased, which may be due to a change in cultural practices or beliefs (Lucy, 1994; Buckberry, 2000). However, the differential treatment of non-adult remains still exists today, with non-adults not regarded as fully human until they have passed a particular developmental stage (Tooley, 1983; Smith and Kahila, 1992; Buckberry, 2000).

The under-representation of non-adults due to differing burial rites, recovery rates or taphonomic conditions can have a significant impact on the resultant palaeodemography (Buikstra and Konisberg, 1985). An under-representation of non-adults will affect the survivorship figures of the adult population, supporting the need to ensure that all non-adult burials are accounted for in the demographic analysis. Many studies that have surmised that this due to the bones of non-adults being poorly mineralised and therefore, more vulnerable to diagenetic changes than adults are. However, few studies have combined the anthropological and taphonomic research to better understand whether this is due to vulnerability the of non-adults remains or if there are other factors involved which would influence osseous diagenesis at the same rate regardless of the age at death of the individual.

Skeletal assemblages typically fall within two groups when assessing sites with unfavourable conditions: those that can provide a demographic profile and those that cannot. At sites with unfavourable conditions that are causing the rapid diagenesis of the osseous material, all skeletons will be affected, not just the non-adult or elderly age groups. At such sites, it would be as difficult to recognise and age an adult skeleton as it would a non-adult, as the extrinsic factors would affect the bone in the same way (Sundick, 1978; Saunders *et al*, 1992). The intrinsic factors determine the speed at which the breakdown of the osseous occurs. Many papers focus on the preservation of the skeletal elements rather than the teeth, which are primarily used to age non-adults. However, the calcium phosphate enamel layer is the hardest tissue type within the human skeleton, and therefore more resistant to breakdown than the bones of the adult skeleton. Caution should be taken here though, due the small size and the high probability that non-adult teeth will be lost if the archaeologist does not follow protocols for the excavation and sieving of all soils removed from the ground.

It is clear when comparing the mortality profiles from historical documents with those derived from skeletal samples that there are significant differences in the resultant mortality profiles. The differences could be due to poor osseous preservation resulting in lost data, truncation or incomplete excavation, which also limits the preservation resulting in the loss of elements. However, regardless of the reason for the limited preservation of an individual, the outcome remains the same: an inconsistency will occur between the documented, exhumed sample and the original, buried population (Bello *et al*, 2006).

The concentration of non-adult burials within a separate area of the cemetery or outside the cemetery boundaries may subject the skeletal remains to different taphonomic influences and therefore affect the preservation rates (Guy *et al*, 1997; Murail, 1996; Bello, 2006). The issue of non-adult graves being missed during the excavation process should not occur if stratigraphic excavation is carried out over the whole site, leading to questions as to whether this is a justifiable theory (Buckberry, 2000). However, it was noted during the Winchester Minster excavations that certain excavators recovered a lower number of non-adult burials despite a high frequency being present at the site (Buckberry, 2000). Buckberry (2000) surmises that non-adult bones are not only smaller, but also more porous, with a higher collagen content than adult bones. This increased collagen content makes them more susceptible to diagenesis in acidic soil (Gordon and Buikstra, 1981). Gordon and Buikstra (1981) carried out a study on the rapid disintegration of bones with a low mineral component, finding that non-adult remains can undergo full diagenesis at marginal pH levels.

The excavations at Christ Church, Spitalfields, resulted in high numbers of well-preserved non-adults, leading Lucy (1994) to question the preservational bias of high collagen levels. However, the issues with the argument here is that the Christ Church burials were recovered from an 18th century crypt (Molleson and Cox, 1993), which would have presented a very different depositional environment and therefore is not comparable to those interred in the ground. A crypt would provide protection from the soil, bioturbation and water, while subjecting the remains to increased airflow, more likely resulting in preservation of mummified soft tissue.

Sex

As discussed previously (see previous subchapter on age), there is a marked difference identified in some sites when considering the preservation of non-adult remains. However, it has also been noted that there can be differential preservation between male and female non-adult skeletons dependent on the age of the individual. The difference in preservation could due to the intrinsic factors of the bone changing as due to the different occupational and lifestyle pathways between males and female, leading to increased resistance to extrinsic factors in the more robust male skeleton (Bello *et al*, 2006).

Pathology

The presence of pathology can increase the rate of decomposition, as the damage to the bones can increase the accessibility of microorganisms (Manifold, 2013). Metabolic diseases, which cause the breakdown of bone and increasing the porosity, can also lead to higher rates of decomposition (Henderson 1987; Breitmeier *et al*, 2005).

The cemetery of St Helen-on-the-Walls has a demographic profile that represents an attritional cemetery, with the low numbers of infants suggested as being due to the exclusion of unbaptised infants from the cemetery and a high rate of adult immigration (Grauer and Roberts, 1989). However, the large number of juvenile deaths (up to 12 years) was noted as being unusual given that those which survive the first 0-4 years, the risk of dying at 5-9 is much lower, and 10-14 even lower still (Brothwell, 1987). St Helen-on-the-Walls was an urban medieval site, with the skeletal analysis revealing the poor diet and squalid conditions present, which most likely led to the high rate of infection and therefore increased mortality risk. Although the non-adult population displayed fewer skeletal stressors than the adult population, Grauer (1989) suggested that the non-adults were more likely to succumb to the illnesses before changes occurred in the skeletal framework. The conditions reported at St Helen-on-the-Walls, were reported at other urban medieval sites (Sabine, 1933, 1934, 1937; Knüsel, 1989; Dyer, 1989), suggesting that the demographic profile produced for urban environments is likely to differ from rural sites. An alternative explanation for the high number of non-adult death was the preferential burial at St Helen-on-the-Walls due to lower costs for burial when compared to the surrounding parishes in York (Margerison and Knüsel, 2002).

Activity markers

Musculo-skeletal markers can also give information on lifestyle, levels of activity and in some cases, indicate possible occupations (Capasso *et al*, 1999). The pattern of degeneration in the skeleton may be indicative of mechanical loading on particular joints lending more support to lifestyle interpretation. The study of the dentition can provide information about diet and health, but also a wealth of information about tooth use in a population. By assessing the level of wear (attrition), calculus and macroscopic damage to the teeth, it is also possible to gain an insight into the cultural and occupational practices within a population. Teeth have been used as tools in a variety of occupations, from leather working (Irish and Turner, 1987) to yarn making in the 10th century Kovuklukaya females (Erdal, 2007). Cultural habits such as pipe smoking have also left their mark on the dentition, especially where the pipe has been held between the teeth for long periods of time (Caffell and Clark, 2011). Smith (1984) looked into the difference in tooth wear of those from different lifestyles, finding that foragers tended to have an even wear pattern, whereas farmers tend to display cupped wear on the occlusal surface, though the level of this wear was much less than the foraging group (Larsen, 1995).

1.3. Aims and objectives

A number of medieval sites in England have undergone population studies, including Fishergate in York (Sullivan 2004), Raunds Furnells in Northamptonshire, St Helen-on-the-Walls and Wharram Percy in Yorkshire and Christ Church Spitalfields in London (Lewis 2002). However, the most extensive palaeodemographic research has been carried out on urban sites, as it is believed that rural sites tend to be limited by the amount of material recovered (Mays *et al* 2007). This may be due to the lack of foetal and infant remains recovered from sites, the reasons for which are given as differential preservation rates in the soil, infants being buried elsewhere or the remains are missed during excavation due to their small size (Cruz and Codinha 2010, Willis and Oxenham 2013).

The assessment of the demographic profiles for two medieval cemetery sites (Poulton Chapel and St. Owens), along with the comparison to 20 previously published sites, enabled a more thorough understanding of the similarities and differences between rural and urban medieval populations. Further investigation was undertaken to determine whether there is a lack of foetal and infant material recovered from excavations or whether other taphonomic factors may be contributing to the bias in recovery rates. The research design was adapted for each site due to the differences in the amount of historical literature available and to incorporate mapping techniques where possible.

1.3.1. Aims

The main aims of the research were:

1. To produce demographic profiles for Poulton Chapel and St Owens Church skeletal samples recovered during the excavations.

2. To determine if there is a difference in the demographics between the skeletal samples recovered from the medieval samples studied in this thesis, and previously published samples from rural and urban medieval sites.
3. To investigate the impact intrinsic and extrinsic factors have on the diagenesis/preservation of human skeletal remains.
4. To understand the influence post-mortem treatments and process have on the resultant demographic analysis.

1.3.2. Objectives

To achieve the aims listed above the following objectives were set:

1. Curate and analyse the samples from the Poulton Chapel (n=751), Chester Greyfriars (n=20) and Southgate Street, Gloucester (n=312) skeletal collections, totalling 1085 individuals.
2. Assess the burial conditions at Poulton Chapel and Chester Greyfriars to determine the impact on the preservation of human bone, in particular the influence of soil, bioturbation and water.
3. Carry out geoarchaeological and geochemical analyses of the stratigraphy at Poulton Chapel and Chester Greyfriars sites to understand how the geology/soils at the sites have influenced the preservation of the human skeletal remains.
4. Determine the influence soil chemistry has on the preservation of human remains.
5. Determine the influence of the burial environment and the potential for providing further information through radiocarbon dating, stable isotopes and DNA analysis.
6. Investigate the impact of varying burial practises on non-adult human remains to determine whether this will affect the demographic profile for the cemetery samples studied.
7. Explore other taphonomic and cultural variables that could contribute to the differences in the demographic profiles of urban and rural medieval populations.
8. Compare the demographic profiles from the medieval cemetery samples studied to published skeletal collections to determine whether there is a difference between rural and urban demographic profiles.

The aim of this research was not to present a historical background for each of the populations, but to concentrate solely on the evidence provided by the human skeleton, the burial environment, the time spent in the deposition environment, and its impact on the resultant demographic profile. Therefore, the historical information for each site will be brief to highlight the potential for comparison between different populations from the human skeletal remains. Parts Three to Five of the thesis will contain the site reports from each of the cemeteries assessed for this research. Part Six presents the results from the site comparison and issues identified during the palaeodemographic analyses. Part Seven will discuss the finding from this research by linking back to the aims and objectives listed in this chapter, before presenting the conclusions.

Chapter 2 – Methodology

2.1. Introduction

With five previously unpublished archaeological sites to assess, this section presents the methodologies used during the assessment of each of the sites prior to presenting the results from each site to avoid unnecessary repetition. Each methodology will detail the sites that used that particular technique, as the differing excavations and timelines required bespoke research strategies.

2.2. Geoarchaeology

To determine the impact the geology had on the archaeology and therefore the preservation of the burials, desktop and site based (where possible) studies were carried out at each of the sites. Carrying out these additional assessments enabled a comparison of the natural physical process from the underlying geology to the archaeological evidence on each of the sites, which would further insight into the factors affecting the preservation of the artefacts post deposition. For each of the sites, borehole data recorded by the British Geological Survey to inform on the groundwater level and macro-stratigraphy present at each of the field locations was retrieved. Historical research on past land use provided information on how the archaeology had altered the landscape and the additional foreign materials that may have been introduced to the site over time. Where possible, soil samples were collected at designated locations during the excavation (Poulton Chapel and Chester Greyfriars sites) to provide information on the micro-stratigraphy, which directly influenced the preservation of the human skeletal remains. Geoarchaeological analysis was undertaken at both Poulton Chapel and Chester Greyfriars as part of this research. As the Gloucester excavations took place in the 1980s, it was not possible to include the microstratigraphy data or stratigraphic sections as the site has since closed and been redeveloped as a carpark.

2.3. Soil analysis

Where possible, soil samples were taken during the archaeological excavation process at each site studied (with only two samples obtained from the 1989 excavation in Gloucester) and subjected to a series of tests to try to determine the influence the burial environment has had on the skeletal remains. Approximately 200g of soil was collected from each location, with the specific sampling technique and results provided in the relevant section for each site.

Sample preparation

Prior to any analytical tests taking place, each soil sample was air dried for a few weeks, ground with a pestle and mortar, and sieved to 2mm. Any material greater than 2mm was discarded with all soil samples subjected to the following tests.

Soil colour determination

Using a clean metal spatula for each sample, the soil samples were compared to a Munsell© soil colour chart to determine Hue, Value and Chroma (Munsell Color, 2000). Each sample was compared to the chart in both damp and dry conditions and the resultant colour recorded using the Munsell© notation of colour and associated colour name. Soil samples were obtained from Poulton Chapel (49 samples), Chester Greyfriars (11 samples) and the 1989 excavation at Southgate Street, Gloucester (two samples).

pH determination

Strongly acidic or alkaline soils can promote degradation of the bone reducing the chance of retrieving usable collagen for stable isotope analysis or radiocarbon dating. Each soil sample was tested to determine the influence the pH of the soil within and between each site. By assessing the pH levels of the surrounding soil, it allowed the potential of the preservation of the human skeletal remains to be explored within different geological environments.

Approximately 10g of soil from each sample was weighed using a Fisher Scientific balance (SG-202; Fisher Scientific, Bishop Meadow Road, Loughborough, Leicestershire, LE11 5RG) and placed into a beaker with 25ml de-ionised water, mixed thoroughly and left to settle for 15 minutes. The pH level was tested using Merck indicator strips (6.5-10.0 and 4.0-7.0 ranges, Millipore (UK) Ltd) to determine the value for that sample. All pH values were plotted and mapped using GIS techniques, to determine if there was a correlation between the burial properties and human skeletal remains. Soil samples were obtained from Poulton Chapel (49 samples), Chester Greyfriars (11 samples) and the 1989 excavation at Southgate Street, Gloucester (two samples).

Magnetic susceptibility

The magnetic susceptibility of a material is a measure of its ability to become magnetised by an external magnetic field (Dearing, 1999). When assessing the burial environment and its impact on the preservation of human remains, the magnetic susceptibility can help to identify the minerals present in the surrounding substrate (particularly Fe-bearing minerals). The measurements can be indicative of anthropogenic influence, burning or soil waterlogging. The readings attained are assigned to one of five categories (ferromagnetism, ferrimagnetism, canted antiferromagnetism, paramagnetism and diamagnetism), dependent on the degree of interference the sample exhibits over the magnetic field (Table 2.1).

Table 2.1. The five categories of magnetic susceptibility and associated examples adapted from Dearing (1999).

Category/ 10^{-6} m^3 kg^{-1}	Level of susceptibility	Minerals
Ferromagnetic (69,000-275,000)	Strong positive	Pure iron, nickel, chromium
Ferrimagnetic (170-1100)	Strong positive	Some iron oxides and sulphides (magnetite, maghemite, prryhotite, greigite)
Canted antiferromagnetic (0.35-1.7)	Moderate positive	Some iron oxides (hematite, goethite)
Paramagnetic (0.01-2)	Weak positive	Many Fe-containing minerals and salts (biotite, olivine, ferrous sulphate)
Diamagnetic (-0.005- -0.009)	Weak negative	Water, organic matter, plastics, quartz, feldspars, calcium carbonate

An empty $10cm^3$ plastic pot was weighed using a Fisher Scientific balance (SG-202; Fisher Scientific, Bishop Meadow Road, Loughborough, Leicestershire, LE11 5RG), then it was packed with soil and then reweighed to determine the amount of soil used for the test (mass). The Bartington MS2 magnetic susceptibility reader and Bartington MS2B dual frequency reader (Bartington Instruments Limited) were used for this testing. The meter was set to low frequency (0.46 kHz) and zeroed, before placing the sample in the meter to take an air measurement (M1). The sample measurement was taken (κ) prior to a second air measurement (M2), once the sample had been removed from the meter. This test is repeated with the meter set at high frequency (4.6 kHz) to provide two sample readings. High frequency readings can identify samples that contain superparamagnetic ferromagnetic crystals, which are formed by specific weathering processes (e.g. soil formation at tropical or ancient sites, or waterlogging).

To calculate the mass-specific magnetic susceptibility (X) of a sample, the sample (κ) must be corrected to take into account the fluctuations in air density and any affect this would have on the sample reading. To determine the κ corrected value the following equation was used:

$$\kappa \text{ (corrected)} = \text{sample } \kappa - ((M1 - M2) / 2)$$

The κ corrected value could then be used to determine the mass-specific magnetic susceptibility:

$$(X)\ 10^{-6}\ m^3\ kg^{-1} = (\kappa \text{ (corrected)} / \text{mass}) / 10$$

These calculations were carried out on all samples at both low (X_{LF}) and high frequency (X_{HF}) settings to enable the calculation of frequency dependence in the sample. This would inform whether there were superparamagnetic grains present in the soil sample:

$$X_{fd\%} = ((X_{LF} - X_{HF}) / X_{LF}) \times 100$$

Sample frequencies were then compared to the guidelines given by Dearing (1999) which are shown in Table 2.2.

Table 2.2. Interpretation of frequency dependent (fd) susceptibility values as given by Dearing (1999).

fd%	Code	Value	Interpretation
Low $X_{fd\%}$	1	<2.0	Virtually no (<10%) superparamagnetic grains
Medium $X_{fd\%}$	2	2.0 - 10.0	Admixture of superparamagnetic and coarser non-superparamagnetic grains, or SP grains <0.005ųm
High $X_{fd\%}$	3	10.0 - 14.0	Virtually all (>75 %) SP grains
Very high $X_{fd\%}$	4	>14.0	Rare values, erroneous measurement, anisotropy, weak sample or contamination

The interpretation of the values obtained from this analysis were coded from 1-4, dependent on the classification of the sample, to enable statistical analysis on both the raw data values and the subsequent interpretation. Soil samples were obtained from Poulton Chapel (49 samples), Chester Greyfriars (11 samples) and the 1989 excavation at Southgate Street, Gloucester (two samples).

Field portable x-ray fluorescence analysis on soil

X-ray fluorescence (XRF) was used to determine the elemental composition of the soil from each site. By determining the elemental composition of the soil and the skeletal material (see Section 5. Cemetery sample analysis – field portable X-Ray fluorescence), it may possible to determine the elements being lost from the skeletal remains and dispersing into the surrounding burial medium. If this is possible, combined with the results from other soil analyses, it may enable the understanding of the potential impact each burial environment has had on the skeleton. ArcGIS mapping will allow the potential for further testing to be assessed, using the parameters from the soil matrix to highlight areas of good and bad preservation.

Approximately 10g of soil from each sample was weighed using a Fisher Scientific balance (SG-202; Fisher Scientific, Bishop Meadow Road, Loughborough, Leicestershire, LE11 5RG) and placed into small bags. Each sample was scanned three times with the Genius 9000 XRF analyser (Skyray Instrument Inc. Optech Solution Ltd. Riverside Court, Beaufort Park, Chepstow, NP16 5UH) on mineral settings, with the resultant elemental compositions averaged. The results for each of the samples were mapped using ArcGIS and compared to results from the soil and skeletal preservation testing. Soil samples were measured from Poulton Chapel (49 samples), Chester Greyfriars (11 samples) and the 1989 excavation at Southgate Street, Gloucester (two samples).

Particle size analysis

Soil particle size analysis can help provide further information on the properties of the soil found at each location. This will indicate areas that are higher in clay and therefore likely to inhibit the movement of nutrients and water, leading to better preservation of the inorganic components of human bone. Areas that contain higher percentages of sandy soil are likely to have poorer preservation of the mineral components of the bone due to high permeability of the soil. Dependent on the other environmental factors present, it may also result in considerable loss of organic bone content.

Approximately 1cm^3 of soil was placed into a 250ml tall form beaker with hydrogen peroxide to remove any organic material. This was covered and then placed on a hot plate until there was no longer an observable chemical reaction. In cases where the reaction was particularly violent, deionised water was added. Once cooled, the hydrogen peroxide was siphoned off, 50ml of deionised water and 2 drops of hydrochloric acid were added to stop the reaction from continuing. This was left overnight before the water was siphoned off. A few drops of Calgon was added and the mixture was placed back onto the hotplate until a paste formed. A small spatula full was added to the LS13320 Aqueous Liquid Module ((Beckman Coulter (UK) Ltd. Oakley Court, Kingsmead Business Park, London Road, High Wycombe, HP11 1JU) and the samples were analysed. Each sample was run through the LS13320 Laser diffraction particle analyser (Beckman Coulter (UK) Ltd.), enabling any variability in grain size within the samples to be measured.

Sample preparation and interpretation of the results was carried out by the author, with the grain size analysis of the soils carried out by David Williams, Senior Technician from the Geography Department, Faculty of Science, Liverpool John Moores University. Soil samples were analysed from Poulton Chapel (49 samples), Chester Greyfriars (11 samples) and the 1989 excavation at Southgate Street, Gloucester (two samples).

2.4. Archaeothanatology

To understand the potential effect the burial environment has had upon the skeletal remains, it is important to account for the position the corpse was placed during interment. The treatment of the remains during burial can also have a significant influence over the access the burial medium has during decomposition and the ability of the leachate to move away from the body.

Archaeothanatology uses taphonomy to understand the circumstances surrounding the burial context (Duday, 2009). By recording the excavation of a skeleton in detail, the original characteristics of the burial can be inferred from the in-situ analysis of the individual skeletal elements present and any surviving material (coffin, shroud or pins) or burial goods placed in the grave.

Using the principles of archaeothanatology, a basic analysis has been carried out, where possible, on each of the sites studied, to determine the influence differing burial practices and types may have on the preservation of human skeletal remains. For each individual burial, the arm position, burial practice, type and alignment was recorded and compared to the biological profiling data, collagen extraction results, XRF analysis and soil data to look for correlations between preservation and potential for further chemical testing on the bone.

Arm position

There are very few studies looking at the significance of the arm placement during burial, with the most detailed study carried out on an excavation of a Muslim cemetery in Tell el-Hesi, Israel, dated to the period 1600-1800AD (Toombs, 1985). Sites in Medieval England have given brief information regarding the position of the hands within the grave, but there is very little detail to these assessments (Daniell, 1997). The position of the arms was recorded for each burial to determine if there was a correlation between this and biological profile of the skeleton. Eight arm positions were identified between the five sites by examination of the burials during excavation, photographic evidence and/or context records (Figure 2.1). A code was assigned to each of the arm positions identified for comparison with other skeletal variables and data analysis (Table 2.3).

Table 2.3. Arm positions identified from the sites studied in this thesis and associated coding for analysis.

Arm Code	Arm position description
1	Both arms placed by side
2	Both arms placed with hands over pelvis
3	Both arms placed across the lumbar region
4	Both arms crossed over chest/ in prayer position
5	One arm by side, one crossed over chest with hand towards opposite shoulder
6	One arm by side, one arm over pelvis
7	One arm across lumbar region, one arm with hand over pelvis
8	One arm across lumbar region, one crossed over chest with hand towards opposite shoulder
9	No information available

Burial practice

A basic analysis to assess the skeletal remains for information regarding the burial practice was undertaken, where possible, at each of the sites studied in this thesis. To keep the analysis of each burial consistent, a list of characteristics for each of the burial categories was designed in accordance with the methodologies set out by Duday (2009). For each of the burials that provided sufficient evidence (through photographs, plans, finds or excavation where the author was present), the characteristics listed in table 2.4 were observed.

Figure 2.1. Examples of the arm positions identified from the sites studied in this thesis. Descriptions and associated codes (1-8) are given in Table 3. ©Poulton Research Project.

Table 2.4. List of observable characteristics identified from the methodologies by Duday (2009), used to infer the burial practice used.

Decomposition in a void

• Rotation of the cranium
  o Dissociation of the mandible
  o Mandible has moved with the cranium
  o Disruption of the cervical vertebrae
• Disruption of the vertebral column
• Flattening of the rib cage
• Rotation of the humerii
• Displacement of the radius/ulna
• Separation of the pubic symphysis
• Slippage of the ilia from the sacrum
• Medial/lateral rotation of the femora
• Displacement of the patellae
• Displacement of the tibia/fibula
• Displacement of the hand and foot bones

Decomposition in a shroud
• Double delineation of the burial • Articulations tightly held in place • Verticalised clavicles

Decomposition in a narrow grave (no shroud)
• Single delineation of the burial • Mixture of shrouded characteristics and slight movement of the skeletal elements

Once the burial practice had been analysed, a code was assigned to each skeleton to identify the practice used to enable the comparison with other skeletal, burial and geological characteristics. (Table 2.5). As the burial practices for this research were identified from photographs and context records in many cases, it was decided that the identification of coffin burials would only be recorded if conclusive evidence existed for the coffin (nails, wood, handles, etc., see Figure 2.2), or the author had been present at the excavation to observe the burial position first-hand.

Table 2.5. Burial practices identified from the sites studied in this thesis and associated coding for analysis.

Code	Burial practice description
1	Non-Shrouded
2	Shrouded
3	Coffin
4	No information available

As future research is planned for a detailed archaeothanatological analysis of the burials from Poulton Chapel, only those that were assessed as having both skeletal and coffin evidence present were recorded as coffin burials at this time. The excavations at Gloucester Congregational Church and the Infirmary burial ground had associated coffin remains enabling easy identification. For St. Owens Chapel, there was very little information recorded about the burials and no photographs to look at the burials practice. The plan drawings did not give sufficient evidence to determine the burial practice, so burial practice was not recorded for this site. Chester Greyfriars had a small sample size (n=20, and as the author was present during the excavation it enabled a more detailed analysis to take place at this site.

Figure 2.2. Skeleton 250 from Gloucester Congregational Church, a coffin burial with associated coffin remains. ©Gloucester Museum.

Burial type

The burial type is crucial in determining the impact the burial environment will have on the preservation of the skeletal material and therefore, the potential for further analytical testing (stable isotopes, radiocarbon dating and ancient DNA). The position of the skeleton in the grave will enable the observer to determine the influence of foreign material filtering into a grave, the skeletal elements affected by a burial wrapping or grave goods placed in a grave (Figure 2.3). Each articulated skeleton was analysed to determine burial types and assigned a code (Table 2.6). This enabled an analysis of the position of these graves to determine if there was any significance in the burial types identified. The burial types were assessed at all the cemeteries studied in this thesis using a combination of on-site excavation, photographs, context records and burial plans.

Figure 2.3. Skeleton 245 from Poulton Chapel demonstrating a flexed burial type. ©Poulton Research Project.

Table 2.6 Burial types identified from the sites studied in this thesis and associated coding for analysis.

Code	Burial type description
1	Disturbed
2	Prone
3	Supine
4	Flexed
5	No information available

Burial alignment

The alignment of the burials was recorded to determine any differences in burial practices, which may be due to religious beliefs, individuals that were accused of deviant behaviour (e.g. witches, vampires, murderers), or women that had died during childbirth. A difference in the alignment of the burial could mean that the body was subjected to alternative treatments when preparing the corpse. Each skeleton analysed was assigned a code to enable an analysis of the position of these graves to determine if there was any significance in the alignment (Table 2.7). Burial alignment was assessed at all the sites studied in this thesis using a combination of on-site excavation, photographs, context records and burial plans.

Table 2.7. Burial alignments identified from the sites studied in this thesis and associated coding for analysis.

Code	Burial alignment description
1	East-West
2	West-East
3	North-South
4	No information available

2.5. Cemetery sample analysis

Quantifying the material

Examination of the excavation documentation from each site determined the number of individuals present for each analysis. Comparison of this information to the physical examination of the material enabled production of the overall demographic profiles of the excavated collections. In some cases, reburial, loss or re-numbering of individuals needed assessing to determine the impact on the overall population size. Furthermore, when assessing the material from Gloucester, it became apparent that there were three separate cemeteries spanning 700 years. Although excavated in the 1980's, a large portion of this material had not undergone post excavational cleaning or analysis. Therefore, this material required sorting and extensive research to determine the origin of each skeleton. Quantification of the material will give a brief overview of the number of individuals studied for each cemetery, along with the amount of disarticulated material recovered. Each cemetery has undergone this assessment as part of this research.

Skeletal completeness

Medieval burial practices differ greatly from modern times. Although many sites began with burials in neat rows, the long life of the cemetery and deterioration of grave markers over time, a number of truncated burials were present at all the sites studied. Although the truncated individuals are not complete, their analysis provided important demographic data and stratigraphic information about the population and the length of time each cemetery was in use (Figure 2.4).

The completeness of each skeleton details the percentage of the skeletal remains that are available for analysis by assigning it to one of four categories (>75%, 75-50%, 50-25% and <25%). For the demographic analysis, only skeletal remains that were articulated were included in the analysis to prevent individuals being counted twice.

Figure 2.4. Skeleton 805 from Poulton Chapel showing extensive truncation from later burials. Note that the remaining elements could still provide indications of age, sex and stature. ©Poulton Research Project.

Skeletal preservation

A number of factors can affect the preservation of bone including taphonomic processes, pathologies and burial type. Taphonomic factors can be man-made or biological factors that disturb the burial following deposition. They can include burial wrappings, coffins, clothing and artefacts buried with the body, fluctuating water levels from poor drainage or proximity to the water table (Figure 2.5). Root and animal intrusion to the grave commonly cause markings on the skeletal material, which can mimic pathology and trauma. Moulds and fungi are an influencing factor when assessing burials from coffins, crypts and vaults due to the unique environment created by the corpse during the early stages of decomposition. Examples of taphonomic interference documented in this thesis include coffin and shroud burials, bioturbation from roots and animals, and water table intrusion into the grave. The impacts due to truncation of burials due to cemetery re-use and the redevelopment of areas are also discussed.

Pathological interference affecting the preservation of the skeletal remains ranges from those that affect the deposition of bone resulting in either increased or decreased bone mass. This can be due to traumatic injuries that increase the vulnerability of human bone, or the influence of taphonomy. Examples recorded in this thesis include those who have suffered from osteoporosis, osteomyelitis and Paget's disease.

Figure 2.5. Skeleton LC1a from Gloucester Congregational Church was wrapped in a shroud and then placed in a lead-lined coffin. The distal end of the right humerus shown here has remains of the burial wrapping adhered to the bone. ©CAL Davenport.

Skeletal preservation was recorded using a system adapted from Brickley and McKinley (2004). This system grades the remains by recording the surface abrasion and erosion due to taphonomic interference following deposition (Table 2.8).

Table 2.8. Post-mortem preservation grading of the articulated skeletal material following excavation using a system adapted from Brickley and McKinley (2004).

Grade	Description
0	No erosion or abrasion present, bone in excellent condition
1	Slight surface erosion, mainly on the epiphyses, patchy, bone morphology is not affected
2	Slight surface erosion extending to the diaphysis, patchy, bone morphology is not affected
3	Deeper surface penetration at the epiphyses, bone morphology is not affected
4	Deeper surface penetration extending to the diaphysis, bone morphology is not affected
5	Heavy erosion with some modification of the bone profile
6	Heavy erosion with extensive modification of the bone profile

When assessing the human skeletal remains from each site, it became apparent that recording the completeness and the surface erosion/abrasion did not fully describe the condition of the remains available for this research. Heavily fragmented remains lead to loss of information when assessing biological profile and pathology (Figure 2.6). As there was no assessment criteria for fragmentation of articulated skeletal remains, a method was devised through recording the condition of each of the skeletons and then placing them into categories created from the descriptions (Table 2.9). As skeletal preservation was assessed following the excavation and cleaning of the remains, it was possible to collect the information for each of the collections studied.

Figure 2.6. Skeleton 018 from Chester Greyfriars, assessed as being extensively fragmented (grade 4) using the grading scale established for this research. ©CAL Davenport.

Table 2.9. Post mortem fragmentation grading and descriptions used for each of the collections assessed.

Grade	Description
0	No fragmentation of elements, bone in excellent condition
1	Minimal fragmentation, few elements affected
2	Some fragmentation but most elements intact
3	Fragmented, few elements intact
4	Extensive fragmentation of all elements

Collagen extraction

To support the preservation data from the skeletal remains, collagen extraction was undertaken on a number of skeletons to determine whether there was a correlation between specific taphonomic variables and collagen yield. The results from this study would provide information on the impact the varying burial environments could have on future stable isotope, carbon dating and ancient DNA results at the different sites. A poor collagen yield will not produce reliable results when bone samples are sent for analytical testing, which leads to ineffective budgeting as more samples than necessary would need to be processed to get the information required for the project. By carrying out simple and inexpensive tests to determine the viability of the bone sample, it would be possible to eliminate the potential for negative results and therefore maximise the available budget.

Collagen extraction was carried out using the “chunk” method as detailed by Berger *et al.* (1964) and then modified to remove humic acids (Ambrose, 1990; Sealy *et al*, 2014). A small chunk of bone (0.5g) was cut and lightly sanded with fine, medium grain sandpaper to remove any surface contaminants prior to weighing. To demineralise the bone, it was placed in a 0.2M hydrochloric acid (HCl) solution and then left at room temperature in a fume hood. The HCl solution was changed every other day until a psuedomorph (translucent and flexible demineralised section of collagen, which exhibited the same size and shape of the original bone) was formed (Figure 2.7). If a psuedomorph did not form or no collagen survived, the treatment was carried out using a weaker solution to decrease the rate of the demineralisation process. The quality of bone is a factor on how long it will take to demineralise, but it was usually between three and ten days.

Figure 2.7. Collagen extraction of LC2 showing an untreated rib fragment from Southgate Congregational Church, Gloucester (bottom) and the psuedomorph of a rib fragment following extraction with 0.2M HCl and 0.1M NaOH, but prior to freeze-drying of the sample. ©CAL Davenport.

Following demineralisation, macroscopic debris was removed from the sample using tweezers, before rinsing the psuedomorph three times with deionised water. The sample was then soaked in a 0.1M sodium hydroxide (NaOH) solution to remove humic acids and lipids for 24 hours (for those repeated due to poor bone quality, this time was reduced to 8 hours). The samples were soaked in deionised water (changed regularly) for up to a week, or until the pH in the water remains approximately neutral. The samples were then freeze-dried and weighed.

The resultant collagen yield was calculated:

$$\frac{\text{Weight of collagen}}{\text{Weight of sample}} \times 100$$

The yield is the percentage of collagen present in the bone sample, with a suggested cut-off of 1% yield for further testing. Although it is possible to test at the 0.5-1% range, there is also a greater risk of the sample failing to produce reliable results (Van Klinken, 1999). The samples were weighed into tin capsules (approximately 0.65mg per capsule, two capsules per sample to run in duplicate) ready for stable isotope testing or radiocarbon dating in the future.

Collagen extractions have been carried out on skeletal samples where the burial environment could be assessed. For Poulton Chapel and Chester Greyfriars, soil samples were collected from the grave fill during excavation and provided direct correlations between the skeletal remains and the burial environment. The Gloucester cemeteries were excavated in 1983 and 1989; therefore, only two soil samples were available. However, collagen extractions have been carried out on the crypt and coffin burials to determine the impact of these particular burial practices on preservation. All the archaeological sites studied (Poulton Chapel, St Owens Church, Chester Greyfriars, Southgate Congregational Church and Gloucester Infirmary burial ground) in this thesis have been assessed for preservation using traditional methods and collagen extraction where appropriate for the samples studied here.

Field portable x-ray fluorescence analysis on bone

To test the differences in the human skeletal remains present at each of the sites, a field portable x-ray fluorescence (FP-XRF) gun provided the chemical composition of the elements present in the bones. Aside from giving information about the elements being leached into the soil from the bone, it also provided information on the burials types present at each site. Calibrations were carried out on the FP-XRF using both the silver (*Ag*) standard supplied with the machine, and National Institute of Standards and Technology Standard Reference Material (NIST SRM) 1486 bone meal.

The first rib (where available) from each skeleton selected for testing was scanned three times with the FP-XRF on the mineral and light elements settings, with the resultant chemical compositions averaged. The results for each of the samples was mapped using ArcGIS and compared to results from the soil and skeletal preservation testing. Correlations were also carried out on the samples to determine if there were any relationships between the variables. Further skeletons were also tested with known burial status (coffin/crypt or shrouded) and with identified pathologies (Phossy jaw, Paget's disease, osteoporosis, etc.) to determine the potential influence other variables may have on the chemical composition of bone. Skeletons from all studied sites (Poulton Chapel, St Owens Church, Chester Greyfriars, Southgate Congregational Church and Gloucester Infirmary burial ground) in this thesis were scanned to provide an overall impression of the differences in bone mineral composition.

2.6. Skeletal analysis – biological profiling

A palaeodemographic analysis requires a biological profile to be carried out on each individual in the sample. For this research age, sex and stature were recorded, with other analyses carried out as separate research projects. Age and sex determination in adults will be assessed using a multivariate approach to ensure all possible data is taken into account

(Lovejoy *et al.*, 1985; Baccino *et al*, 1999). All information collected from each individual was entered onto the appropriate recording sheet (see Appendices A1 and A2).

Sex determination

The sex of non-adults was not determined for the purposes of palaeodemography study, as adult morphology is not attained until puberty. The determination of sex only applied to those individuals that had undergone fusion of the *os acetabuli* of the pelvis and therefore displayed sexually diagnostic characteristics. The estimation of sex in adults was assessed using both morphological and metric methods.

Although the remains were assessed using the standard categories (females, probable female, unknown, probable male, male and non-adult), for the ease of assessment and comparison, the probable categories were folded into the relevant sex grouping (Table 2.10). This was due to the other samples in the literature occasionally omitting the probable criteria, therefore not enabling a direct comparison. All sites studied (Poulton Chapel, St Owens Church, Chester Greyfriars, Southgate Congregational Church and Gloucester Infirmary burial ground) in this thesis were assessed to determine the sex for all identified burials using the methods described below.

Table 2.10. Final groupings for sex determination analysis used for each sample studied in this thesis.

Sex	Code
Non-adult	1
Male	2
Female	3
Unknown	4

Morphological analysis

Seven morphological traits were assessed on the innominate (sub-pubic angle and concavity, presence of ventral arc and pre-auricular sulcus, medial aspect of the ischiopubic ramus, greater sciatic notch and obturator foramen (Bass, 1995 and Phenice 1969)). The curvature of the sacrum was also assessed (Bass, 1995). Female individuals were also assessed for potential evidence of pregnancy (Stewart, 1970; Houghton, 1974; 1975) to aid in the production of fertility tables.

Sexually diagnostic morphological characteristics of the cranium assessed were supra-orbital ridge and margin, nuchal crest and mastoid processes. The mental eminence, gonial angle and mental aversion were characteristics assessed on the mandible.

Metric analysis

Metric measurements were taken of the humeral head (Stewart, 1979a), radial head (Berrizbeitia, 1989) femoral head (Pearson, 1917-1919), bicondylar width of the distal end of the femur (Stewart, 1979b) and glenoid cavity of the scapula (Dwight, 1984). Comparisons of the measurements taken were compared to those given in the literature to determine sex (Table 2.11).

Table 2.11. **Metric measurements taken from adult skeletal remains and the associated sex determination categories assigned from each method.**

Measurement	Female	Sex?	Male
Glenoid cavity length	< 34mm	34-36mm	>36mm
Vertical diameter of the humeral head	<43mm	44-46mm	>47mm
Maximum diameter of the radial head	<21mm	22-23mm	>24mm
Greatest diameter of the femoral head	<42.5mm (<43.5 probable)	43.5-46.5mm	>47.5 (>46.5 probable)
Bicondylar width	<72mm (72-74 probable)	74-76mm	<78mm (76-78 probable)

Parity status

A brief assessment of the number of each type of sulcus has been covered in this thesis on the adult skeletons from each site. A more in-depth study of the Poulton and Southgate Street Gloucester collection is has been undertaken as part of a separate PhD project by Sarah Canty at Liverpool John Moores University.

Age estimation

Age estimation was undertaken on all individuals, with differing methods used for adult and non-adult human skeletal remains, as detailed below. Following age estimation, the individual would be placed into a coded age category for statistical analysis (Table 2.12). Non-adults under the age of 10 years were placed into one-year age categories due to the development of the skeleton providing a greater number of factors to take into account during age assessment, enabling a more accurate age estimation. The length of age ranges increase after 10 years due to the decrease in developmental age markers in adolescence and senescence once development is complete.

A number of individuals could not be aged due to incompleteness or pathological interference, or provided estimates that fell into more than one age category. To enable inclusion in data analysis for sex determination or stature, the individual was placed into either the unaged adult or non-adult category. All sites studied (Poulton Chapel, Chester Greyfriars, St Owens Church, Southgate Congregational Church and Gloucester Infirmary burial ground) were assessed to estimate the age for all identified burials.

Table 2.12. Age ranges and associated codes for use in statistical analysis.

Age Ranges (yrs)	Code
<0	1
0-1	2
1-2	3
2-3	4
3-4	5
4-5	6
5-6	7
6-7	8
7-8	9
8-9	10
9-10	11
10-14	12
15-19	13
20-24	14
25-29	15
30-34	16
35-39	17
40-44	18
45-49	19
50-59	20
60+	21
Adult unaged	22
Non-adult unaged	23

Adult age estimation

A number of techniques were used to estimate the age of the adult skeletal remains from each of the sites. The methods comprised of the pubic symphysis (Brooks and Suchey, 1990), sternal 4th rib end (Işcan *et al.*, 1984, 1985), auricular surface (Lovejoy *et al.*, 1985b), medial clavicle and iliac crest closure (Webb and Suchey, 1985), dental attrition (Lovejoy, 1985) and cranial suture closure (Meindl and Lovejoy, 1985). All provided age estimates, which were then combined to indicate the age category that best described that particular individual.

Non-adult age estimation

Age estimation in non-adults used the ossification (Fazekas and Kósa, 1978; Scheuer and Black, 2000) and epiphyseal union (Ubelaker, 1987) of the skeletal elements, along with the calcification and eruption of the dentition (Mincer *et al*., 1993; Buikstra and Ubelaker, 1994; Huda and Bowman, 1995; AlQahtani *et al*., 2010). Dental calcification was assessed using radiographs to ensure all unerupted teeth were included (Figure 2.8). All age estimations were then combined to indicate the age category that best described that particular individual.

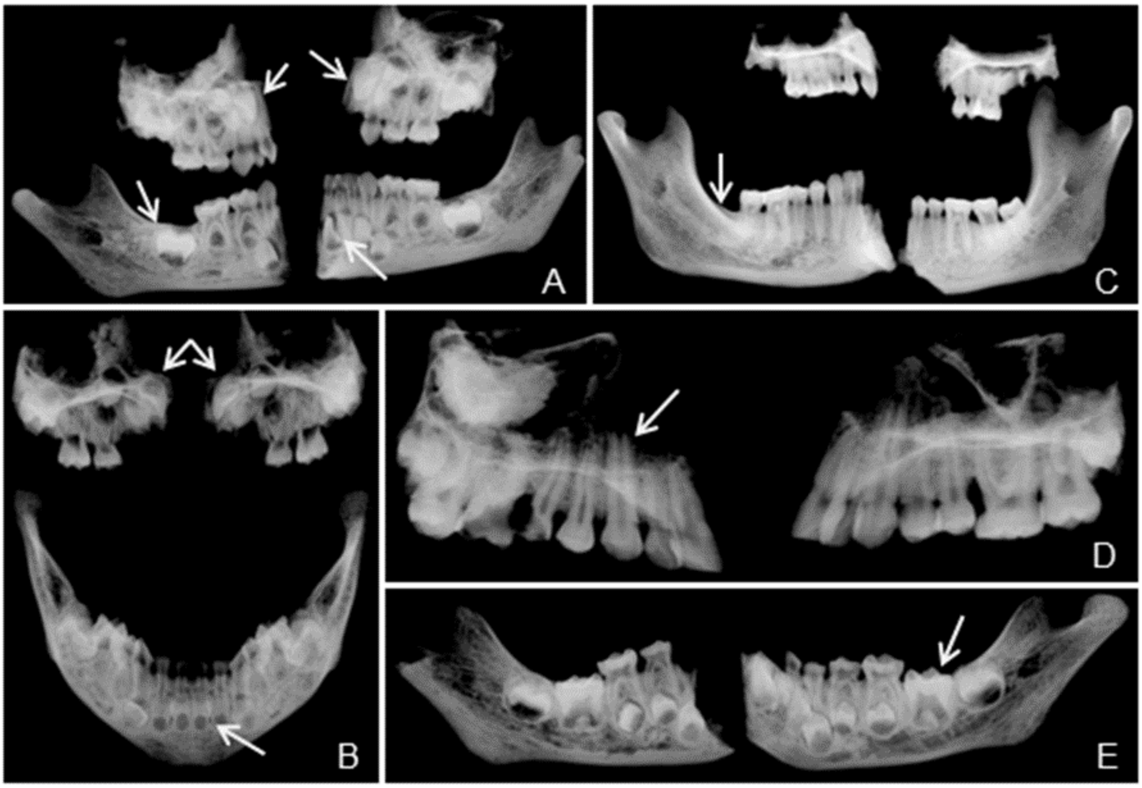

Figure 2.8. Dental radiographs showing: (A and B) calcification of the permanent dentition within the alveolar bone; (C) asymmetrical congenital absence of the third permanent molar; (D) incomplete root formation; (E) eruption of the first permanent molar. ©Carla Burrell and CAL Davenport.

During the course of the research, it became clear that some methods were not providing estimates consistent with other aging techniques. Therefore, other projects were developed in parallel to the PhD, to test the techniques given for the *pars basilaris* and non-adult long bone lengths (Burrell *et al.* 2015; 2018).

Stature estimation

Complete long bone measurements

Stature estimation was carried out on all adult individuals with complete long bones using the regression formulae as set out in Trotter and Gleser (1952; 1958), enabling a direct comparison between the sites when assessing whether environmental (i.e. rural or urban) factors had a direct impact on growth rates. Stature was not assessed for non-adults, as the growth process was not complete. However, long bone measurements were taken to allow further investigation into the growth rates of non-adults when assessing age in a separate study (Burrell *et al.,* 2015).

The maximum lengths of all complete long bones present were measured, with the left side measurement being preferred over the right for consistency. The measurement used for a stature estimate was chosen based on the formula that gave the lowest standard error value (Table 2.13). Corrections to the stature estimates due to age have not been calculated at this stage due to the broad age estimates attained for the skeletons. All sites studied

(Poulton Chapel, St Owens Church, Chester Greyfriars, Southgate Congregational Church and Gloucester Infirmary burial ground) in this thesis were assessed to estimate the stature for all articulated burials containing long bones.

Table 2.13. Long bone regression formulae for estimating stature (cm), adapted from Trotter and Gleser (1952; 1958).

White Males				White Females			
2.38	Fem	+61.41	±3.27	2.93	Fib	+59.61	±3.57
2.68	Fib	+71.78	±3.29	2.90	Tib	+61.53	±3.66
2.52	Tib	+78.62	±3.37	2.47	Fem	+54.10	±3.72
3.08	Hum	+70.45	±4.05	4.74	Rad	+54.93	±4.24
3.78	Rad	+79.01	±4.32	4.27	Ulna	+57.76	±4.30
3.70	Ulna	+74.05	±4.32	3.36	Hum	+57.97	±4.45

Fragmentary femora measurements

When assessing stature, the methodology using complete long bone measurements is not always possible due to fragmentation of the remains. Therefore, a technique by Steele (1970) and adjusted by Simmons *et al* (1990) has been used to assess stature in these cases. As the technique had been created using the Terry collection (800 individuals dating from 1822-1943), it was important to determine whether the technique was usable on the medieval samples investigated as part of this research. To assess the feasibility of the method measurements were taken of the complete femora, along with those as described by Martin (1957); vertical head diameter (VHD), proximal femur breadth (VHA) and lateral condyle height (LCH). All the femoral measurements taken are shown in figure 2.9.

Figure 2.9. Human femur with associated measurements taken for fragmentary femora comparison data. Measurements used for this study are VHD (blue arrow), VHA (green arrow) and LCH (yellow arrow). ©CAL Davenport.

The results were then analysed using the revised stature estimation and femur length regression formulae provided by Simmons *et al* (1990) to determine whether the resultant femoral length was comparable to that of the measurement taken (Table 2.14).

Table 2.14. Simmons *et al* (1990) regression formulae presented for Caucasian males and females. Adapted from the published table.

	Femur Length			Height		
	Slope	Intercept	S.E.	Slope	Intercept	S.E.
	Predictor Variable: VHA					
White Males	0.29	14.81	2.10	0.78	89.64	6.10
White Females	0.21	21.50	2.10	0.73	91.54	6.67
	Predictor Variable: LCH					
White Males	0.54	20.86	2.18	1.47	107.09	6.24
White Females	0.42	24.96	2.09	1.94	86.10	5.77
	Predictor Value: VHD					
White Males	0.43	23.57	2.32	1.11	113.89	6.77
White Females	0.47	20.22	2.06	1.35	99.22	7.16

For femoral length estimations, a significant correlation would provide sufficient support for this method to be used in this study. This method was repeated comparing the mean stature estimation from the Trotter and Gleser (1952; 1958) femoral formulae for white males and females to the estimates attained from each fragmentary femora landmark. Although the resultant mean statures could not be compared to known measurement, it provided an indication of whether the estimates provided were reasonable for each sample. If the correlations were significant, the formula could then be used to estimate stature for those individuals lacking complete long bones, but with fragmentary femora present. Poulton Chapel and St Owens Church were assessed to determine the suitability for this method due to the larger sample sizes present, with stature estimations provided where possible.

Craniometrics

Although a number of skulls were recovered from all sites, many were fragmented and required restoration prior to the collection of craniometric data. This work has been undertaken as a separate PhD study on the Poulton and St Owens, Gloucester material by Satu Valoriani at Liverpool John Moores University. A craniometric analysis of the Chester Greyfriars material was carried out by the author and presented in this thesis.

Postcranial indices

The postcranial indices of the Chester Greyfriars individuals were recorded by the author for the purposes of the osteology report and are presented in this thesis to provide further context for the influence of robusticity on bone preservation. Postcranial indices were observed on the Chester Greyfriars adult individuals (n=15) to assess the robusticity of the humerus and femur. The assessment was not carried out on the Poulton or Southgate Street, Gloucester samples, with no further research planned to complete this assessment.

Non-metric traits

The non-metrics within the Poulton Chapel and Gloucester collections were studied in detail by Carla Burrell during the completion of her PhD thesis at Liverpool John Moores University. An analysis of 32 non-metric traits was carried out for the skeletons recovered from Chester Greyfriars (n=20) as part of the osteological contract, with the information presented in this thesis. This will enable potential familial links (Saunders, 1989), or the impact of environmental or mechanical stress on the skeleton (Trinkhaus, 1978; Kennedy, 1989), to be explored.

Pathology and trauma

The trauma and pathology exhibited within the collections in this thesis was not studied in detail for the purposes of this thesis, due to the volume of material to assess. However, the trauma and pathology has been covered as part of other research projects at Liverpool John Moores University. Burrell *et al* (2016a; b) have investigated the prevalence of Paget's disease and fracture rates in medieval populations. The spinal pathology types and rates of Poulton Chapel and St Owens were compared by Clair Richardson for MPhil research and Sharon Martin has documented the full epidemiology of the Southgate Congregational Church and Gloucester Infirmary burial ground. The pathology present on the Chester Greyfriars sample has been recorded by the author for the purposes of the osteology report, with the information will be presented in this thesis to provide further context for the influence of pathological conditions on preservation.

Occupational markers

Occupational markers were not examined in detail for all samples as part of this research. However, the analysis of the human skeletal material from Chester Greyfriars was examined for evidence of past activity or occupation as part of the osteological report, with the results provided in this thesis.

Inter- and intra-observer error

The accuracy of the assessments are dependent on the completeness of the skeletal remains (Meindl *et al*., 1983, Mensforth and Lovejoy, 1985), and the experience of the researcher in applying the techniques. Inter- and intra-observer error assessments were carried out on age and sex estimates to determine the levels of consistency among the observational ratings applied in this study. For inter-observer error, the Poulton Chapel and St Owens, Gloucester collections were assessed by the author and a second observer with a similar level of experience in the biological profiling of human skeletal remains. Both analyses were carried out independently from each other as part of separate projects, with the resultant profiles used for this testing. Intra-observer error was carried out on both samples by the author, with the analyses of the individual skeletons carried out at least a year following initial profiling to ensure that no information was retained from the prior assessment.

For each collection and variable (age or sex), Cohen's Kappa coefficient (Cohen 1960) was assessed in SPSS v.23, with the resultant statistical output presented in this thesis. Cohen's Kappa ranges from -1 to 1, with greater numbers indicating better reliability and numbers less than zero indicating any agreement is more likely due to chance. Landis and Koch (1977) recommended benchmarks to interpret the Kappa statistic produced from the statistical analysis (Table 2.15).

Table 2.15. Recommended benchmarks as described by Landis and Koch (1977).

Kappa (κ) Statistic	Strength of Agreement
<0.00	Poor
0.00-0.20	Slight
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Substantial
0.81-1.00	Almost Perfect

2.7. Geochemical studies on human material

Radiocarbon dating

At the start of this research, there was only one radiocarbon date available from the medieval Poulton Chapel and no dates were available from the skeletal remains at the other four sites. Although there are estimated start and end dates for the chapels at all sites, the timespan for when the cemeteries were in use may differ, which would have an impact on any subsequent palaeodemographic analysis.

Radiocarbon dates (n = 6) were included in the post-excavational analysis for Chester Greyfriars by Stephenson Developments to determine the timespan for the cemetery use at the excavated locations. For Poulton Chapel and St Owens, Gloucester, an application to obtain further radiocarbon dates for the Poulton Chapel and St Owens, Gloucester collections was submitted to the NERC radiocarbon laboratory in Oxford. In 2016, the initial application was not successful for this testing, with a further application planned as part of future projects. During the course of this research, funding was obtained to submit further samples for Poulton Chapel, with the results discussed later in this thesis.

Sample preparation: An adult tooth (preferably 2nd molar or canine) with complete roots was required from each skeleton selected for radiocarbon dating (Figure 2.10). Each tooth was photographed prior to extraction and then carefully removed to prevent any damage to the alveolar socket. To maximise the potential for results, each tooth was chosen on the basis that it had minimal dentine exposure, no caries and no damage to the crown or root.

All samples were photographed and then sealed in a Ziploc bag prior to sending for analysis. For the Poulton Chapel samples, only the root was requested with the crown retained by LJMU for future testing. However due to a change in protocol, when sending the samples for Chester Greyfriars, the whole tooth was requested, so that the roots could be used for radiocarbon dating and the crowns for stable isotope analysis (carbon and nitrogen). All samples sent for combined radiocarbon dating and stable isotope (carbon and nitrogen) analysis were sent to Beta Analytic (Beta Analytic Inc. Miami, Florida, USA).

Figure 2.10. Left upper second molar from skeleton 004 from Chester Greyfriars selected for radiocarbon dating and palaeodietary isotope analysis, showing occlusal view above and buccal surface below. ©CAL Davenport.

Stable isotope analysis

The analysis of palaeodiet through stable isotopes has become increasingly used in the past few decades to provide information on the lifestyles of archaeological populations for some time (Bentley 2006; Katzenburg and Harrison 1997; Schoeninger and Moore 1992). To determine whether dietary differences between rural and urban medieval populations could have influenced the average life expectancy of individuals from Poulton Chapel, St Owens, Gloucester and Chester Greyfriars, carbon and nitrogen stable analysis testing was carried out using a range of samples.

Dental collagen

For Poulton Chapel and St Owens, Gloucester, an application to obtain carbon and nitrogen values for the Poulton Chapel and St Owens, Gloucester collections was submitted to the NERC radiocarbon laboratory in Oxford. The initial application submitted in 2016, was not successful, with further applications planned as part of future projects. During the course of this research, funding was obtained to submit two samples for Poulton Chapel, with the results discussed later in this thesis.

Carbon and nitrogen stable isotope analysis (n = 6) was included in the post-excavational analysis for Chester Greyfriars by Stephenson Developments to analyse the palaeodiet of this sample together with the radiocarbon dates requested. Samples were selected using the same protocol as those selected for radiocarbon dating, with the samples sent to Beta Analytic (Beta Analytic Inc. Miami, Florida, USA) for testing.

Dental calculus

When assessing bioarcheological remains for palaeodietary analysis, there is often concern regarding the processes used to obtain results (Poulson *et al.* 2013). Until recently, destructive sampling on bone/teeth has been the primary option to understand the impact of diet on the biochemical components of the human skeleton. As a potential alternative, new research has been carried out to determine if dental calculus (Figure 2.11) has sufficient carbon and nitrogen to provide reliable estimates of stable isotope compositions largely consistent with those derived from conventional biomaterials.

Figure 2.11. Mandibular dentition with dental calculus adhered to the labial and buccal surfaces of the teeth. © G. Richard Scott.

Sample preparation: Approximately 30mg of calculus was collected from the dentition using a dental pick, wrapped in tin foil, bagged and labelled clearly with the details of the skeleton the sample had originated from. The samples were packaged and sent to Professors G Richard Scott and Simon Poulson at the University of Nevada, Reno, USA, for carbon and nitrogen isotopic analysis, as part of a collaboration project to investigate the potential use of this biofilm material for dietary analysis.

The calculus samples were washed in deionised water, air-dried and then powdered using a pestle and mortar. Approximately 5-10mg of dental calculus was used for each analysis to determine elemental concentration and stable isotope results. The samples were analysed after the method of Werner *et al*. (1999), using a Eurovector elemental analyser interfaced to an Isoprine stable isotope ratio mass spectrometer. A second sample of calculus underwent acid extraction to separate the organic and inorganic carbon components. The organic carbon samples were then re-analysed using the same method mentioned above to determine whether there is a difference in the isotopic values produced.

Samples were collected by the author and then sent to Professors Simon Poulson and G. Richard Scott at the University of Nevada, Reno, USA, for analysis using the above protocols. This work was part of a National Science Foundation Award for a project entitled, 'Testing Stable Isotopes of Human Dental Calculus as a Nondestructive Proxy for Paleodiet' (NSF PLR-1335302). The stable isotope results obtained were sent to the author for dietary interpretation. The sites included in this testing phase were Poulton Chapel (*n* = 28), St Owens (*n* = 26), Southgate Congregational Church (*n* = 4) and one from Gloucester Infirmary burial ground.

Hair keratin

There was no plan to send any hair samples for stable isotope testing as part of this research. However, a number of the coffin burials excavated from Gloucester Congregational Church (n = 4) provided hair samples, which were recorded to provide evidence for the differential preservation of the remains (Figure 2.12). When preparing the calculus samples to send to the University of Nevada, the potential for a comparison to the calculus values arose and a hair sample was collected from skeleton II191 from Southgate Congregational Church. This sample was sent with the calculus and the results are included in this thesis.

Figure 2.12. An example of the hair samples that survived with the skeletal remains of skeleton LC1a, a lead-lined coffin burial from Gloucester Congregational Church. ©CAL Davenport.

2.8. Demographics

The age estimations were grouped into five-year age categories (with further one-year categories for individuals less than 10 years-at-death) to account for any error in the estimates. Sex determination allowed the differences in demographic profiles between the sexes. The initial data is then used to plot the number of individuals in each age category or the mortality curve. Figure 13 was produced following the first year of the research from the data collected at Poulton Chapel. The sample size was not complete and the ages below five years were not combined in this example. This curve demonstrates the percentage of the sample that died in each five-year period. It can clearly be seen in this curve the high percentage of non-adults that were lost in the 5-9 year age category. The 0-4 year age category is split into single year intervals, all of which demonstrate a higher percentage of deaths than some of the later age intervals. It should be noted that both articulated and disturbed burials were used for this example.

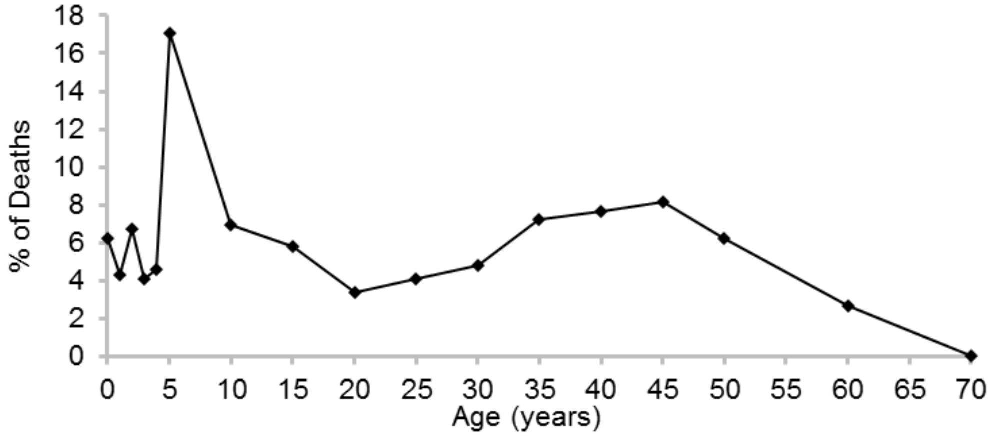

Figure 2.13. Mortality curve from Poulton Chapel data collected by the end of year one (n = 515).

The survivorship curve shows the percentage of the sample that survives at the end of each five-year period (figure 14). It is the reverse of the mortality curve (Ubelaker, 2008), but can be used to compare the demographics to other samples to determine the differences in the profiles.

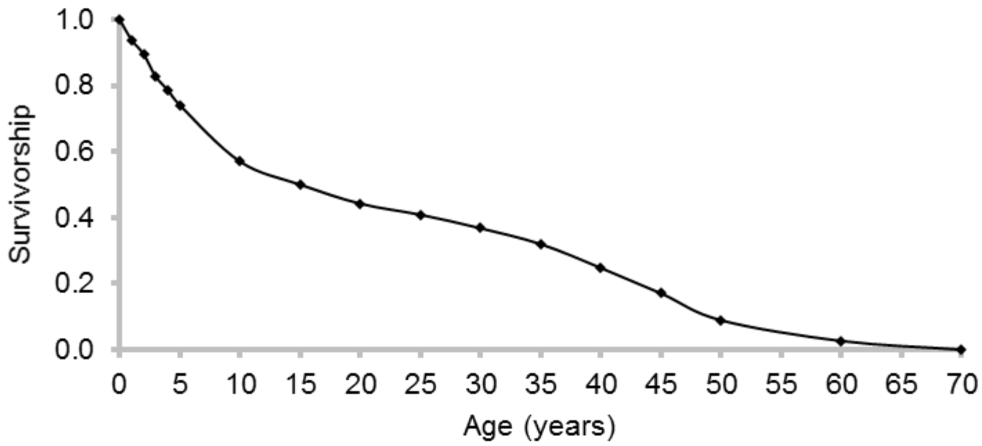

Figure 2.14. Survivorship curve from Poulton Chapel data collected by the end of year one (n = 515).

The data provided by the age estimations can also be used to produce a life table. The table can provide information on the life expectancy of an individual at each of the five-year intervals. The life table categories are calculated from the age estimates and number of individuals in each interval (Ubelaker, 2008). For each age category, the following information is recorded:

x	Age interval
Dx	Number of deaths
dx	Percentage of deaths
lx	Survivors entering age interval
qx	Probability of death
Lx	Number of years lived by all individuals during the age interval
Tx	Total number of years of life remaining for the rest of the population
e°x	Average number of years each individual entering the interval can expect to live

A reduced life table was produced for the Poulton Chapel data at the end of the first year of research (Table 2.16). In this, the large percentage in deaths below five years of age demonstrates how life expectancy from a young age was low. Almost 42% of the sample did not survive past 10 years of age. Conversely, those who survived to ten years of age could expect to live a further 25 years on average based on the demographic analysis, although life expectancy gradually decreased from this age onwards.

Table 2.16. Life table reconstructed from Poulton Chapel (n = 416) on which macroscopic age analysis was possible.

Age Interval (x)	No. of Deaths (Dx)	% of Deaths (dx)	Survivors Entering (lx)	Probability of Death (qx)	Life Expectancy (e°x)
0	26	6.25	416	0.063	22.097
1	18	4.33	390	0.046	22.537
2	28	6.73	372	0.075	22.603
3	17	4.09	344	0.049	23.403
4	19	4.57	327	0.058	23.593
5	71	17.07	308	0.231	24.018
10	29	6.97	237	0.122	25.464
15	24	5.77	208	0.115	23.666
20	14	3.37	184	0.076	21.427
25	17	4.09	170	0.100	17.985
30	20	4.81	153	0.131	14.706
35	30	7.21	133	0.226	11.541
40	32	7.69	103	0.311	9.175
45	34	8.17	71	0.479	7.183
50	26	6.25	37	0.703	6.486
60	11	2.64	11	1.000	0.000

The crude mortality rate gives the average number of deaths per 1000 individuals in a population each year (Ubelaker, 2008). It is calculated from life expectancy at birth:

$$M = \frac{1000}{e^{\circ}}$$

For the example used from Poulton Chapel, this would be approximately 45 people that would die per 1000 individuals in a population each year. From this it is possible to estimate the population size required to sustain the cemetery and number of burials present there.

This is calculated from the number of individuals included in the demography (N), the crude mortality rate and the length of time the cemetery was in use (T):

$$P = \frac{1000\ N}{MT}$$

For the example given by Poulton Chapel, based on the overall timespan of the site (343 years), the population size would be approximately 27 individuals. It should be noted that this estimate is based on the assumption that there was no movement in or out of the community. As no stable isotope analysis using oxygen, strontium or lead, has been carried out at the sites, it is not possible to determine the rate of migration into or out of the community. Furthermore, it should be noted that the sites undergoing demographic analysis are not currently fully excavated and therefore the population size is likely to increase as the excavation continues. Therefore, the population estimate given is the minimum number of individuals required to sustain the number of burials present at the cemetery over its lifespan.

Demographic analyses were carried out at Poulton Chapel and St Owens for comparison between the sites and to published medieval sites. Southgate Congregational Church underwent demographic analysis for comparison to the parish records. This would indicate whether the material available for analysis is representative of the cemetery sample. The Infirmary Burial Ground (n=25) and Chester Greyfriars (n=20) were not included in the demographic analysis, as the sample size available is not large enough.

2.9 Rural and Urban comparison sample sites

The typical demographic profile of a rural medieval sample has not been identified due to the small number of published sites that have been studied in the UK (Lewis and Gowland, 2007). Although in-depth comparisons between the Poulton Chapel and St Owens Church show differences in the profile, comparison to published cemetery sites will enable the evaluation of the differences between rural and urban sample demographics. Therefore, data on British medieval monastic samples has been collected from the Archaeology Data Service (ADS) published data compiled by Research Fellow Barney Stone, following the award of a major research grant by the Arts and Humanities Board (now Council) in 1999 (Gilchrist and Sloane, 2005). The research grant was awarded to undertake a national survey of medieval burial practice from excavated cemetery samples. Additional data from the sites of St Mary Spital (Connell *et al*, 2012) and Wharram Percy (Mays *et al*, 2007) were also included.

The cemeteries represent a variety of cultures and burial practices, including Jewish, cathedral and emergency cemeteries. Each of the cemeteries served the local community, ensuring the demographic profile is representative of the sample residing in the immediate area. The data available for each cemetery lists the basic biological profile for each individual interred with age separated into ranges, as shown in Table 2.17, which enabled direct comparison of the samples. The data collected from the osteological analyses of Poulton Chapel and St Owens Church were also placed into the broader age categories for comparison.

Table 2.17. Age categories assigned to the medieval cemetery samples studied as part of the Arts and Humanities Research Board grant in 1999.

Category	Age
Foetal	Pre-birth (<0 years)
Infant	0-5 years
Non-adult	6-10 years
Immature	11-15 years
Young Adult	16-25 years
Adult	26-45 years
Old Adult	46+ years
General Adult	16-46+ years
General Immature	6-15 years
No Age Established	N/A

Of the 76 sites listed on the Archaeological Data Service (Gilchrist and Sloane, 2005), 20 were selected as demographic comparison sites (Table 2.18), based on the total number of burials (*n*>100) and the cemetery type (urban or rural). A brief description and overview for each of the demographic comparison sites is provided in the following sections.

Rural Site descriptions

Linlithgow Whitefriars (*n*=207) produced the lowest estimate of all sites and was noted to have unusual cemetery samples in both the chapel and the friary phases identified (Lindsay, 1989). The chapel phase demonstrated an unusual population demographic due to its sex bias of 0.26 males to each female and high number of non-adult burials (54% of the chapel population). The friary was founded in 1401, with the chapel present on the site since the mid-13th century. The cemetery linked to the friary also showed a sex bias, with 0.88 males to every female present, a non-adult population comprising 47% of the total sample and the elderly accounting for 3%. Friary cemeteries are usually male dominated, with the lay population being burial elsewhere, however the high number of females present in the cemetery at Linlithgow suggests that the strict rules observed in urban friaries may have been more relaxed in the rural setting.

SS Peter and Paul was an Augustinian priory (1158-1538) which had a longer timespan than Linlithgow Whitefriars, but fewer burials (*n*=158) were recovered from the area of the cemetery which underwent excavation, which could lead to a discrepancy in the results (Gilchrist and Sloane, 2005). The area of cemetery excavated was given a *terminus post quem* date of the later 14th century due to the burials overlying a bell pit, which could be

Table 2.18. All urban and rural medieval sites used in the demographic comparison, along with the life expectancy at birth listed for each.

Name	Location	Rural/Urban	Total No. of burials	Founded	Dissolved
Aberdeen Whitefriars	Aberdeen	Urban	121	1273	1559
Carlisle Blackfriars	Carlisle	Urban	214	1233	1539
Carmarthen Greyfriars	Carmarthen	Urban	154	1284	1538
Chelmsford Blackfriars	Essex	Urban	134	1277	1538
Holy Trinity/St. Mary Graces	London	Urban	1,214	1348	1538
Hull Austin Friars	Yorkshire	Urban	255	1316	1538
Ipswich Blackfriars	Suffolk	Urban	250	1263	1538
Linlithgow Whitefriars	W. Lothian	Rural	207	1401	1570
Norwich Greyfriars	Norfolk	Urban	136	1226	1538
SS James and Mary Magdalene	Sussex	Urban	386	<1118	1621
SS Peter and Paul	Somerset	Rural	158	1158	1538
St. Andrew Fishergate	York	Urban	272	1200	1538
St. Clement	York	Urban	249	1130	1536
St. Nicholas	Sussex	Urban	102	<1085	1810
St. Oswald	Gloucester	Urban	602	1153	1536
St. James	Avon	Urban	284	1129	1538
St. Mary Merton	Surrey	Urban	727	1117	1538
St. Mary Stratford	Langthorne	Urban	654	1135	1538
St. Martins, Wharram Percy	Yorkshire	Rural	687	950	1538
Poulton Chapel	Cheshire	Rural	836	1086	1519
St. Mary Spital	London	Urban	10,516	1040	1539
St. Owens Church	Gloucester	Urban	222	<1100	1643

*No of Individuals – the total number of individuals included in the demographic analysis.

dated to this point, and was thought to be in use until the dissolution of the friaries in 1538. This site showed no sex bias, although the number of non-adult burials was high as with the other sites (33%) and elderly burials remained low (9%).

St Martins at Wharram Percy (950-1538) was a medieval parish church serving a population of approximately 70 individuals at its peak based on the archaeological evidence from the excavation of the surrounding village (Mays *et al*, 2007). However, the excavated skeletal sample places this estimate at 20 individuals (20.31), suggesting that the population size may have fluctuated over time. As with the other rural sites, the life expectancy at birth was low (20.14 years), with a top end age estimation category of 45+ years using the archaeology data service categories. Of the excavated sample, 52% (*n*=313) were non-adult burials, with 32% of these falling in the 0-4 year age category (including neonates). The high percentage of individuals from this 0-4 year age range have contributed to the low life expectancy at birth (20.14 years) given when using the Archaeology Data Service (ADS) age estimations.

Urban site descriptions

Aberdeen Whitefriars (1273-1559) was a Carmelite friary based in Scotland with a small excavated sample, which could provide age estimations for demographic analysis (95/201 burials). It is thought that the burials recovered dated from the mid-14th century until 1559, which was later than the dissolution of the friaries (1538). The life expectancy at birth was calculated to be 26.26 years, non-adult burials totalling 20% of the overall sample (Stones *et al*, 1989). There was a slight sex bias identified at this site, with 1.6 males for each female recovered. The site has only been excavated as required for building or development work, therefore the sample is incomplete. Evidence of construction work that had taken place prior to the excavations was also found, with sewer pipes displacing some of the individuals The number of non-adults and females present in the sample, indicate the excavation uncovered part of the lay cemetery, rather than that of the friars, which would be interred elsewhere.

Carlisle Blackfriars (1233-1539) was a Dominican friary which uncovered 214 burials, with 107 of these included in the demographic analysis (McCarthy, 1990). The burials were recovered from the cemetery north of the church, and from within the church itself. The skeletons were mainly adult, with only 6.3% of the sample represented by non-adult burials. The life expectancy at birth for this site was 30.25 years. There was a slight male bias at the site, which is to be expected of a friary, with 1.88 males to every female, of these 8.2% of the samples were classed as elderly. The site of Carlisle Blackfriars has not been fully excavated, making the sample incomplete.

The site of Carmarthen Greyfriars (<1284-1538) was a Franciscan friary, which provided information on 154 burials from the Archaeology Service Database (Gilchrist and Sloane, 2005), of which 112 were available for demographic analysis. The burials were excavated from the east cloister walk, chapter house, choir and northern cemetery. There was a male bias of 4.4 males to every female at this site, with 12% of the aged sample representing the non-adult sample; life expectancy at birth was calculated as 31.23 years. Although multiple excavations have been carried out on this site (James, 1997; Manning, 1998), it is not fully excavated, making the sample incomplete.

Chelmsford Blackfriars (1277-1538) in Essex was a Dominican friary represented by 134 burials containing 145 skeletons (Gilchrist and Sloane, 2005). Of the sample represented on the Archaeology Service Database, 72 could be used for the demographic comparison, with a life expectancy at birth given as 31.28 years. A slight male bias was identified at the site, with 1.5 males for every identified female. Those identified as elderly represented 9% of the sample, with 10% of the aged consisting of non-adults.

Holy Trinity (1348-1538) in London was used as a Black Death cemetery between 1348 and 1350, before becoming St Mary Graces, a Cistercian Abbey. The cemetery was split into three sections: the Black Death cemetery, the abbey (church, cloister and cemetery), and a later cemetery, which was thought to be in use during later plague epidemics (1350-1400). The Black Death cemetery comprised of three mass graves and a number of single graves (Grainger *et al*, 2008), with there being a minimal sex bias of 1.3 males to every female and a non-adult burials comprising 29% of the total sample. The age estimation top-end age estimation band was noted as 45+ years, with 12% of adult individuals falling within this category. The Abbey burials had a stronger sex bias, with 2.75 males to every female, a non-adult sample of 11% and elderly burials comprising 17%. The later plague cemetery was similar to the Black Death cemetery, with 1.25 males for every female, 12% of which were categorised as elderly. Approximately 22% of the sample from this cemetery was non-adult. As the cemeteries covered the same period, the demographic profile consisted of those from all three burial locations, which produced a life expectancy at birth of 24.83 years. The excavations on the site were vast and covered most of the site, making this one of the more complete urban samples for study.

The Augustinian friary of the Hull Austin Friars (1316-1538) in Yorkshire produced 255 burials from the church, cloister alleys, garth and northern cemetery, with a life expectancy at birth of 33.17 years. The skeletons revealed a sex bias of 2.6 males to every female, with 15% of these classified as elderly and 13% of the sample were non-adult burials. There was no information available on the extent of this excavation through the Archaeology Data Service, so it is not known whether the excavations are complete.

The Dominican friary, Ipswich Blackfriars (1263-1538), produced 250 burials from the 1983-1985 excavations of the church, cloisters, chapter house and southern cemetery (Mays

1991). Life expectancy at birth was calculated at 34.61 years, from a sample represented by mainly adult burials (90%), with a male bias of 2.3 males to every female, 24% of which were classified as elderly. Excavations that were carried out in the late 19th century also produced burials; however, the information regarding the demographics for these individuals is not available (Gilchrist and Sloane, 2005).

Norwich Greyfriars (1226-1538) was a partially excavated Franciscan friary producing 136 burials, which could be used in the demographic analysis, producing a life expectancy at birth of 27.20 years. This urban site had a high proportion of non-adult burials (32%), and 62% of the total aged sample died before the age of 30 years. There was a sex bias, with 5.6 males to every identified female burial.

The leper hospital of SS James and Mary Magdalene (<1118-1621) in Sussex was excavated in two phases (1986-1987 and 1993) producing 386 skeletons (Magilton *et al*, 2008). From which 358 provided age estimations for demographic analysis, with non-adults representing 26% of the total aged samples. There was a sex bias of 2.4 males to every female, of which 22% were classed as elderly (45+ years).

The Gilbertine priory of St Andrews (1200-1538) in Fishergate, York produced 272 burials from the excavations of the church, cloisters, chapter house and eastern cemetery (Kemp and Graves, 1996). The demographics were assessed from the 236 individuals that provided age estimations, with a life expectancy at birth of 36.29 years. The excavations had identified clear zones where the number of burial increased, with 93% of the burial in the eastern cemetery identified as male. Overall, there was a sex bias of 3.2 males to every identified female, with 36% of the adult skeletons identified as elderly (45+ years). The non-adult burials represented 14% of the overall aged sample.

St Clements (1130-1536) in York was a Benedictine nunnery that produced the remains of 249 articulated and disarticulated skeletons (Gilchrist and Sloane, 2005). The emergency excavation carried out on the site meant that plans were not available to determine the locations of the burials and the skeletal catalogues produced present discrepancies in the number of skeletons analysed. Of the skeletons that were analysed, age estimations were available for 140 individuals, which presented a life expectancy at birth of 30.82 years. The sex bias at St Clements identified 0.44 males to every female present, with 9% of the adult sample identified as being elderly (45+ years). The non-adult burials represented 14% of the total aged sample.

St Nicholas (1085-1810) in Lewes, East Sussex was a hospital that was controlled by the priory in Lewes and thought to have been established as an infirmary for the poor (Barber and Sibun, 2010). The site was excavated due to planned construction works to take part on the site, with a portion of the hospital cemetery uncovered during the works. The burials

(n=103) that were included in the demographic comparison for this site were from the northern cemetery of the hospital. There was a sex bias of 4.25 males to every female, only 3% of which were classed as elderly. There was a small non-adult sample (8%) identified in this cemetery, however, it should be noted that 34% of the sample was represented by young adults.

St Oswald in Gloucester (1153-1536) was an Augustinian priory, which was founded on the site of the former minster (Heighway and Bryant, 1999). The 214 burials excavated from this site ranged from the early to late medieval periods. There was a large non-adult sample (36%) identified, with a further 8.4% of the burials identified as elderly. The number of males to females was fairly even, with 1.3 males to every female identified.

The Benedictine priory of St James (1129-1538) in Bristol was a partial excavation of the cemetery, with two trenches producing 284 skeletons (Gilchrist and Sloane, 2005). Of the sample available for demographic comparison, 14% were non-adult burials, half of which were infants. There was a sex bias of 3.3 males to every female identified.

St Mary Merton (1117-1538) was an Augustinian priory in Surrey, which produced a large skeletal assemblage of 727 burials from the church, cloister chapter house, and the north, south and west cemeteries (Gilchrist and Sloane, 2005). The number of skeletons available for the demographic comparison was 564, which showed a significant sex bias with 11.2 males to each female, of which 28.5% were classed as elderly (45+ years), and a small non-adult sample of just 1.5%.

St Mary Stratford (1135-1538) in Essex was a Savignac abbey before merging with the Cistercian order in 1147 (Barber, 2004). The excavations of the northeastern cemetery and church produced 654 burials, with 538 providing data for the demographic comparison. A large sex bias of 19.8 males to every female was observed during the skeletal analysis, of which 23% were classed as elderly (45+ years). There was a small non-adult sample, which accounted for 4% of the aged burials.

St Mary Spital (1197-1538) in London was a large Augustinian priory and hospital, which produced 10,516 burials during the excavations carried out by the Museum of London between 1991-2007 (Thomas *et al*, 1997; Connell *et al*, 2012). Osteological analysis has been carried out on 5,387 skeletons to date, of which 5,202 are included in the demographic comparison. The skeletons were recovered from the cemeteries in the south and west, as well as the chapel. A targeted approach of combining stratigraphic analysis with radiocarbon dating has led to the different phases of the site being identified. The site overall has provided a life expectancy at birth of 28.90 years. The earlier phase of the south cemetery, the west cemetery and chapel observed a small sex bias of 2.2 males to every female, with 11% categorised as elderly (45+ years). The non-adult burials represented 29% of the overall age sample from the earlier phases. The later southern cemetery observed a sex bias of 0.62 males for every female identified, and a non-adult burial represented 10% of the aged sample.

Chapter 3 - Poulton Chapel, Cheshire

3.1. Site background

Poulton (SJ 4037 5836) is located approximately three miles south of Chester (see figure 3.1), alongside before the England-Wales border. It has been suggested that it may have been an important trading route for Chester. The discovery of Roman roads on the site suggest possible trade routes to the city; or perhaps religious significance given its prominent position, due to archaeological evidence of an Iron Age Roundhouse complex, Roman Abbey and associated grange, and the medieval chapel and Cistercian Monastery (*pers. comm.* Dr. Kevin Cootes, 2017). The cemetery remains recovered from the Medieval Poulton Chapel are considered in this PhD thesis.

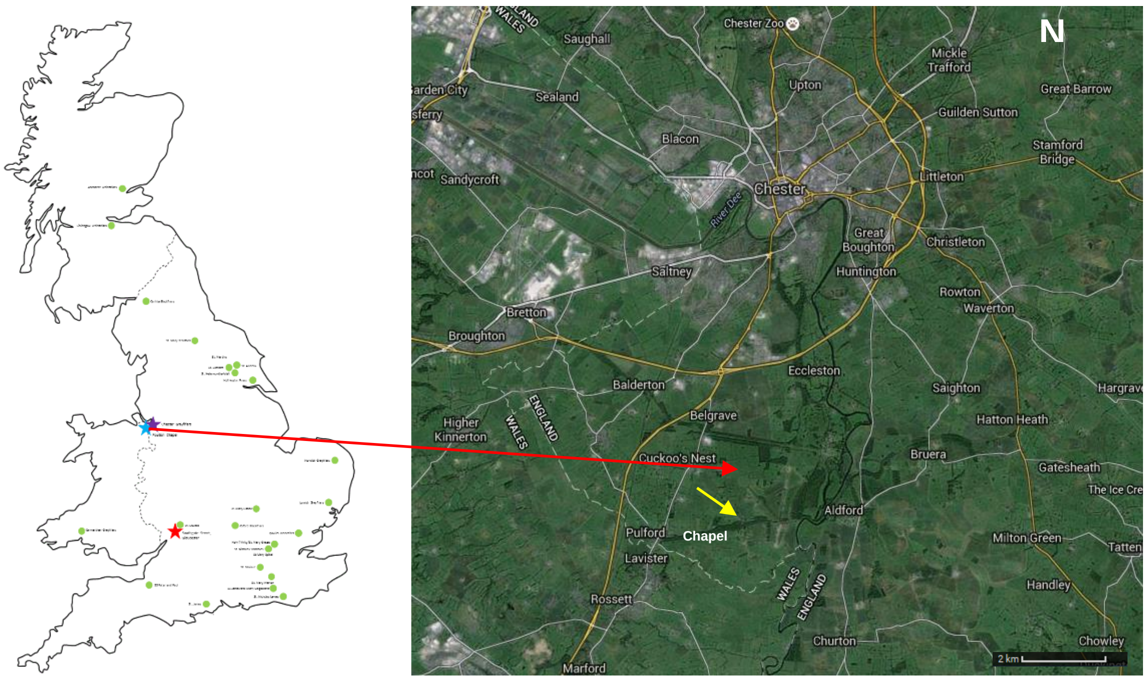

Figure 3.1. The location of the village of Poulton is approximately three miles to the south of Chester city (red arrow), with the Chapel located close to the England-Wales border (yellow arrow).

The Domesday Book (1086) provides the first documented mention of Poulton, providing evidence that the village predated the Cistercian Abbey and grange founded by Robert the Butler between 1146 and 1153. The entry in the Domesday Book reads:

> 'Ricardvs pincerna ten de com PONTONE. Eduin tenuit. 7 lib ho fuit. Ibi i hida geld. Tra e. v. car. In dnio sunt. iii. car. 7 vi. bouar. 7 pposit 7 iii. bord. cu. ii. car. Ibi. viii. ac pti. T.R.E. ualb. xl. sol. 7 post tntd. Modo. iiii. lib'
>
> (Domesday Book, 1086. Catalogue reference: E 31/2/2/2851)

The entry translates to:

'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 five ploughs. In demesne there are 3 ploughs and 6 ploughmen; a reeve and 3 smallholders with 2 ploughs. There are eight acres of meadow. In the time of King Eadweard the Confessor it was worth 40s; later the same. Now £4.'

(Emery *et al,* 1996, p6)

Richard Pincerna also held Calvinton, which was mentioned in the next entry in the Domesday Book (Morgan, 1978) and lay beside Poulton (Figure 3.2). Further evidence exists from the ceramics recovered from the earliest phase of the chapel, which suggests the chapel could have been in use as early as the 10th century. Further work is underway to establish whether the chapel at the site has Anglo-Saxon origins (pers. comm. Dr Kevin Cootes, 2017).

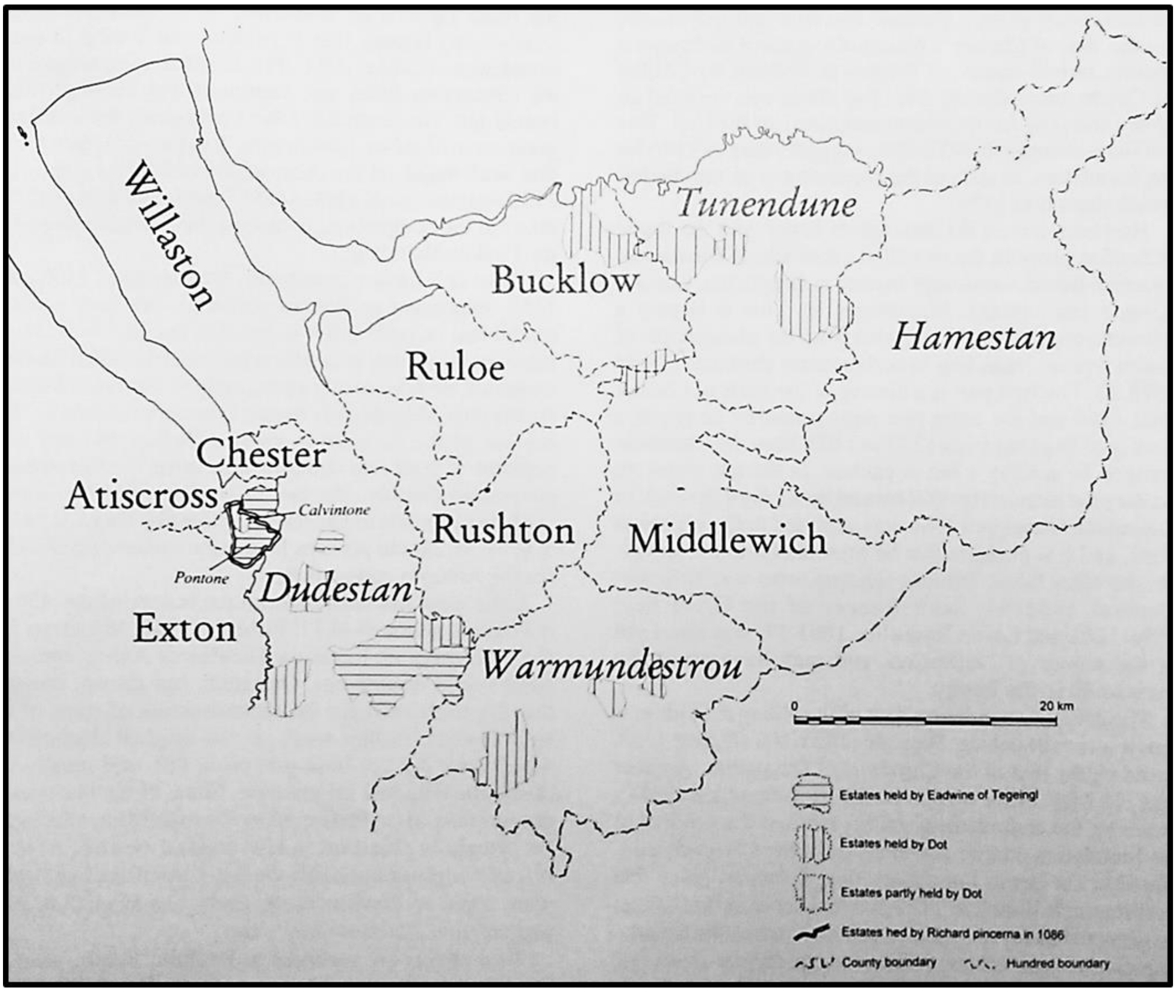

Figure 3.2. Map of Domesday holdings, with the location of Pontone (Poulton) highlighted. After Emery *et al* (1996).

The Abbey of St Mary and St Benedictine was one of three daughter houses to Combermere Abbey in Cheshire. The Abbey was only in use for approximately 60 years, with it stated that one of the reasons the abbey was relocated to Leek, Staffordshire in 1214 was the repeated attacks by Welsh marauders leading to many of the monks sustaining injuries (Fisher, 1984). The monks were relocated to Dieulacres Abbey, with the site of Poulton Abbey becoming a monastic grange cared for by lay brothers (*conversi*). The location of the Abbey was lost over time and is still unknown to this day. Documentary evidence of the chapel itself is rare, although a '*Certificate of the Abbot of Dieulacres that his Chapel in Poulton is to be no prejudice to the mother church*' dating to 1250, provides the earliest mention to date (Ormerod, 1882).

In 1493, the Abbot of Dieulacres leased both land and buildings (including the chapel) to John Manley, with his son (also named John) being named as the leaseholder in 1504. This new lease was for a duration of 89 years, with a rent of £50 per year. It is believed that during the lease of the Manley family, the chapel was retained as a private place of worship and burial. The last recorded burial at Poulton chapel took place following the death of Sir Nicolas Manley (~1450-1519), as per his request in his will (dated May 1519):

> 'I Nicholas Manley, whole of body and perfect of mind, intending to avoid discord after my death, make my will. My body to be buried in the chapel of Pulton in the Chancel. After my death and my wife's a priest to be found to sing there for my soul... Residue of the issues to be spent on the chapel of Pulton... Henry Manley, my son, to have my farme and holding, held of the Abbot of Dieulacres... provided that he dwell in the hall of Pulton wherein I now do dwell, and do not sell without the advice of my executors.'
>
> (Emery *et al*, 1996, p81)

In 1544, following the dissolution of the monasteries (in 1538), the chapel and surrounding lands were granted to Sir George Cotton, although the Manley family retained their lease. In 1601, the last male Manley heir died childless resulting in the estate being passed to his widow's family, the Grosvenors. Although the chapel site is now owned by Richard Fair, a local dairy farmer, it is still accessed through Grosvenor land.

During the English Civil War (1642-1651), evidence supports the theory that the chapel was used during the siege of Chester (1645-1646) as stables and a lookout post due to the high vantage point and strong structure of the tower (Emery, 2000). Parliamentarian troops were stationed in the villages of Farndon, Aldford, Dodleston and Eccleston, which surround Poulton, due to the protracted siege of Chester by the Royalists which ended in 1646 (Carrington, 1994). Documentary evidence from the Parliamentary commander, Sir William Brereton, called for guards for Poulton Hall and Green. The first was a letter sent by Sir William Brereton to Colonel John Jones on 7th January 1646:

> ‘Col. John Jones
> 4pm. I send you verbatim the intelligence that I have received this instant. This last night there came 11 men from Chester to Holt and are to return this night. One [John] Starre is come from Chirck thither this morning with a great packet which is going into Chester this night. Pooton Green and Wayrooke's bridge are the places to be watched. It is of great consequence to intercept these men and letters. At this time your sentries must be doubled, one behind another, esle some of them will pass our single watches. The forces about Denbigh have some sudden design in hand. They send their scouts as far as Yale and take up horses in the country and keep those together. My intelligence thinks they will part this night on this side Ruthin. If they come so near, they will attempt another relief or storming of some quarters. Slight not these advertisements. I have them from good hands. Remember to send us powder and match.
>
> (Emery *et al*, 1996, p82)

The second letter, which was sent by an unknown author ‘…to a loving friend’ and believed to have dated from around the same date is:

> ‘I am sorry to see so many as I do pass to Chester and back again, but I hope this my letter will make you more careful. There comes every day in the week four men and carry provisions in of the best, as pigs, turkeys and other things for the great men, which makes them stand out so. Some times there comes six or seven men and some of them carry pike staves on their shoulders. The way they go is through the Neerhackes and Pooton and along the water to Eaton. Sometimes they go through the fields betwixt Poulton Green and Pulford and so to the Gorstelow behind Dodleston. I pray be careful to set a strong guard on Poulton Green and one by the waterside by Poulton Hall near Eaton Boat and one at the Gorstella in the fields. But especially let there be a private guard of foot in the Werhacks near the bridge under some hedge, and you may be sure to take those wicked men who do a great deal of hurt. Their times of going from the Holt is two or three hours within the night and when they come back from Chester is about three or four o'clock in the morning. The Lord direct you that you may take these vile fellows. They report to friends in private that Chester is in a poor condition and can hold out but seven or eight days without relief. Have a strong coy on this side the water for there is provision providing for relief of Chester within this four or five days. Ld. St. Pol, general of the horse in Chester, is come out to hasten the relief. Sir Rich. Lloyd

reports there will be relief at Holt within this five or six days. Have a special care of the sands that go over the water betwixt Flint and Hawarden for, as I hear, they will venture over and relieve Chester in at the Watergate. Have a careful regard on Poulton Green and see they make no private way for horse to march that way. Sir Rich. Lloyd sent for hay to Aldford and Barton and for 40 loads to Escoyde. If you can prevent him the saieth forces will come to Holt. Have an eye on High Ercall Chirck and the mountains for, take my word, there are forces in private drawing nigh. Be not careless of this letter, but let your general see it and seriously consider of it, and the Lord give us a blessing. They that bring you this letter will tell you my name; let it be known to none.'

(Emery *et al*, 1996, p82)

During the excavation at Poulton Chapel, a number of musket balls have been recovered, along with flint exhibiting strike marks, which provide evidence for skirmishes occurring at the chapel around the time of the English Civil War (Figure 3.3). The siege of Chester ended less than a month following the delivery of the letters, when Lord Byron surrendered the city of Chester to prevent the starvation of those living within the city. The site was reported to be in a state of disrepair in 1673 by Sir Peter Leycester, with Bishop Gastrell (Raines, 1845) stating in 1718 that 'nothing is left of it now….'

Figure 3.3. Musket balls of various sizes and materials (bottom), along with flint bearing strike marks (top right) recovered during the excavations at Poulton Chapel. A large stone ball, thought to be of Roman origin is also present (top left). ©Clark Tilling/Poulton Research Project.

Archaeological investigation has determined that the chapel likely underwent three phases of development. The chapel started as a small single-cell structure, which may have been used by the local population or as a temporary place of worship for the monks during the construction of the Abbey. Around the 12th century the chapel was rebuilt following Cistercian recommendations; the structure was 9 x 4m, plain, with an earthen floor, undecorated walls and a stone slab altar. It was not until the Manley family leased the land and buildings in 1487 that the chapel became the three-cell structure (Figure 3.4), which was apparent from the foundations uncovered during the archaeological excavation. With a separate nave, chancel and tower, slate roof, painted window-glass and expensive floor tiles from Seville, the chapel was most likely used as a private chapel and mausoleum for the Manley family.

Figure 3.4. Artist's impression of Poulton Chapel's three-cell structure following the commencement of the Manley family lease in 1487. ©Jane Braine.

Many questions surrounding the lifespan of the cemetery have been raised, with Poulton being mentioned prior to the Abbey formation. The earliest mention of the village was in the Domesday Book, leading to questions on when the cemetery became active. It could be that the dead were buried at nearby St. Mary's in Pulford, a church built just outside Pulford Castle, approximately 2.2 miles away. Alternatively, when the chapel became a private place of worship, were the dead then sent to St. Marys in Pulford for burial and did the burials stop immediately at Poulton chapel or was there a period of transition?

If the chapel does predate the Abbey, there could be a possibility that there are Anglo-Saxon burials at the site given its rich archaeological history; therefore, a more in-depth study into the dating of the Poulton Chapel burials is essential.

3.2. Collection to date

The archaeological excavations at Poulton began in 1995, however, it was in the 1960's that the current landowners were given an indication that the fields surrounding them would give an insight into the history of the area when a glazed ceramic floor tile was recovered (Figure 3.5). By the end of the 2015 excavation season, 836 burials had been identified, with 753 of those providing human skeletal material for analysis. Of the remaining burials, 56 skeletons were reburied at Mount St. Bernard during the early period of the excavation, as it was believed that the cemetery belonged to the Cistercian Abbey that occupied the area between 1146 and 1214 AD. However, it has since become clear that this was a Christian burial ground comprising of the local lay population and later, the Manley family. Two of the remaining skeletons were reported as lost and several skeletons have been identified for excavation later. The remaining outstanding context numbers were burials that were assigned alternative context numbers at a later date (Emery 2000, Emery *et al*. 1996).

Figure 3.5. Glazed ceramic floor tile found by the late Gerry Fair when field walking on what would become the Chapel site in the 1960s. ©Poulton Research Project.

The site is open for excavation as a teaching and research site to the public for 14 weeks each year (4 weeks at Easter and 10 weeks over the summer). Further excavation takes place on the site as part of undergraduate and postgraduate degree programmes at Liverpool John Moores University. Due to the nature of the excavation, it should be noted that the human remains are exposed to the elements over 2-3 days prior to lifting; however, every precaution is taken to ensure they are shielded as much as possible. During times of heavy rainfall, the graves can become waterlogged which can affect the burial position and preservation of the remains. The author of this thesis has worked closely with the site and its Trustees since 2008, providing osteological support both on the site and for post-excavational analysis once the human skeletal remains are received at Liverpool John Moores University.

The majority of the skeletal collection is held at Liverpool John Moores University (at the time of writing, 591 articulated individuals, 160 identified disturbed individuals and 68 boxes of disarticulated material including 2 charnel pits), with 99 skeletons housed at the University of Liverpool. A temporary loan (three months each year) of up to 20 articulated skeletons is made to the University of Huddersfield, for osteology teaching, from the collection held at Liverpool John Moores University. The collection is used for teaching and research, with several PhD and MPhil projects currently underway assessing differing aspects of the human skeletal material.

3.3. Excavation methods

There have been two separate methods used at Poulton Chapel since excavation began at the site. Up until 2014, the site was not excavated stratigraphically, causing issues with the production and development of a Harris Matrix for the cemetery. The earlier excavations were based on the site being a teaching and research excavation and as such, the burials were identified and excavated at various points around the cemetery rather than following the recommended protocol as set out in Guidance for Best Practice for Treatment of Human Remains Excavated from Christian Burial Grounds in England (Heritage England, 2005). As it was not possible to determine the relationship between disturbed remains using this technique, the volume of disarticulated remains prior to the 2014 excavation season was much higher than expected for a medieval cemetery excavation.

There was then a transition period during the excavation seasons of 2014 and 2015 as the site was brought in line with standard excavation protocol. This involved the excavation of all previously exposed remains, before stratigraphic excavation commenced in the area highlighted in Figure 3.6. Stratigraphic excavation has significantly reduced the amount of disarticulated material produced, with only three boxes produced during the 2015 season (2.5 boxes of charnel and 0.5 of disarticulated human skeletal remains).

The aim of the Poulton Research Project is to continue the excavation of areas 1 and 2, to gain a better understanding of the number of burials that could potentially be present (*pers.comm.* Kevin Cootes, 2017). As the site is now being excavated in this manner, the number of burials excavated each year has been reduced to ensure that correct recording methods and a higher standard of teaching is provided to each student of the excavation course.

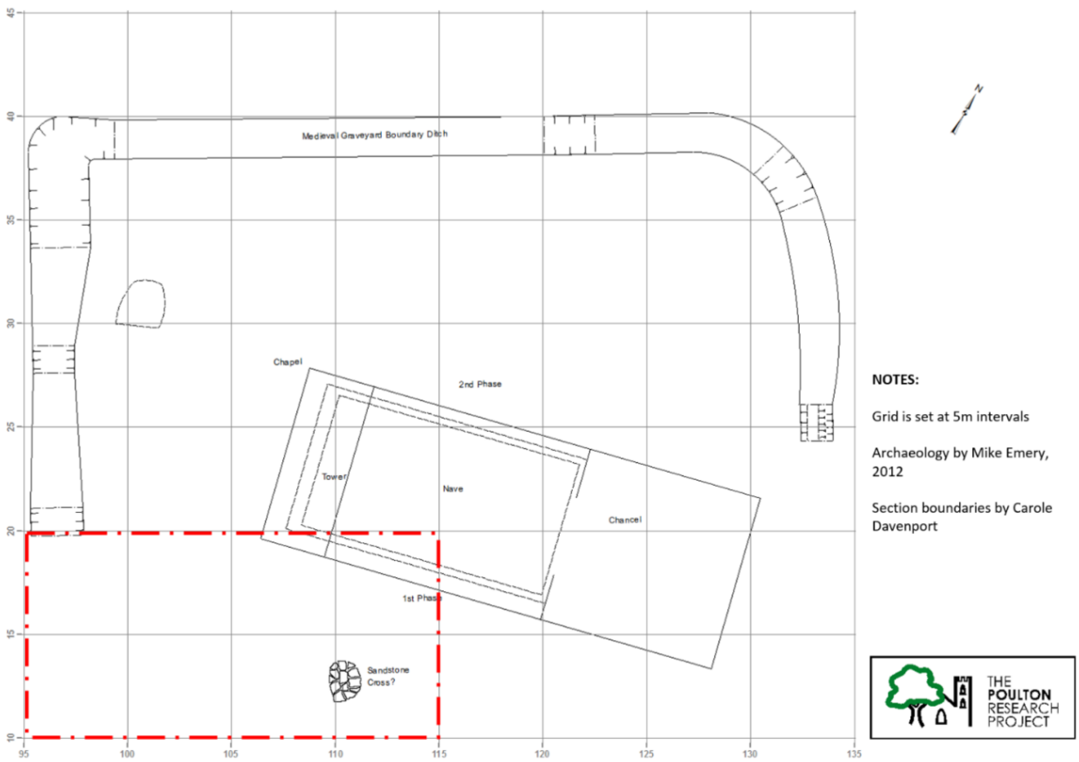

Figure 3.6. Map of the medieval site under excavation at Poulton Chapel. Red section boundary lines highlight the area under stratigraphic excavation during 2015 following the change in protocols at the site. ©CAL Davenport

Due to the high clay component of the soils at the site, sieving was not carried out at Poulton Chapel. To ensure maximum retrieval of each skeleton, all soil clumps are broken down as far as possible to ensure nothing is missed. Following recording and lifting of the skeleton, the grave is cleaned thoroughly to ensure all skeletal material has been recovered before final photography of the cut. To maximise teaching time and to preserve samples for scientific analyses such as DNA testing, the skeletons are no longer cleaned on site. All cleaning of the skeletal material takes place at Liverpool John Moores University under controlled conditions following collection, which occurs on a weekly basis during the excavation season.

3.4. Geoarchaeology

To assess the preservation of the human skeletal material at Poulton Chapel, it is essential that the burial environment is understood. The Poulton site has a long history, which has led to a mix of building materials, natural and redeposited soil being present in the burial environment. In turn, this has led to differential preservation of the inhumations, both within and between different individuals.

Macrostratigraphy

The cemetery is on gently sloping ground and is bordered along one side by a mature hedge with roots that often disturb the burials on the South side of the chapel. Further bioturbation has occurred from the presence of moles tunnelling through the site and in some cases disturbing the burials (Figure 3.7).

Figure 3.7. The excavation of skeleton 487 demonstrated the influence bioturbation has on the burial. Disturbance of the ribs, vertebrae and sternum are caused by roots (indicated by white arrow) from the hedges along the south side of the cemetery. ©Poulton Research Project.

Although there is a flood plain in close proximity to the site, it was determined that the level of the water table and the position of the site above the flood plain was not a factor affecting water drainage at Poulton Chapel. Boreholes have been drilled to the east (SJ 3965 5836; SJ 4019 5829) of the site, both showing the water table level to be too far below the surface to affect the burials (13.72m and 8.15m below ground level respectively). As well as providing data on the water table height, the borehole at Chapelhouse Farm provided stratigraphic information for 'the furthest chappell fielde' to the east of Poulton Chapel (Figure 3.8).

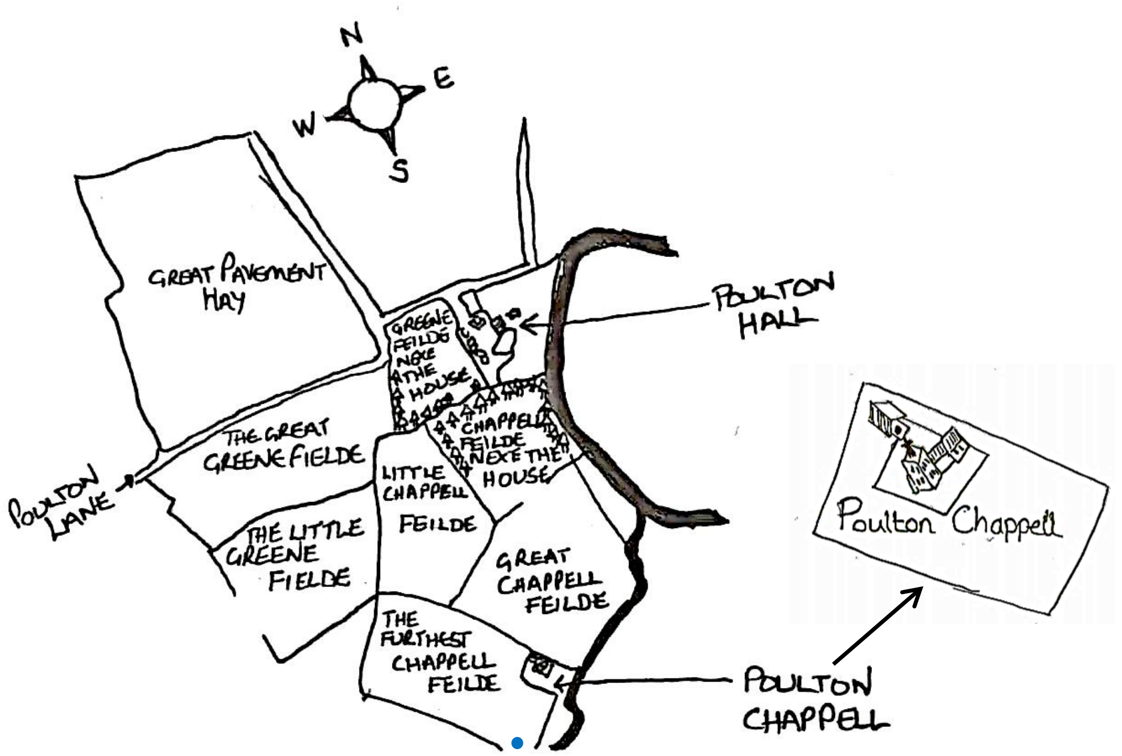

Figure 3.8. Re-drawn from a seventeenth-century estate map (pre-1675; Grovesnor Archives Maps). The blue dot highlights the approximate location of borehole SJ 4019 5829. Map is not to scale. ©CAL Davenport

As this area is believed to be relatively undisturbed by the archaeology, the regional stratigraphic information presented by this borehole has been provided in Table 3.1. For the micro-stratigraphy of the site relative to the archaeology, several test trenches were recorded to determine how the continued use of the site had affected the skeletal remains. The information gathered from the micro-stratigraphy at Poulton is provided later in this chapter.

Table 3.1. British Geological Survey stratigraphic descriptions and depths obtained from the borehole at Chapelhouse Farm, Poulton (SJ 4019 5829) in 2004.

Description of strata	Thickness (m)	Depth (m)
Top soil/clay	0.25	0.25
Stiff, dark brown clay	15.82	16.10
Medium/coarse sand and gravels	1.20	17.30
Red/brown, stiff, sandy clays	21.20	38.50
Weathered, red/brown sandstone	1.00	39.50
Red/brown sandstone	35.50	75.00

***gravel layer was noted at 51.5m**

The British Geological Survey gives information on the bedrock formation of the region, which agrees with the results from the boreholes (BGS, 2016). The Kinnerton Sandstone Formation from the early Triassic epoch consists of a red-brown to yellow sandstone, which is generally pebble free. Overlying the sandstone on top of the slope is Devensian till; a clay with rock inclusions from the erosion caused by the movement of a glacier on the top of the slope; this gives way to an alluvium deposit on the flood plain. It is reasonable to expect a transition between the top and bottom of the slope and dependent on the previous agricultural use of the land, some further mixing of the deposits that may affect the preservation of the burials near the top of the slope.

Microstratigraphy

The North side of the cemetery provides evidence for occupational use during the Roman and Medieval periods, before the return to agricultural use during recent times (pers. comm. Dr Kevin Cootes, 2017). The materials used during the construction and demolition of buildings, gulleys and agricultural land use, will have contributed to the taphonomic environment in which the burials are interred. To understand the influence of anthropogenic activity on the preservation of the remains, sections were excavated relative to the chapel to determine the microstratigraphy formed from the development of the site. Two main control sections were taken (Figure 3.9); one with no interference from the archaeology (C4) and a second section to the North of the medieval cemetery (C1). Two further small sections were taken within the cemetery alongside the Roman gulleys, to determine whether there had been an influence on the poor preservation of the burials excavated form this area (section C2 and C3). The latter sections were taken for the purposes of obtaining soil samples at the level of the human burials.

Figure 3.9. Aerial photograph showing the locations for the control sections (indicated by yellow dots; Image courtesy of Google Maps©).

Control section C1 was located in the northeast corner of the cemetery, close to the medieval cemetery boundary (SJ 40373 58376). This area produced a number of burials, which demonstrated differential preservation most likely due to truncation from the later inclusion of a field drain (Figure 3.10). The section provided four stratigraphic layers from the topsoil to the natural, with the total section depth at 76cm (Figure 3.11). The first stratigraphic layer consisted of topsoil consisted of a dark brown fine sand with a small amount of clay. This layer has inclusions of red brick and slate, rootlets from the grass, with a transitional contact at a depth of 22cm. Three soil samples were taken from the top, middle and bottom of this layer (9, 16 and 22cm respectively). The second stratigraphic layer is predominantly orange with a mottled brown appearance in places. The clay content increased and there are isolated gravel inclusions up to 2.8cm in length. A soil sample was taken at a depth of 34cm, with a lower transitional contact identified at 37cm. The third stratigraphic layer consists of a medium brown fine sand, with charcoal (3mm – 2cm) and isolated gravel inclusions <1cm). An incisor from a non-adult domestic pig (*sus scrofa*) was recovered (4.5cm long, root had not fully closed) at 43cm. One soil sample was collected from this layer at a depth of 44cm. The final layer is a predominantly orange clay layer with a few small charcoal inclusions (<5mm), no gravel, but increased insect activity (earwigs and millipedes). Two soil samples were taken at depths of 55cm and 72cm.

Figure 3.10. Skeletons 520-525 excavated to the south of section C1, showing differential preservation and truncation by a field drain. ©Poulton Research Project.

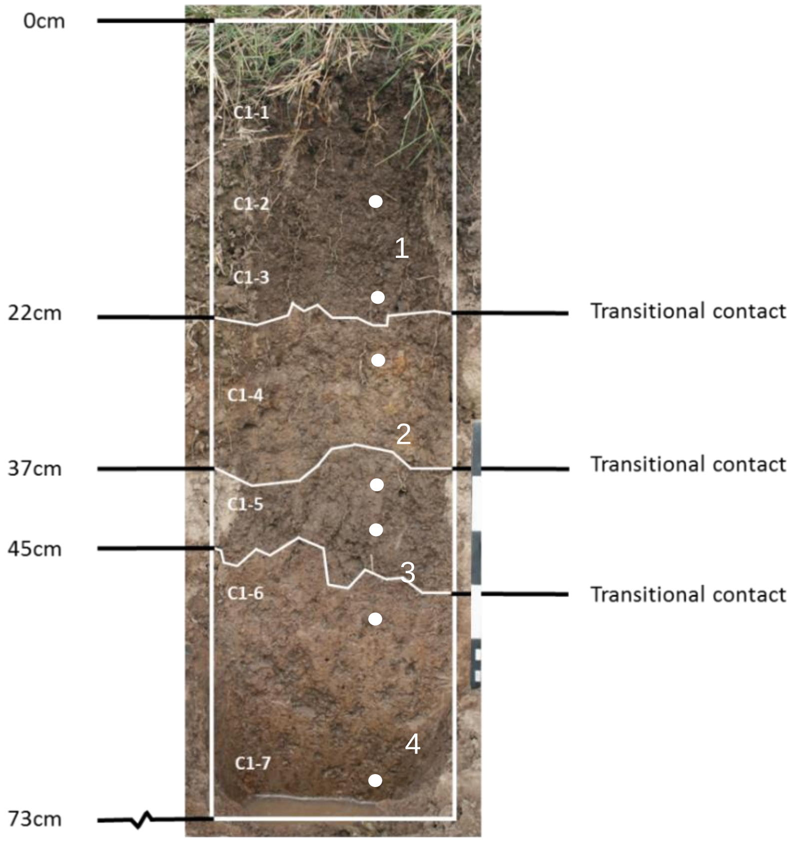

Figure 3.11. Control trench C1 at Poulton Chapel showing the depositional over time at the cemetery site. Highlighted are the depths of each of the layers and the approximate points (white dots) at which soil samples were taken. ©CAL Davenport.

Control section C2 was a soil sample taken from the Roman level on the north side of the chapel (SJ 40373 58388). This area had been covered with plastic sheeting before the Roman gulleys were excavated fully in 2015. Although no burials were present in this area at the time of sampling, previous excavation seasons had seen burials recovered from the overlying layers. This area was of interest as the skeletons excavated show poor preservation, which may be due to the backfilled Roman gulleys they cut into. The soil sample in this area has a heavy orange coloured clay component with no inclusions, roots or insects present.

Control section C3 was taken from the Roman level of deposition in a location closer to the northwestern end of the chapel walls (SJ 40386 58382). This area had not been fully excavated, with burials still *in situ* alongside the north chapel walls. The surface layer of this area had been backfilled to protect the underlying archaeology and burials, with all measurements taken from this superficial layer. The total section depth was 52cm, with the bottom lying at the level of the burials in this area. The superficial backfill layer transitioned into a grey-brown sandy soil with at a depth of 25cm. There is a small amount of clay present, but otherwise no inclusions except roots towards the top of the layer. Towards the bottom of the layer, small sandstone inclusions are present (<5mm). Two soils samples were taken from this layer, one at 36cm and the second at a depth of 50cm.

Control section C4 was located approximately 100 metres north of the medieval cemetery, close to the site of the Iron Age settlement (SJ40365 58469). This area was undergoing excavation and an area unaffected by archaeological interference was identified. The section was excavated to a depth of 110cm to ensure there were no stratigraphic changes (Figure 3.12). The colour difference at the top of the section is due to the lack of moisture on the surface, whereas the previously unexposed soil had retained some moisture. The section consists of orange-brown clay with grey mottling and had occasional granite inclusions, most likely deposited during the glacial period. Three soil samples were taken at depths of 46cm, 70cm and 100cm. The soil samples collected from each of the stratigraphic sections were analysed in the laboratory to provide a basis for assessing the potential impact the burial environment had on the skeletal remains recovered from Poulton Chapel.

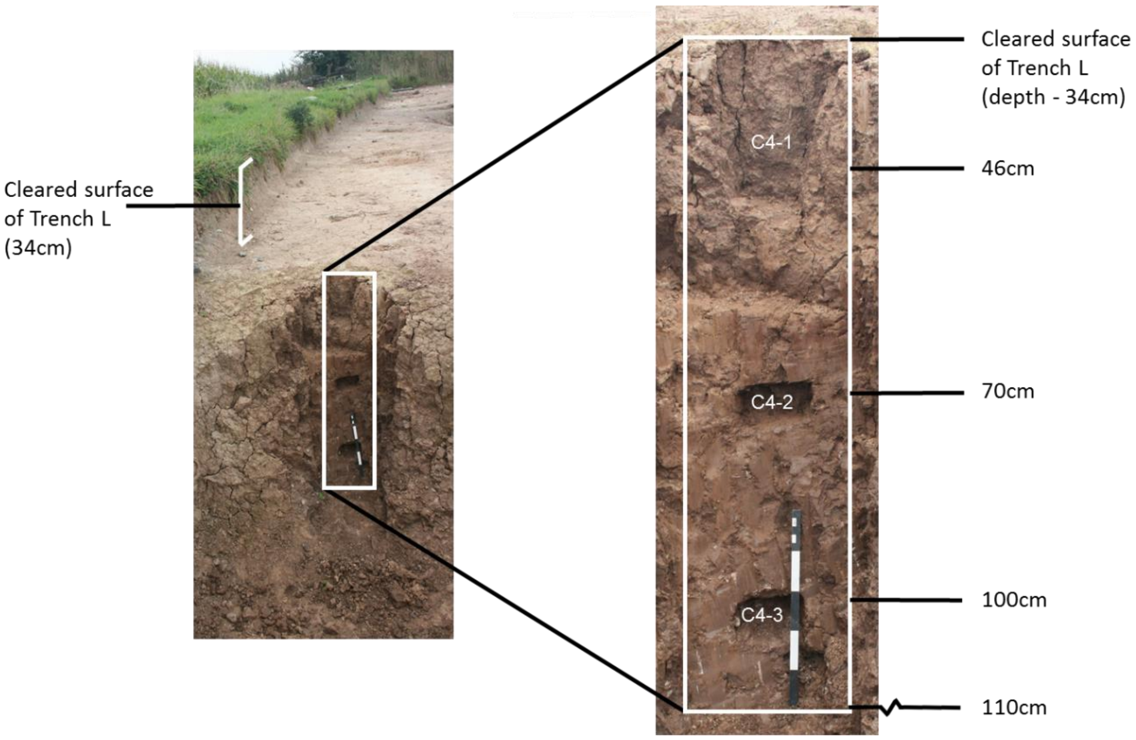

Figure 3.12. Section C4 produced one stratigraphic layer of naturally deposited reddish-brown clay. Three soil samples were taken at points C4-1, C4-2 and C4-3 ©CAL Davenport.

3.5. Soil analysis – cemetery level

To assess the potential impact the burial environment had on the preservation of the skeletal remains at Poulton Chapel, a total of 49 soil samples (13 control samples and 36 burial samples) were collected from the site. The soil control samples collected from each of the stratigraphic layers identified from the trenches would allow the investigation of the soil matrix prior to both archaeological interference of any kind and the burials. In areas where both the archaeology and burials were present, it would provide information on how previous site occupation influences the preservation of the human skeletal remains. Soil samples were taken from both within the graves (n=28) and, in some cases, from the cranial vaults of skeletons whose skulls had been lifted as a block for controlled excavation in the laboratory. In all cases, the soil was taken from an area that was in contact with the burial (Table 3.2).

Table 3.2. Skeletons selected from the Poulton Chapel site for soil sample analysis and the sample type recovered.

Skeleton Number	Sample location
750	Grave soil
773	
775	
777	
779	
781	
785	
787	
788	
791	
691	Cranial soil
793	
794	
795	
796	
797	
798	

Each inhumation differed in preservation and selection was limited to those being excavated during that particular season (summer 2014 excavation for the articulated burials; Easter 2015 excavation for the cranial soil samples). The number of soil samples taken from around each of the burials were determined by the differential preservation of the skeleton and its proximity to other individuals that were being sampled. The locations of all soil samples analysed are shown in Figure 3.13. Cases where the grave had been reopened for later burials were investigated to see if this had had an impact on the preservation of the remains (Figure 3.14).

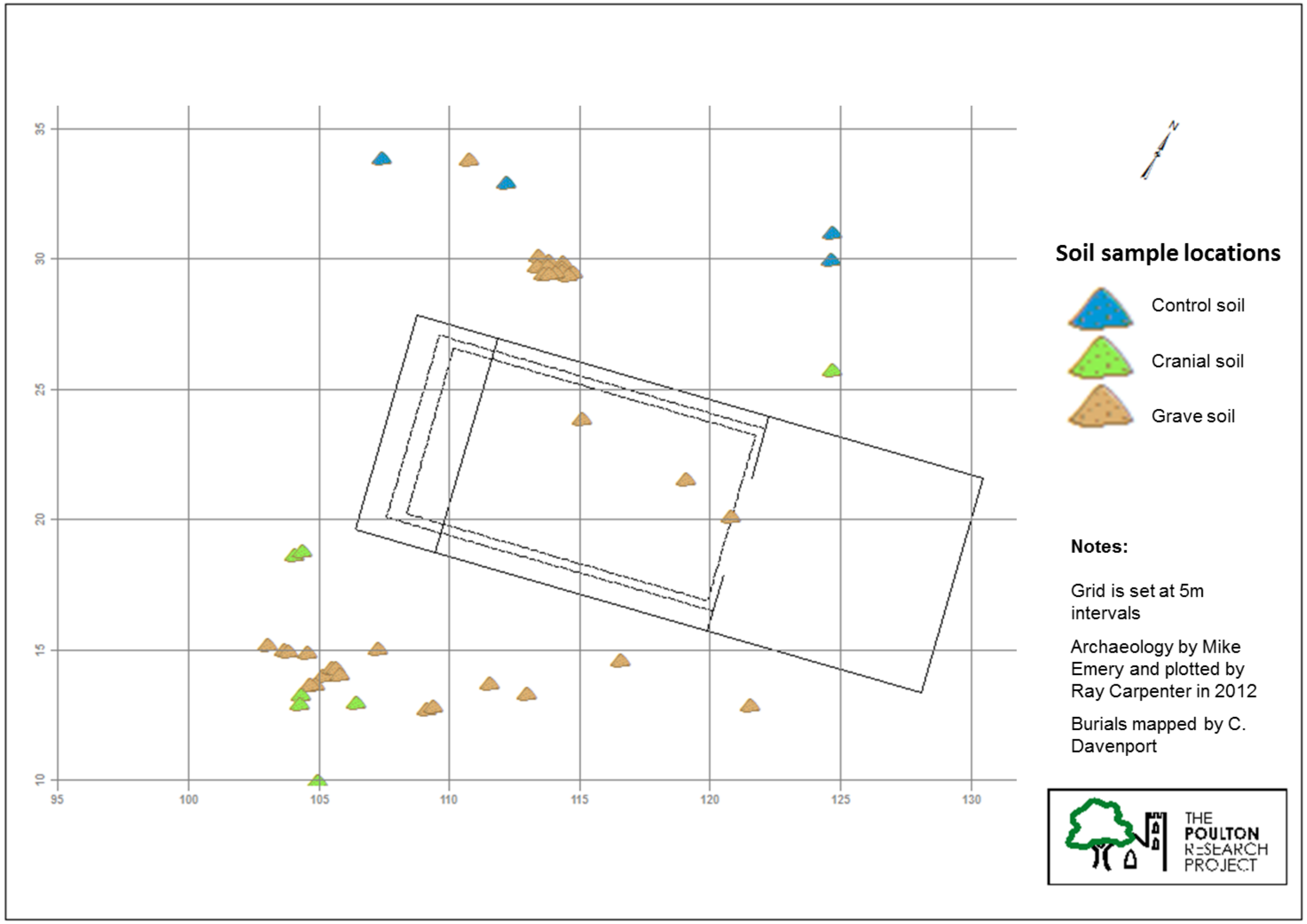

Figure 3.13. Soil sample locations and types taken from the cemetery at Poulton Chapel. Samples were taken from the control sections and graves and seven crania. Map plotted using ArcMap 10.2.2. ©CAL Davenport

Figure 3.14. Skeletons 750, 773, 777 and 775 and associated soil sample locations. Note the disturbance of both skeleton 773 and skeleton 777 by later interments. ©Poulton Research Project

The medieval cemetery at Poulton Chapel has provided a number of contemporary burials during the excavation and the grave of skeletons 779 and 781 (Figure 3.15) enabled samples to be taken from one such grave to determine if this would further affect preservation. It is often the case when working on mass gravesites, that the rate of decomposition will be greatly reduced by the increased number of burials in close contact (Troutman *et al.* 2014). Although not a mass grave, the presence of more than one body in a single grave may still have an impact, not just on the decomposition of the soft tissues, but the skeletal framework. Furthermore, skeleton 781 has been disturbed by a later interment, which could further affect the preservation of this skeleton.

Due to the previous excavation methods, there were many instances of burials being partially uncovered whilst locating burials to be used as part of the Easter and Summer schools, before being covered with plastic sheeting until needed. Unfortunately, the burials were not always excavated in the following days. During the transition period, individuals were uncovered that had been 'found' and then forgotten about the previous year. Skeleton 785 was one such burial; upon excavation, it was noted that the areas covered with plastic sheeting were badly degraded compared to the areas that had not been excavated. The pressure of the overlying soil and subsequent land use had caused many of the burials to fragment, especially in the case of infants where the bone is very delicate. Skeleton 787 was a partial infant burial, which demonstrated a high degree of fragmentation and poor preservation.

Figure 3.15. Skeletons 779, 781, 785 and 787 and associated soil sample locations. ©Poulton Research Project

The final two graves selected for soil sampling lay alongside the charnel pit excavated during the 2014 summer season. Positioned end to end and relatively undisturbed, the burials appeared well preserved, enabling a comparison to those that were compromised by taphonomic influences (Figure 3.16).

Figure 3.16. Skeletons 788 and 791 and the associated soil samples taken from these burials. The head of skeleton 791 lies at the foot of skeleton 788's grave. ©Poulton Research Project

Further soil samples (n=7) were collected from the cranial soil from skulls that were lifted as a block during the 2014 Easter excavation season. This provided comparisons to the chemical components of the soil in direct contact with the remains. A plan of the cemetery showing the locations for each of the burials providing soil samples is shown in Figure 3.17.

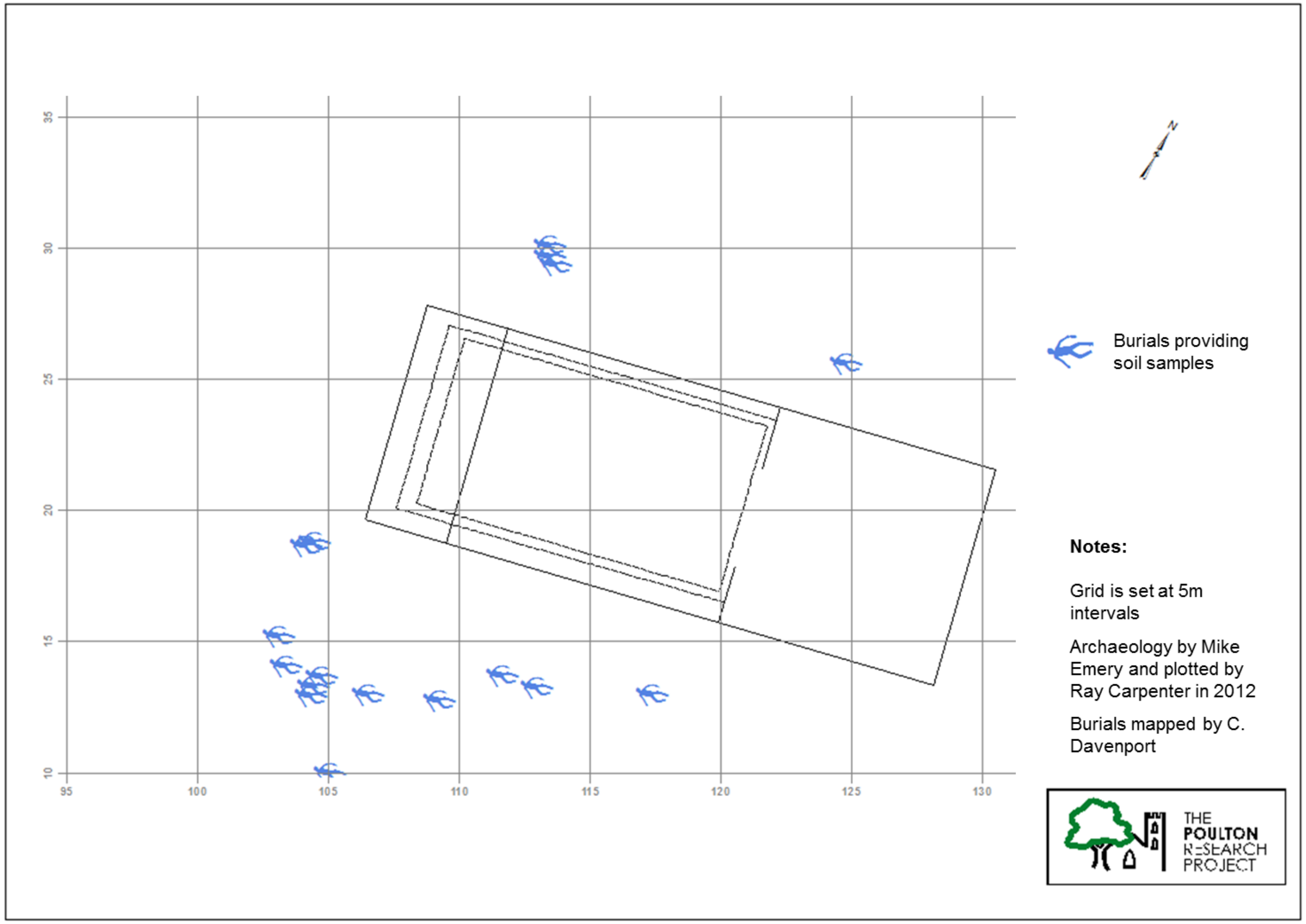

Figure 3.17. Locations for the burials (n=17) from the Poulton Chapel cemetery providing soil samples for analysis. Map plotted using ArcMap 10.2.2. ©CAL Davenport

Soil colour determination

The soil samples collected from both the control sections and the Poulton Chapel burials were compared to Munsell© colour charts in both damp and dry conditions. The dry sample colours ranged from brown to dark yellowish brown, with darker soils being present on the south side of the chapel and an area on the north side of the cemetery which is in the same area of section C1 (Figure 3.18). Control section C4 showed no difference in colour for dry samples, with all identified as 10YR 5/4 or yellowish brown. As the depth increased within section C1, the hue ($r_{s(7)}$=0.866, p=0.012) and value ($r_{s(7)}$=0.955, p=0.001) of the damp soil increased, although there was no relationship identified between chroma and the stratigraphy ($r_{s(7)}$=0.726, p=0.064).

The damp samples ranged from light brown to yellowish brown across the site (Figure 3.19), with the hue becoming darker the further north the samples were located for both dry ($r_{s(35)}$=0.597, p<0.001) and damp ($r_{s(35)}$=0.360, p=0.033) soil samples. The darkening of soil colour can be an indication of areas of high organic content or increased foreign material in the soil (for example, charcoal).

pH determination

Control section C1 showed a pH range from 5.3 at the surface, to 5.8 at the deepest sample point (0.73 metre depth), however there was no difference between the stratigraphic layers ($\chi^2_{(6)}$=6.000, p=0.423). Control sections C2 and C3 produced levels of 5.5 and 5.8 respectively. The pH levels for the samples for control section C4 ranged from 5.3 at the surface, to 7.0 at the deepest point (1.1 metre depth). When comparing all control sections, no significant difference identified, most likely due to the gradual increase in pH from the surface layers, down to the natural ($\chi^2_{(3)}$=6.413, p=0.093). The only relationship identified between the pH and other control section soil characteristics was the overall decrease in pH as the percentage of sand particles increased ($r_{s(13)}$=-0.601, p=0.030). The controls sections C1, C2 and C3 fall within the ranges observed for grave samples (range 5.0-6.8).

The increased number of samples taken from across the site enabled a more in-depth look at the relationships with pH, with the levels increasing as the sampling moved towards the east side of the cemetery ($r_{s(39)}$=0.662, p<0.001). The previously identified decrease in pH as the percentage of sand increased was reassessed, however the strength of the relationship had decreased and was no longer significant ($r_{s(41)}$=-0.237, p=0.135). The pH ranges for burial level of C1, samples for C2, C3 and the burial samples were mapped using ArcMap and the resultant density map shown in Figure 3.20.

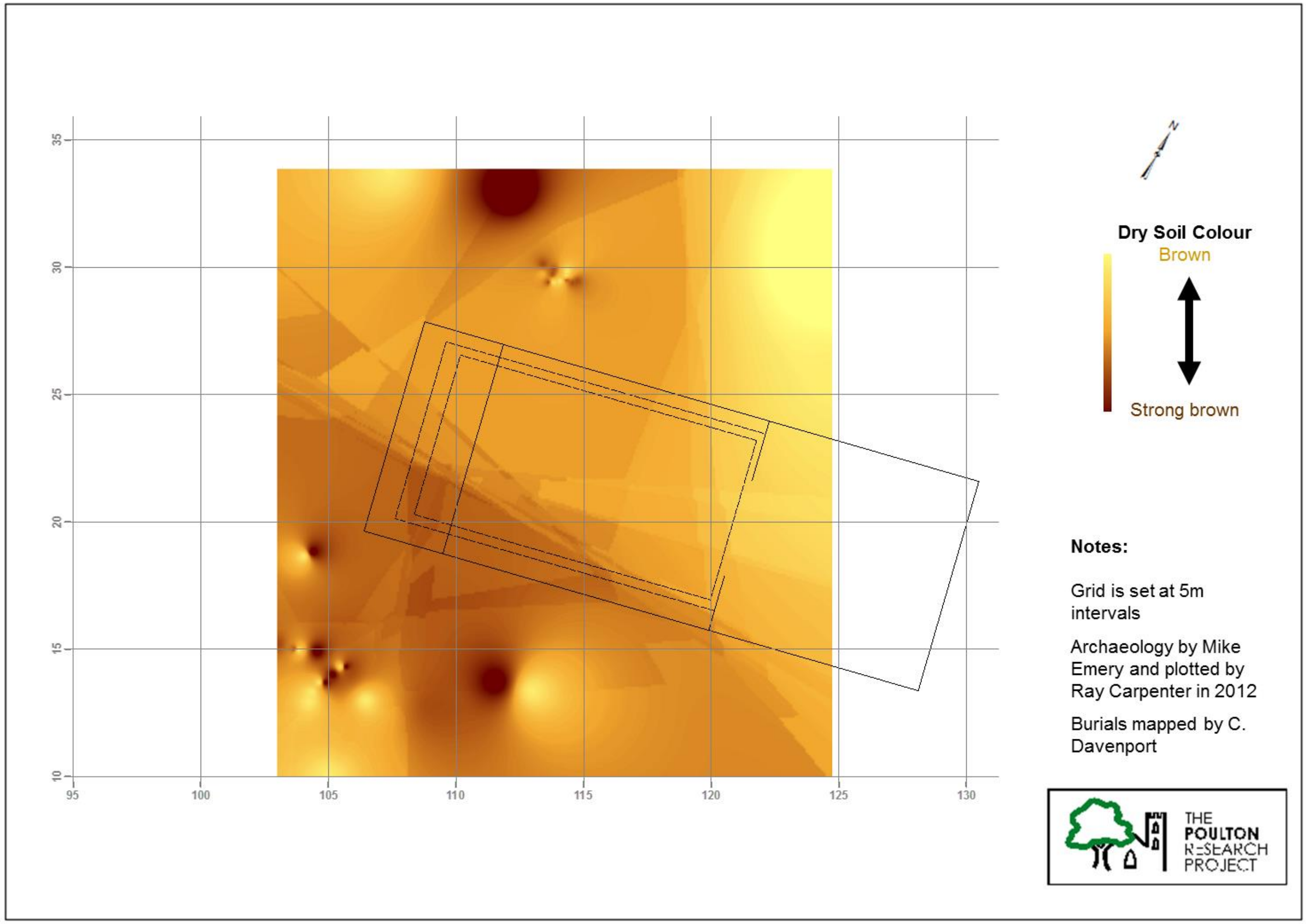

Figure 3.18. Dry soil characteristics recorded from the samples collected from Poulton Chapel. Mapped in ArcMAP 10.2.2 using an inverse distance weighted (IDW) interpolated raster. ©CAL Davenport

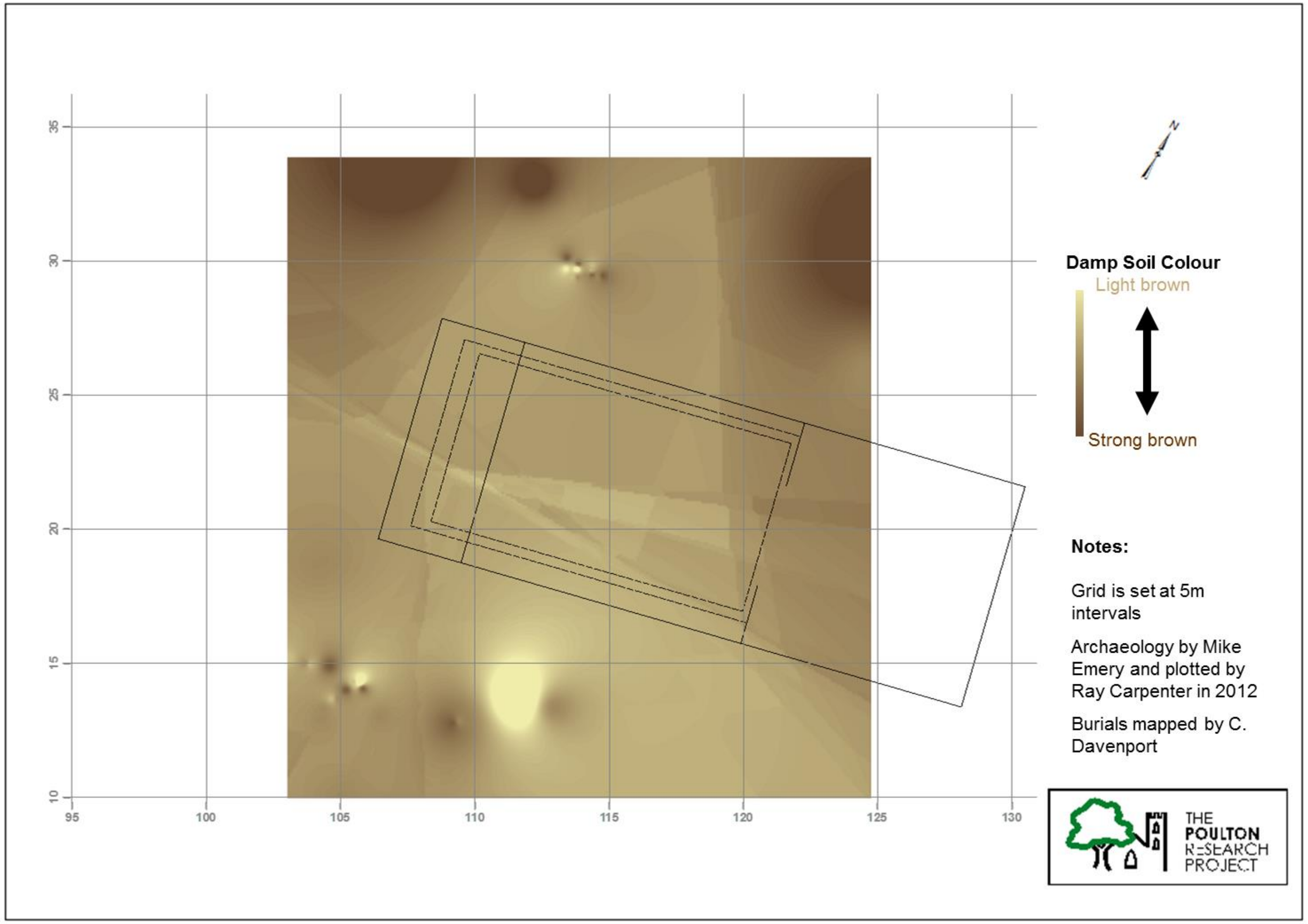

Figure 3.19. Damp soil colour characteristics recorded from the samples collected from Poulton Chapel. Mapped in ArcMAP 10.2.2 using an inverse distance weighted (IDW) interpolated raster. ©CAL Davenport

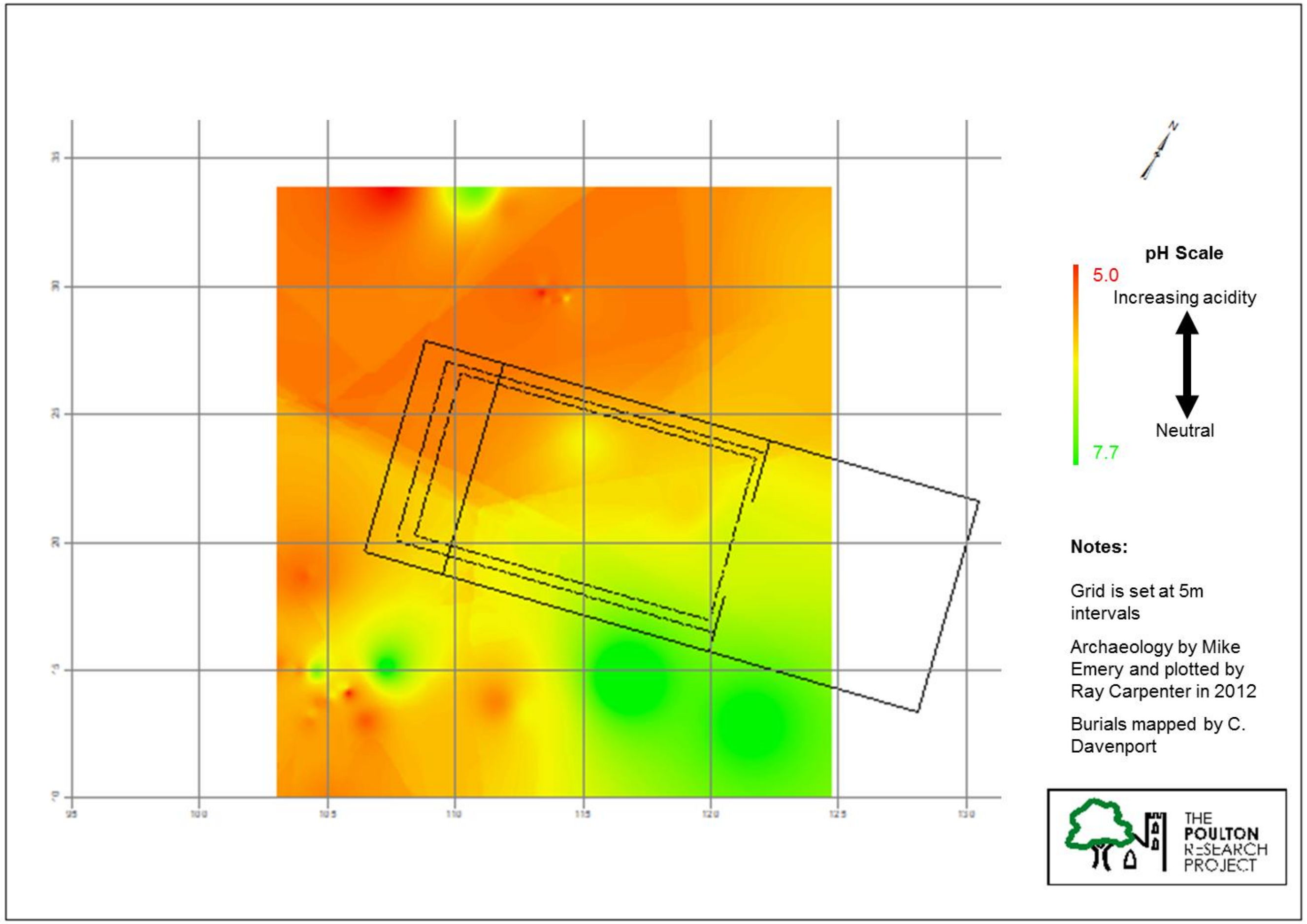

Figure 3.20. Soil pH levels recorded from the samples collected from Poulton Chapel. Mapped in ArcMap 10.2.2 using an inverse distance weighted (IDW) interpolated raster. ©CAL Davenport

Magnetic susceptibility

The control section samples (n=13) and 28 grave soil samples underwent magnetic susceptibility testing. All samples produced weak positive magnetic susceptibility readings consistent with paramagnetic or Fe-bearing minerals and salts. Therefore, the main properties of the soil are lithogenic, or derived from the parent material. Further investigation using high frequency measurements to calculate the frequency dependent susceptibility showed that although 26 of the samples contained virtually no superparamagnetic grains, ten samples were an admixture of grain types, and three samples fell within very high ranges. The values for control section C4 varied from high frequency dependent values at the top of the section (>75% superparamagnetic grains) to low at the deepest point of the section (<10% superparamagnetic grains).

Statistical analysis for the cemetery identified a significant negative relationship was identified between the percentage of silt present and frequency dependent magnetic susceptibility ($r_{s(7)}$=-0.808, p=0.28), when looking at the stratigraphy of control section C1. This relationship indicated that as the percentage of silt particles increased, the magnetic susceptibility decreased (Figure 3.21). However, it should be noted that the R^2 linear does not take into account the increased dispersal of the particles at frequencies greater than zero. The differences in the frequency dependent magnetic susceptibility were not due to the differing depths of the samples ($r_{s(7)}$=0.492, p=0.262), which was further supported when assessing the relationship across the all cemetery samples ($r_{s(38)}$=-0.035, p-0.836).

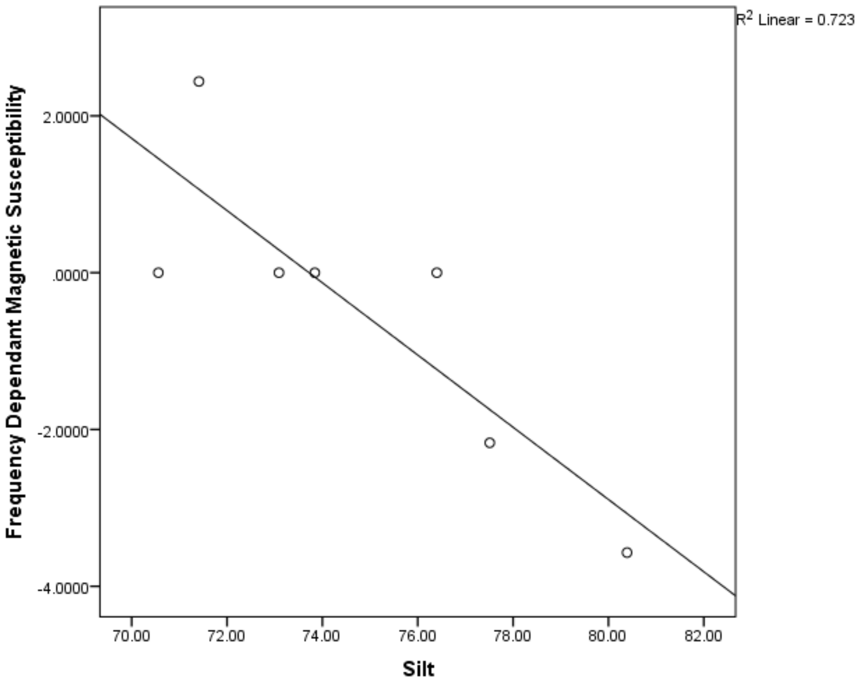

Figure 3.21. Visual representation of the relationship between the grain size for silt and frequency dependent magnetic susceptibility for the soil samples collected from control section C1.

The frequency dependent susceptibility values for the burial level of the control sections C1 (samples 5-7), C2, C3, and the burial samples are mapped in figure 3.22. The map shows that frequency dependent magnetic susceptibility decreased as you move further east across the site, with the highest values in the south west corner of the cemetery ($r_{s(28)}$=-0.440, p=0.019).

The high frequency dependent magnetic susceptibility levels at the cemetery sites highlights areas of anthropogenic activity as the parent material becomes mixed with foreign material brought to the site. The areas demonstrating higher levels of activity at the site coincide with the extension of a Roman ditch and its associated backfill on the western edge of the cemetery (*pers. comms*. Kevin Cootes, 2017). Further areas to the south of the chapel have produced redeposited medieval construction material. Disturbance was noted on the North side of the chapel, particularly in the North East, which could relate to the Roman ditches that run through this section of the cemetery. The north side of the chapel gave values that compared more directly to the natural clay. This was most likely due to the samples being taken from areas around the Roman ditches, and therefore derived from the parent material instead of the foreign materials brought on to the site during periods of occupation. As only a few samples were taken from inside the chapel, the activity in this area is not thoroughly mapped, although it is expected that this area would also show higher values due to the strong disturbance from the construction phases.

Field portable x-ray fluorescence on soil

Field portable x-ray fluorescence was carried out on the soil samples to determine the distribution of the main elements associated with decomposition; calcium (Ca), iron (Fe), potassium (K), phosphorous (P) and Magnesium (Mg). Calcium and phosphorous were not detected in any of the control or cemetery samples, either due to them not remaining in the soils or being present in quantities too small to pick up using the forensic setting on the analyser. To confirm this, the tests were repeated using the mineral setting for calcium, and the light elements setting for phosphorous, which also showed no values present for these elements.

There was no difference between the levels of iron, potassium or magnesium for control section C4 (independent samples t-tests, $p>0.05$). Control section C1 showed that as the depth increased the percentage of iron increased ($r_{s(7)}$=0.842, p=0.018), with a significant difference between each of the depths analysed ($t_{(6)}$=12.848, p>0.001). There were no significant relationships identified between the percentages of potassium and magnesium (independent samples t-tests, $p>0.05$), in relationship to depth, however there the levels of potassium increased as the levels of iron increased ($r_{s(7)}$=0.815, p=0.026).

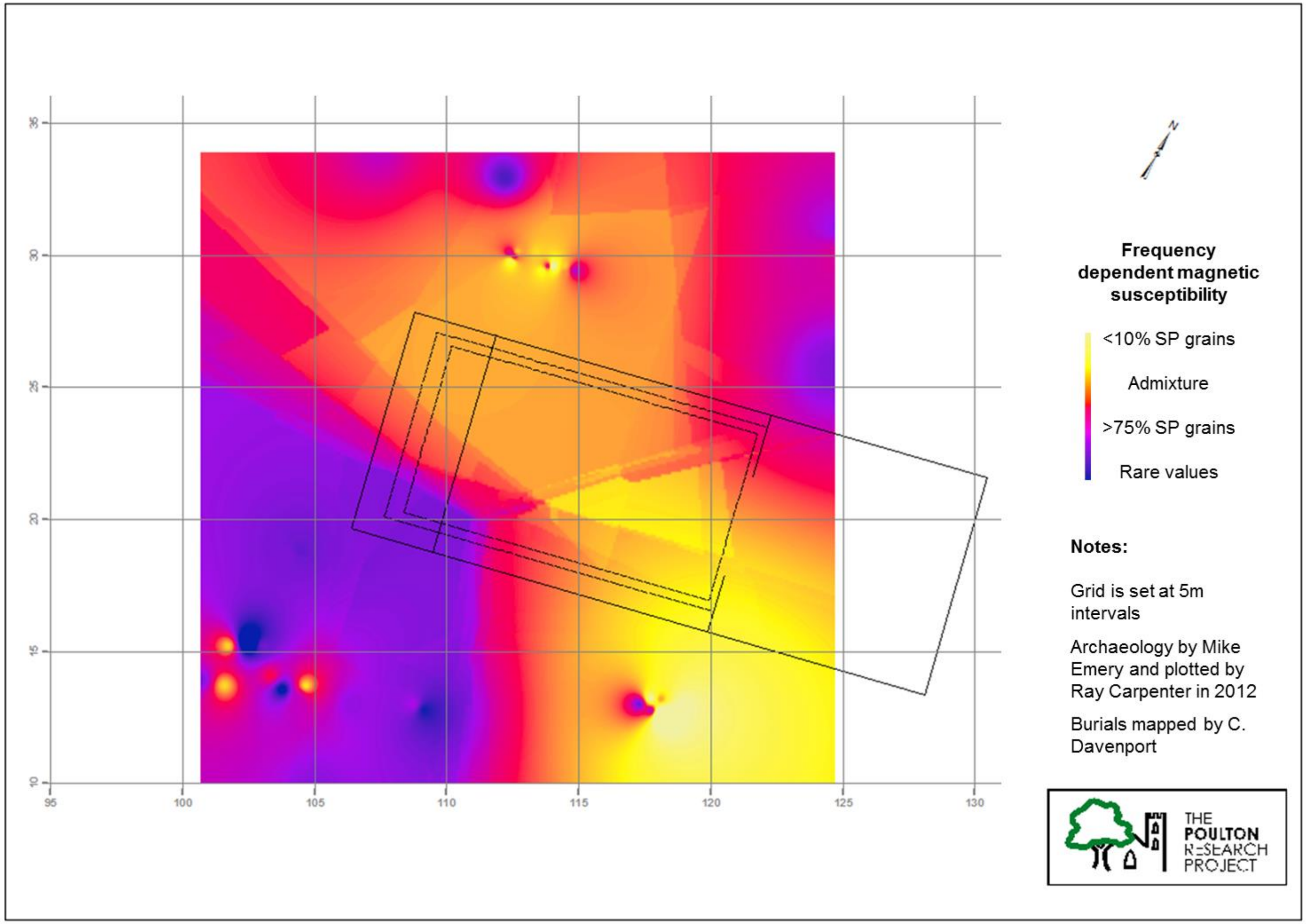

Figure 3.22. Frequency dependent magnetic susceptibility values derived from the soil samples collected from Poulton Chapel. Mapped in ArcMAP 10.2.2 using an inverse distance weighted (IDW) interpolated raster. ©CAL Davenport

There was no relationship in iron percentage when compared with pH levels, frequency dependent magnetic susceptibility or percentage of magnesium, nor was there any relationship between the percentage of iron and location (Spearmans rank correlations, $p>0.05$; figure 3.23). Significant relationships were found between the percentages of clay ($r_{s(41)}=0.843$, $p>0.001$) and sand ($r_{s(41)}=-0.599$, $p>0.001$) when compared to the level of iron present, but not with silt ($r_{s(41)}=-0.303$, $p=0.054$). As with the control section, the levels of potassium were shown to increase across the cemetery as the levels of iron increased ($r_{s(41)}=0.775$, $p>0.001$).

The levels of potassium across the cemetery showed no relationship with respect to location (Figure 3.24), magnesium, pH levels or frequency dependent magnetic susceptibility (Spearmans rank correlations, $p>0.05$). Aside from the correlation with the levels of iron mentioned previously, the percentage of potassium also showed a relationship with levels of clay ($r_{s(41)}=0.809$, $p>0.001$) and sand ($r_{s(41)}=-0.611$, $p>0.001$), but not with silt ($r_{s(41)}=-0.290$, $p=0.066$).

Only magnesium showed a relationship with the levels of sand present in the cemetery ($r_{s(41)}=-0.422$, $p=0.007$; figure 3.25). There were no relationships identified with location, pH level, frequency dependent magnetic susceptibility, or the other elements, iron or potassium (Spearmans rank correlations, $p>0.05$)

Particle size analysis

Control section C1 provided seven samples for comparison, which indicated strong relationships between the percentage of clay present and the chroma of the dry soil samples ($r_{s(7)}=0.794$, $p=0.033$). There were strong positive relationships identified between clay and the wet soil colour profiles, with the hue ($r_{s(7)}=0.828$, $=0.021$), value ($r_{s(7)}=0.929$, $p=0.002$) and chroma ($r_{s(7)}=0.794$, $p=0.0033$) all increasing as the percentage of clay increased. When compared to the XRF results, only iron showed a significant relationship with the soil profile. It showed that the amount of iron present in the soil increases as the clay content increases ($r_{s(7)}= 0.870$, $p=0.011$), with the levels decreasing as the number of sand particles increased ($r_{s(7)}= -0.785$, $p=0.036$). There was no relationship identified between the amount of silt present and iron levels. This was expected as iron levels tend to be lower in sandy soils and higher in clay soils (McGovern, 1987). There were no other relationships identified between the soil profiles and characteristics. There were significant differences between the levels of clay ($t_{(6)}= 8.354$, $p<0.001$), silt ($t_{(6)}= 56.141$, $p<0.001$) and sand ($t_{(6)}= 6.168$, $p=0.001$) present in the samples from this section (Figure 3.26).

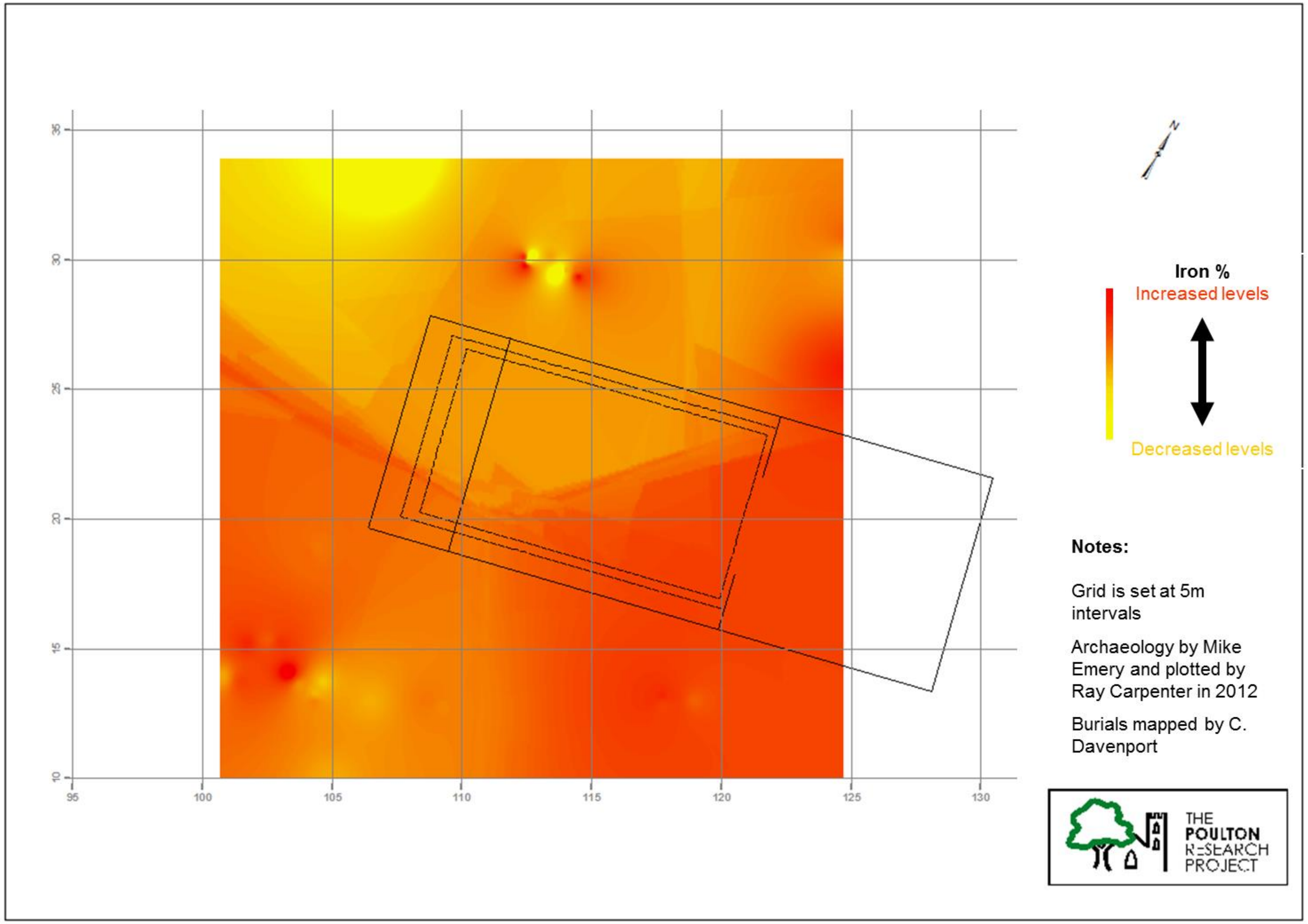

Figure 3.23. Percentage of iron derived from the soil samples collected from Poulton Chapel. Mapped in ArcMAP 10.2.2 using an inverse distance weighted (IDW) interpolated raster. ©CAL Davenport

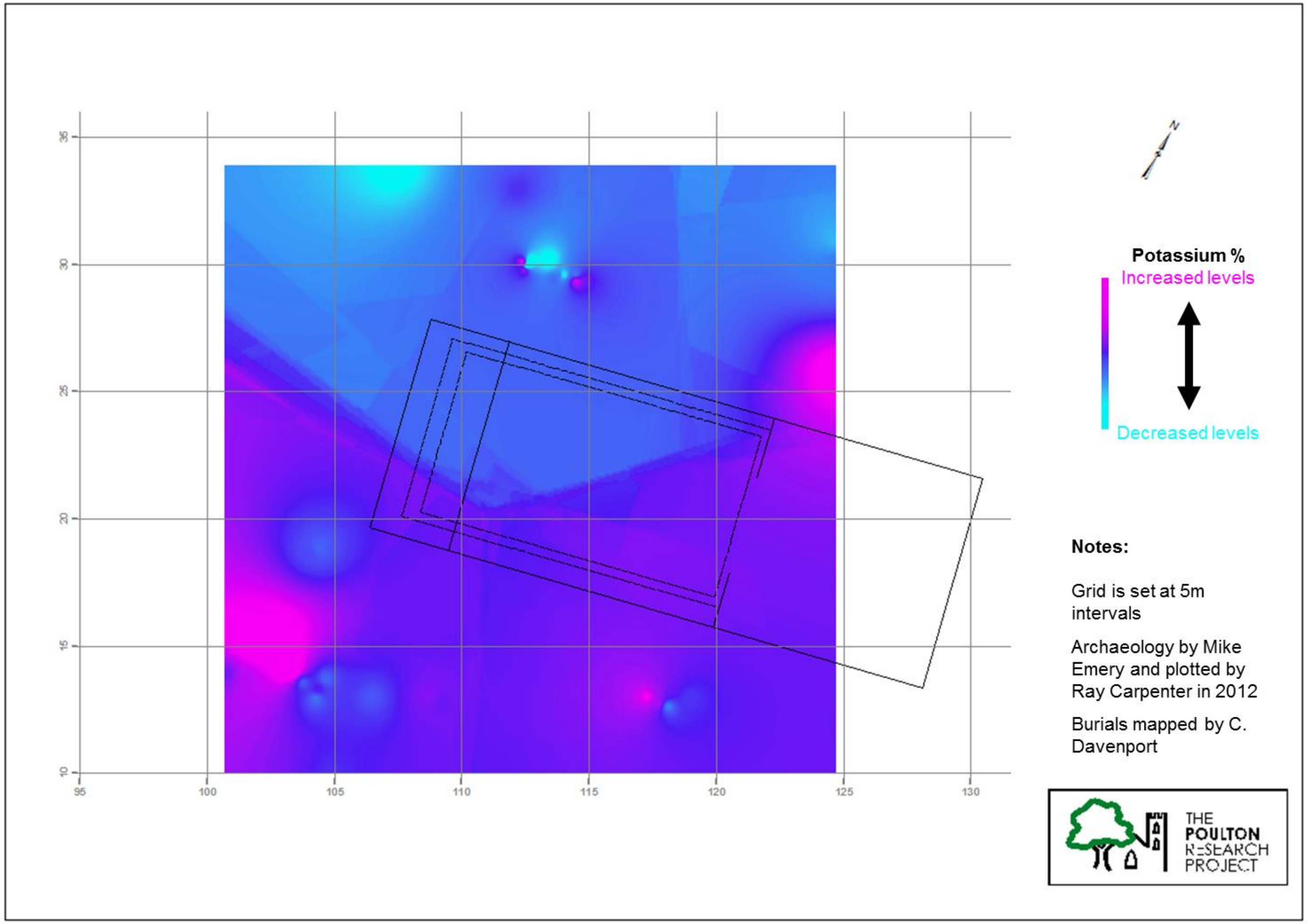

Figure 3.24. Percentage of potassium derived from the soil samples collected from Poulton Chapel. Mapped in ArcMAP 10.2.2 using an inverse distance weighted (IDW) interpolated raster. ©CAL Davenport

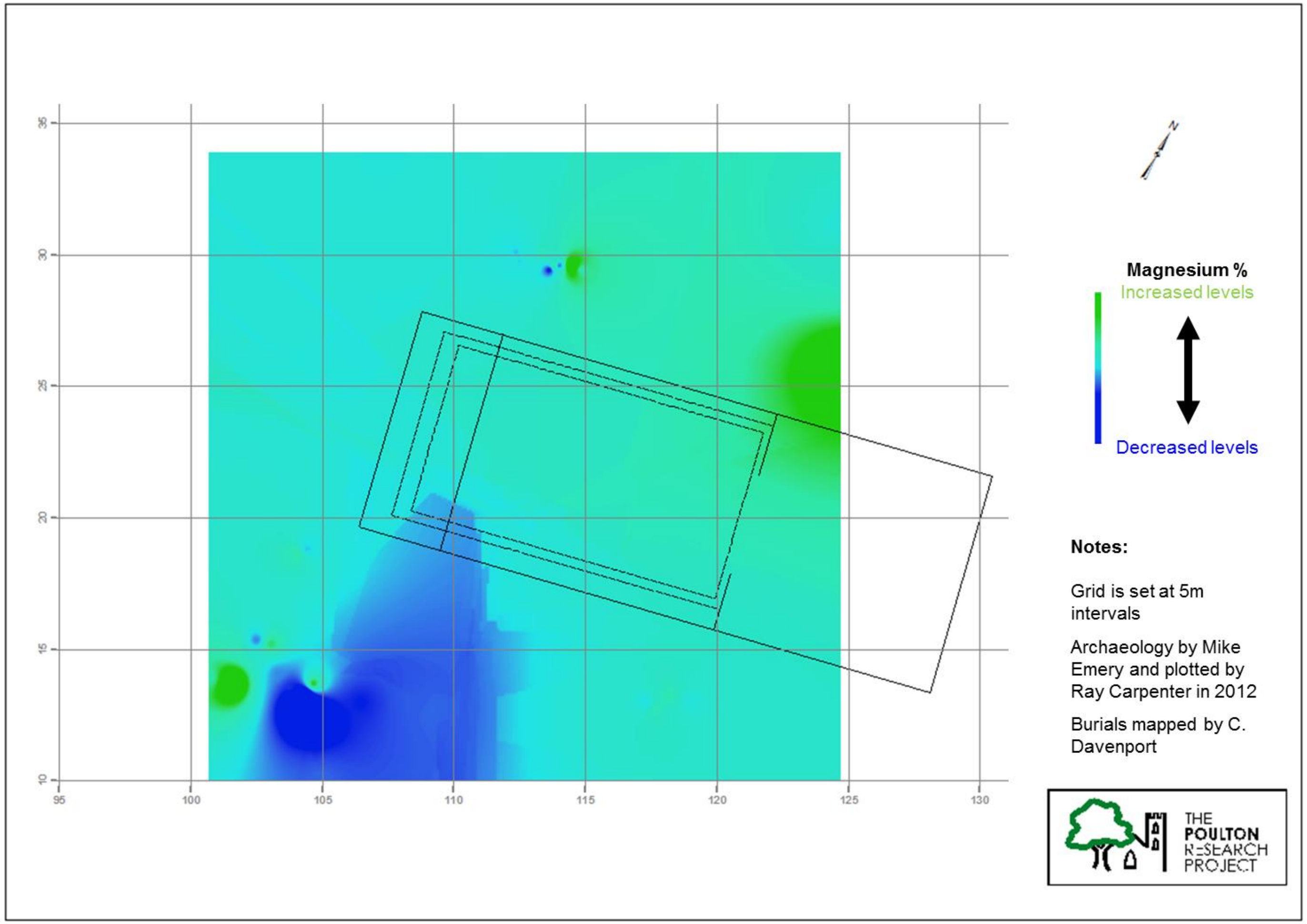

Figure 3.25. Percentage of magnesium derived from the soil samples collected from Poulton Chapel. Mapped in ArcMAP 10.2.2 using an inverse distance weighted (IDW) interpolated raster. ©CAL Davenport

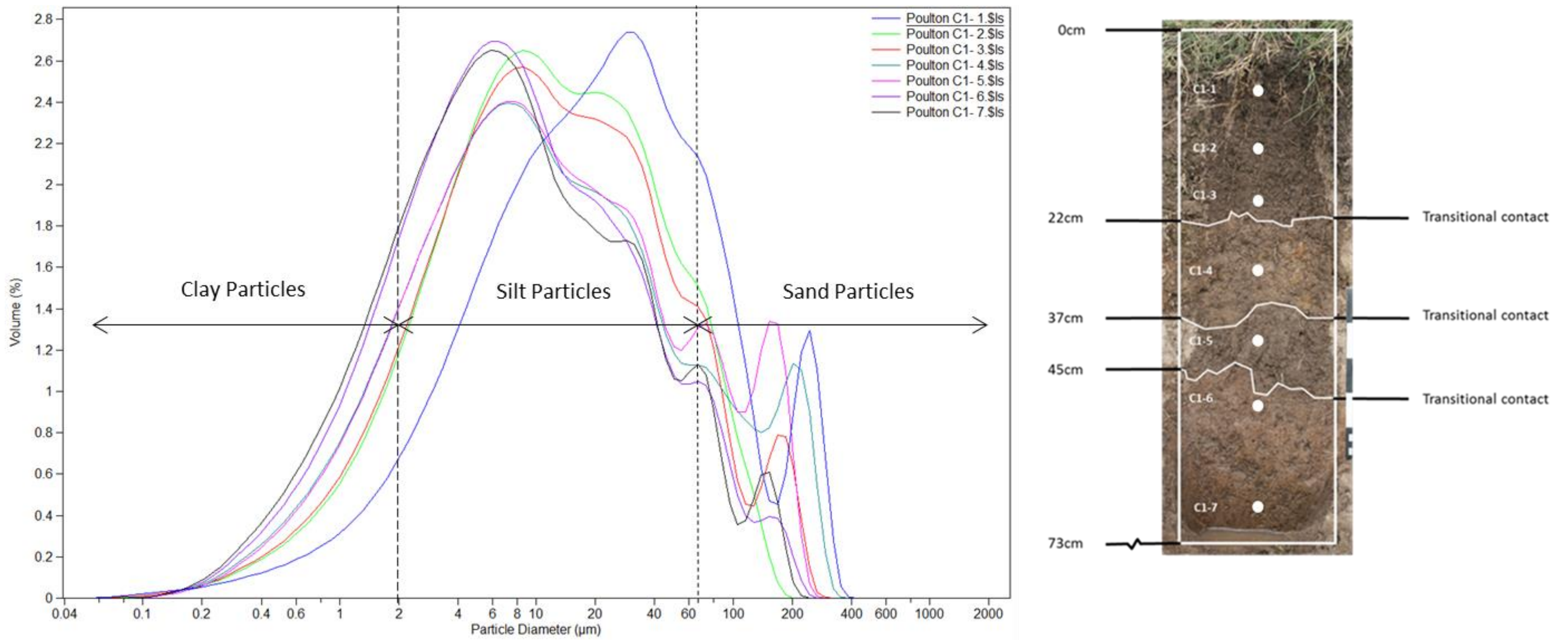

Figure 3.26. Differential grain size volume (%) of the seven soil samples taken from stratigraphic control section C1, showing the differences in the amount of clay (<2µm), silt (2-63µm) and sand (63-2000 µm) particles at the different depths. Stratigraphy of the control section is shown on the right for the sample location points (white dots). ©CAL Davenport

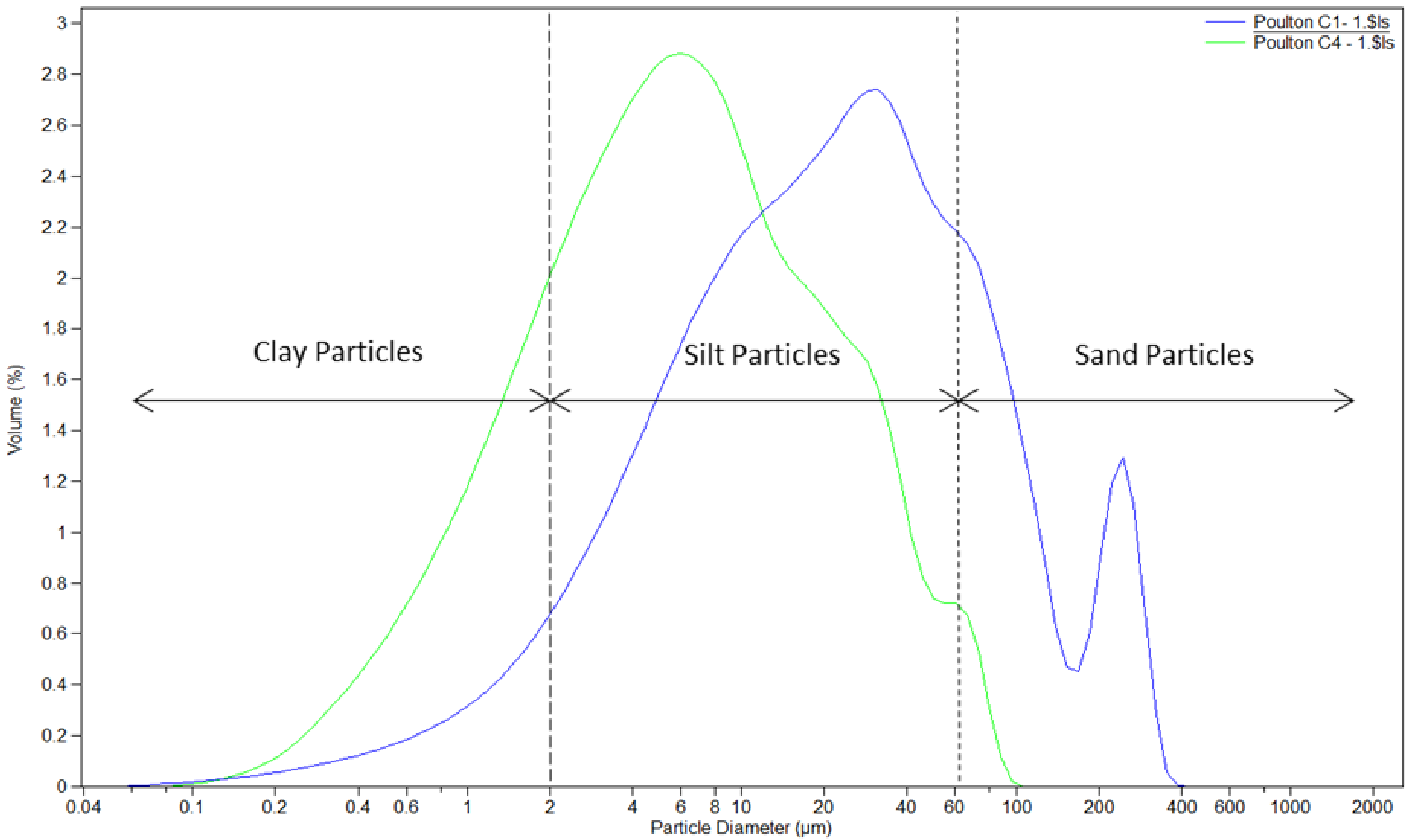

Figure 3.27. Differential grain size volume (%) of control soil samples from C1-1 and C4-3, highlighting the difference between the upper level soils found close to the cemetery and those derived from the parent material. ©CAL Davenport

Control section C4 provided three samples for comparison. There were no relationships identified between the soil profile and XRF results, however a relationship between the amount of clay present in a sample and the pH level was found to be significant ($r_{s(3)}$= 1.000, p=0.016). This relationship was not present with either silt or sand, but this may be due to the small sample size for this section. There were significant differences in the soil profile for levels of clay ($t_{(2)}$= 16.371, p=0.004) and silt ($t_{(2)}$= 47.401, p<0.001), but no differences in the amount of sand ($t_{(2)}$= 3.845, p=0.061). No relationships were identified between the soil colour and profile for section C4 due to the similarity between the samples at all three levels (Spearmans rank correlations, p>0.05).

Comparisons between sections C1 and C4 showed that there were differences in the soil profiles for clay ($F_{(1,8)}$=18.270, p=0.003) and sand ($F_{(1,8)}$=11.727, p=0.009), but no significant differences in the levels of silt ($F_{(1,8)}$= 1.376, p=0.734). As the levels of clay decrease the levels of sand increase, with the silt levels remaining consistent across the samples overall. Although visually there are different levels of silt in the upper level of section one when compared to section four (Figure 3.27), the lower levels of the section are closer to the parent material from the site.

The soil samples collected from across the cemetery were plotted using ArcMap to allow visual analysis of the site and aid in the understanding of the statistical comparisons with the other burial characteristics (Figures 3.28-3.30). The particle size data were compared against the XRF, frequency dependent magnetic susceptibility, and pH results from 41 samples from the cemetery; including burial level controls from C1, C2 and C3. As no calcium or phosphorous was identified in the soil, it was not possible to discern a relationship for these elements at this site. However, there were relationships identified with iron, potassium and magnesium levels in the soil. The analysis shows that as the percentage of iron increases, the amount of clay in the soil creases ($r_{s(41)}$=0.843, p<0.001), whereas sand shows a decrease ($r_{s(41)}$=-0.599, p<0.001). This pattern is also seen with potassium when compared with the amount of clay ($r_{s(41)}$=0.809, p<0.001) and sand ($r_{s(41)}$=-0.611, o<0.001) present in each sample. However, magnesium only showed a relationship with sand ($r_{s(41)}$=-0.422, p=0.007), with the amount of clay and silt having no correlation with this element (Spearmans rank correlations, p>0.05). There were no significant relationships identified between the soil particle profile and frequency dependent magnetic susceptibility at cemetery level (Spearmans rank correlations, p>0.05). This was also the case with pH when compared to the quantities of clay, silt or sand present in the samples (Spearmans rank correlations, p>0.05).

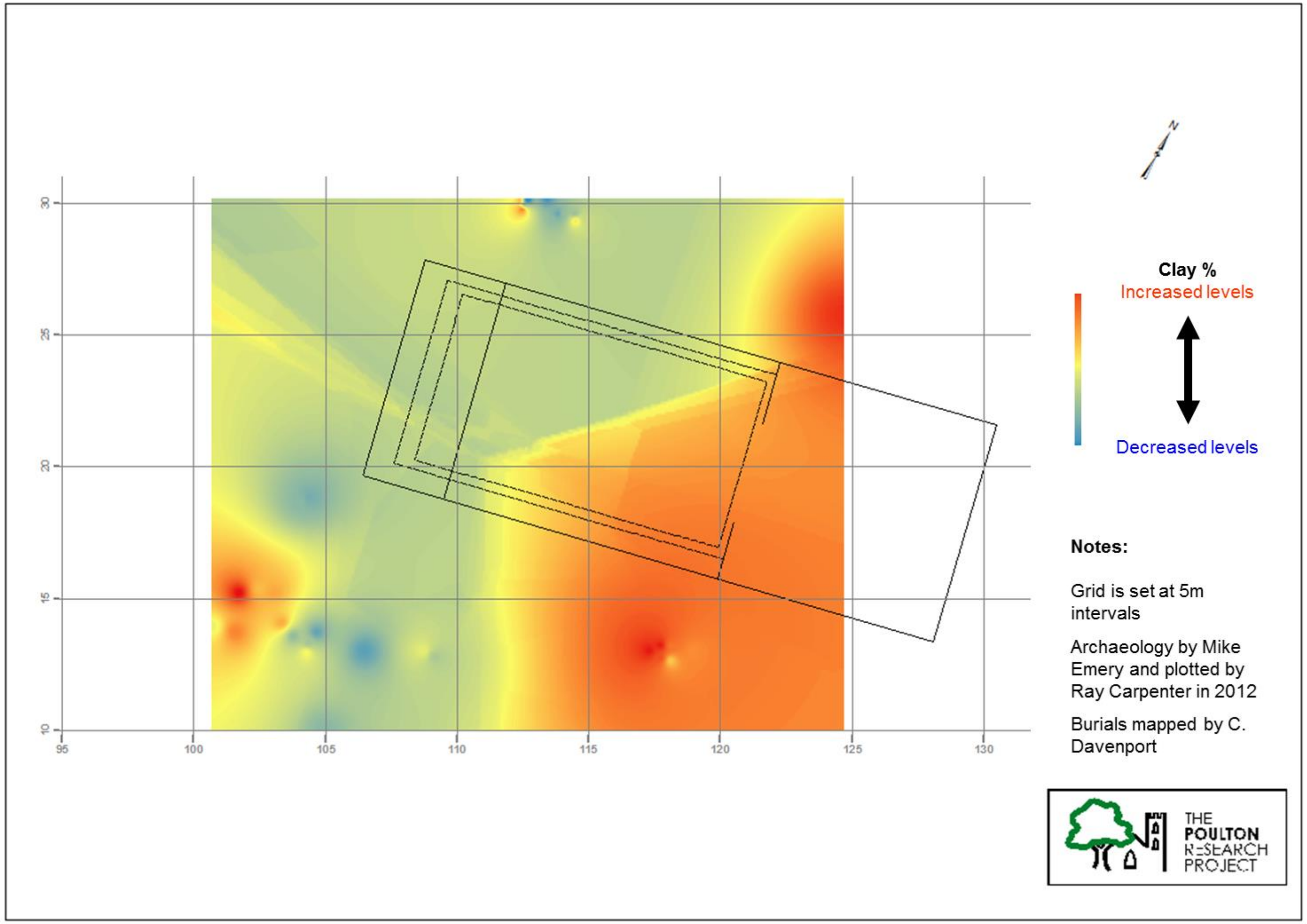

Figure 3.28. Percentage of clay present in the soil samples collected from Poulton Chapel. Mapped in ArcMAP 10.2.2 using an inverse distance weighted (IDW) interpolated raster. ©CAL Davenport

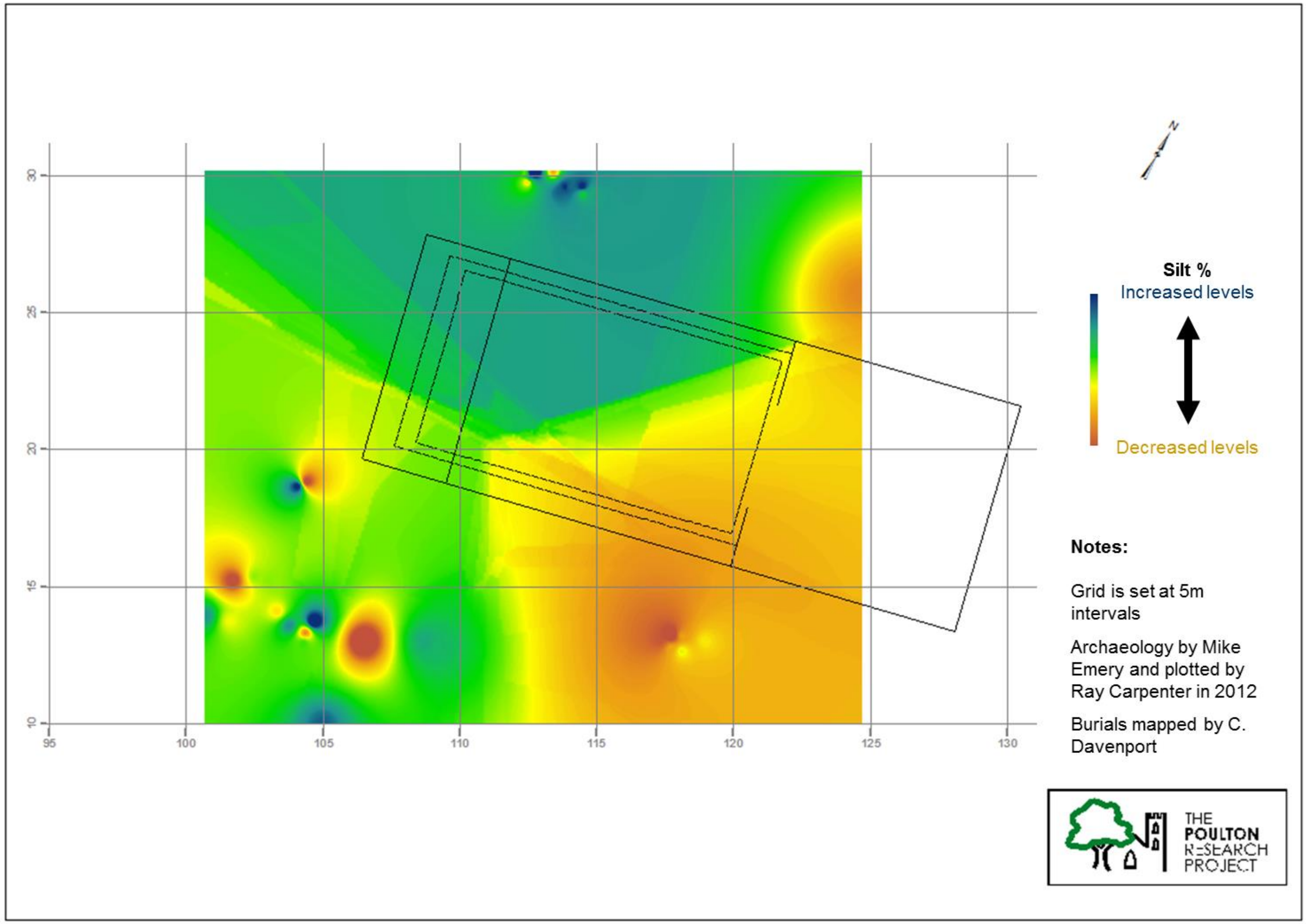

Figure 3.29. Percentage of silt present in the soil samples collected from Poulton Chapel. Mapped in ArcMAP 10.2.2 using an inverse distance weighted (IDW) interpolated raster. ©CAL Davenport

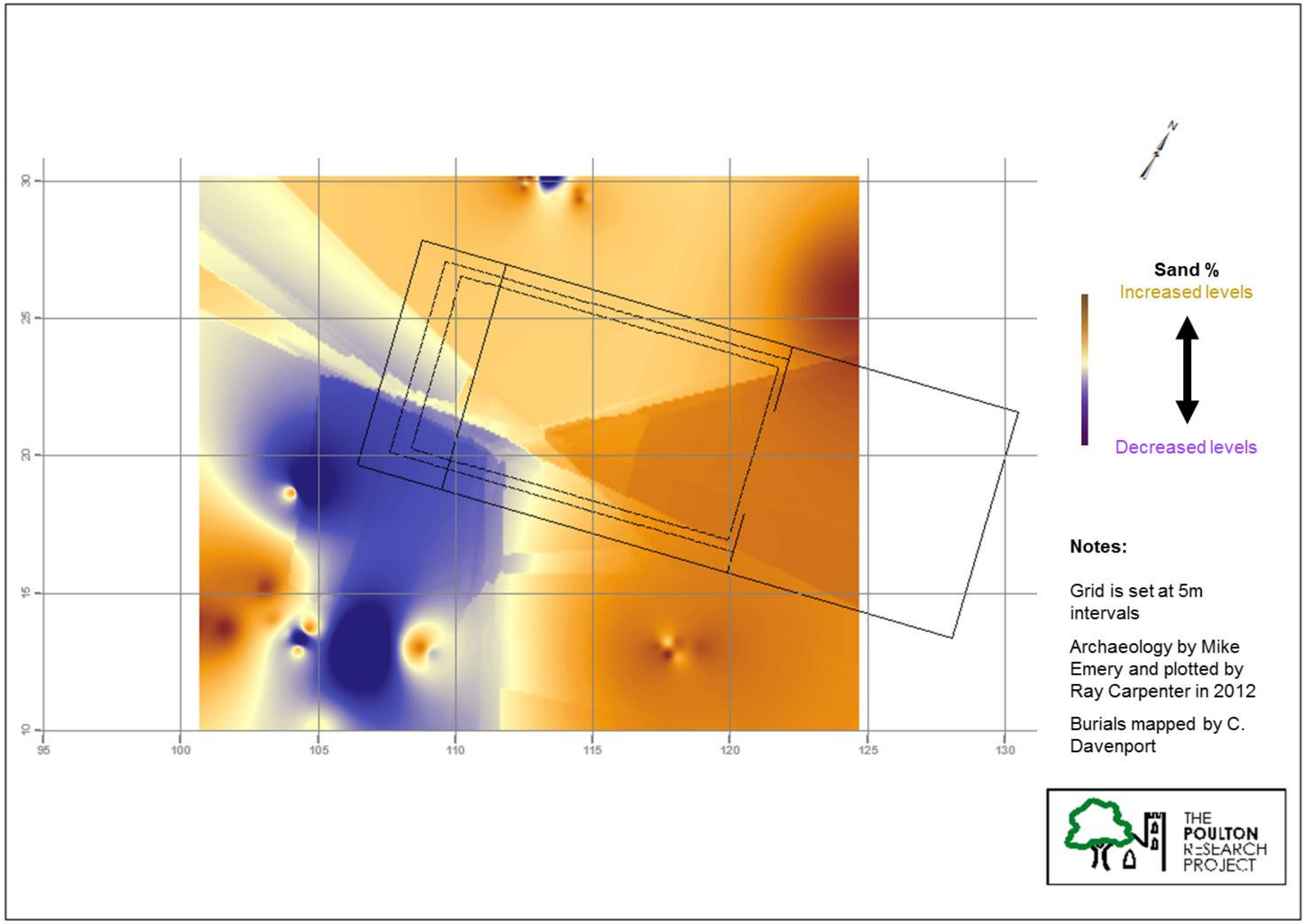

Figure 3.30. Percentage of sand present in the soil samples collected from Poulton Chapel. Mapped in ArcMAP 10.2.2 using an inverse distance weighted (IDW) interpolated raster. ©CAL Davenport

3.6. Soil analysis – individual grave level

Analysis carried out within the grave would determine whether the soil profile fluctuates within a small area, potentially leading to differential preservation of the individual skeletal elements within a single burial. The samples provided pH levels, frequency dependent magnetic susceptibility and soil chemistry (iron, potassium, and magnesium) and soil grain size (clay, silt and sand) information. Calcium and phosphorous could not be assessed for differences between grave samples, as they were not present. As the number of samples in each grave varies, one-sample *t*-tests (Student, 1908; De Winter, 2013) were used to assess the differences, along with descriptions and spatial analysis (where possible).

Skeleton 750

There were significant differences in pH for each of the samples ($t_{(5)}$=34.417, p<0.001), with levels ranging between 5.5 at the right elbow and 6.8 above the cranium (Table 3.3). Magnetic susceptibility fluctuated within the grave, showing values consistent with an admixture of superparamagnetic and non-superparamagnetic grains in the lower portions of the grave, but virtually no superparamagnetic grains present by the head and left shoulder ($t_{(5)}$=6.325, p=0.001). The levels of iron ranged between 4.33% at the feet and 4.74% at the right elbow, were noted as significantly different ($t_{(5)}$=78.815, p<0.001), along with the levels of potassium present ($t_{(5)}$=32.754, p<0.001). The percentage of magnesium present ranged between 14.33% at the head and 15.44% at the right knee ($t_{(5)}$=80.930, p<0.001). The locations of the six soil samples collected from the grave of skeleton 750 are shown in figure 3.31, along with the particle size analysis results. Significant differences were found for in the amount of clay ($t_{(5)}$=35.201, p<0.001), silt ($t_{(5)}$=107.999, p<0.001) and sand ($t_{(5)}$=2.822, p=0.037) present within the samples taken from the grave. There were no differences identified between the samples when assessing dry and damp soil colour (independent t-tests, p>0.05). A spatial analysis of the grave characteristics is shown in figure 3.32.

Table 3.3. The mean soil analysis results for pH, frequency dependent magnetic susceptibility (FDMS), iron (Fe), potassium (K), magnesium (Mg), clay, silt and sand, for the six samples collected from the grave of skeleton 750.

Sample	pH	FDMS	Fe %	K %	Mg %	Clay %	Silt %	Sand %
1	6.8	8.888	4.67	1.80	14.33	25.08	74.41	0.51
2	6.1	2.564	4.53	1.69	15.39	24.06	75.93	0.01
3	6.1	-72.000	4.58	1.44	14.84	20.88	77.51	1.62
4	6.5	-33.300	4.33	1.56	14.51	22.52	76.95	0.53
5	6.1	-15.100	4.63	1.62	1544	23.06	75.76	0.66
6	5.5	-33.300	4.74	1.68	14.92	25.08	72.83	2.09

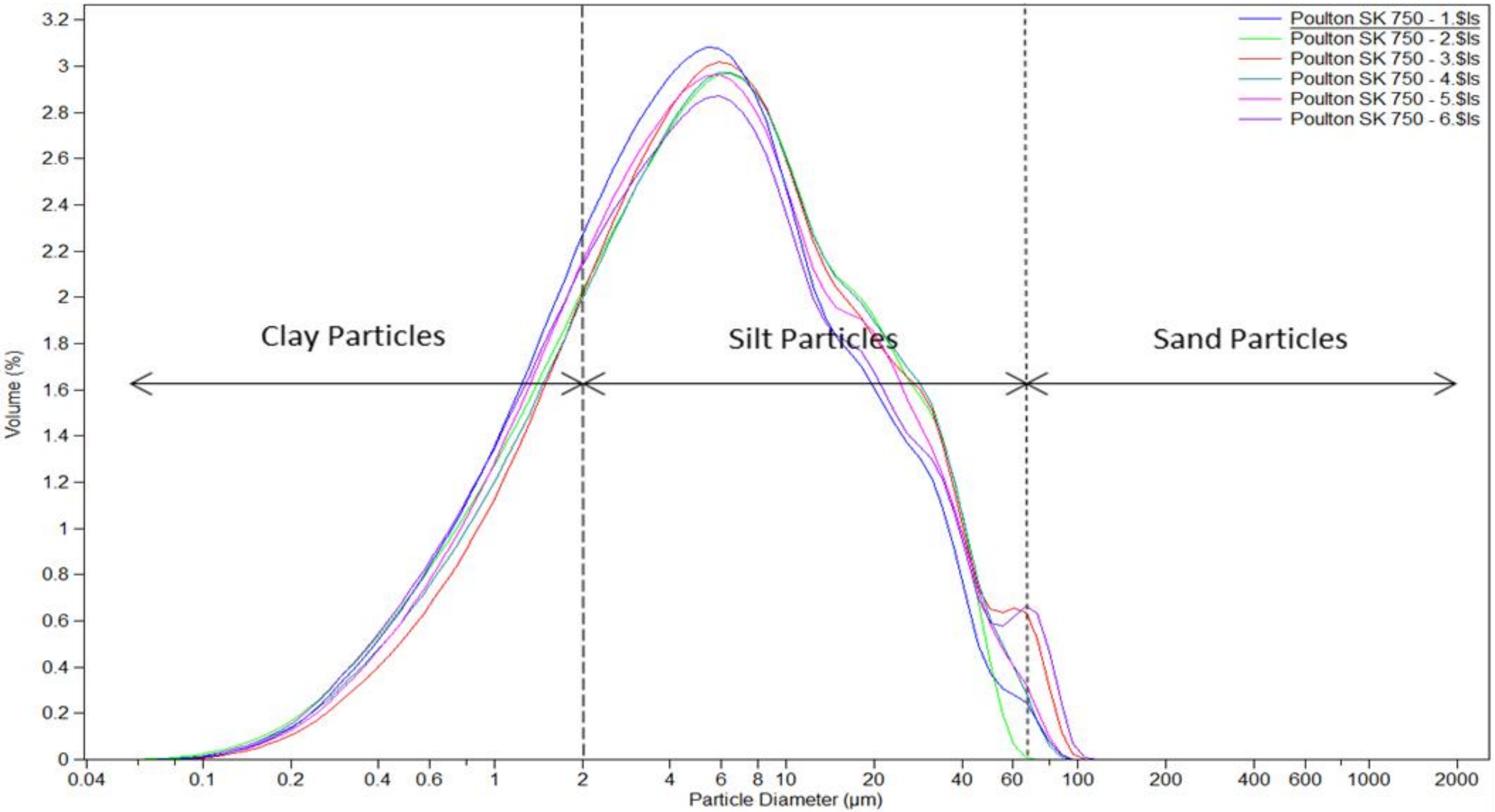

Figure 3.31. Soil particle analysis overlay plot (left) for the six samples collected from the grave of skeleton 750 (right). ©CAL Davenport and Poulton Research Project.

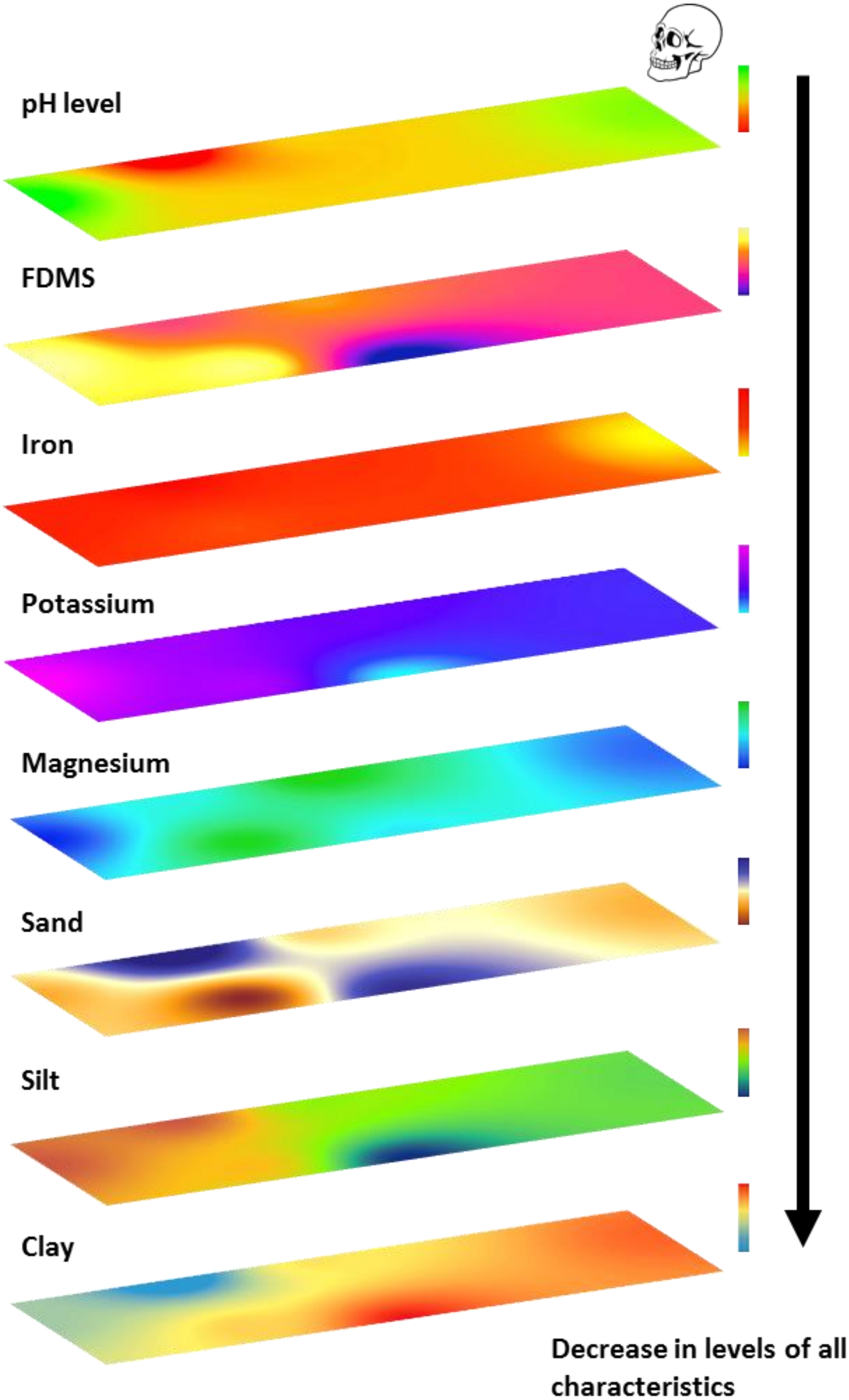

Figure 3.32. Spatial mapping of the soil characteristics of the grave of skeleton 750. Skull indicates the end of the grave the head was placed. Mapped in ArcMAP 10.2.2 using an inverse distance weighted (IDW) interpolated raster. ©CAL Davenport

Skeleton 773

There were only two soil samples collected from skeleton 773 due to the disturbance to the burial caused by the later interments, therefore samples were only collected from above the cranium and by the feet (Figure 3.33). When assessing the values for magnetic susceptibility within this grave, there appears to be a difference, but this was not found to be statistically significant (Table 3.4; $t_{(1)}$=3.000, p=0.205). There were significant differences in the levels of both iron ($t_{(1)}$=14.000, p=0.045) and potassium ($t_{(1)}$=40.070, p=0.016) but not magnesium ($t_{(1)}$=12.083, p=0.053). The soil particle analysis gave mixed results, with differences for both clay ($t_{(1)}$=12.711, p=0.050) and silt ($t_{(1)}$=52.839, p=0.012), but no significant difference in the amount of sand present ($t_{(1)}$=1.000, p=0.500). There were no significant differences identified between the samples when assessing dry and damp soil colour (independent t-tests, p>0.05). A spatial analysis of the grave was not possible due to the low number of sample points.

Table 3.4. The mean soil analysis results for pH, frequency dependent magnetic susceptibility (FDMS), iron (Fe), potassium (K), magnesium (Mg), clay, silt and sand for the two samples collected from the grave of skeleton 773.

Sample	pH	FDMS	Fe %	K %	Mg %	Clay %	Silt %	Sand %
1	5.3	-19.300	4.56	1.71	18.39	22.76	77.24	0.00
2	5.3	5.714	3.95	1.63	15.58	19.44	80.22	0.34

Skeleton 775

Three soil samples were collected from the grave of skeleton 775 during the excavation of the skeletal remains (Figure 3.34). There were significant differences in pH for each of the samples ($t_{(2)}$=36.248, p=0.001), with levels ranging between 5.0 at the cranium and 5.5 at the right elbow (Table 3.5). Frequency dependent magnetic susceptibility was not found to statistically different within the grave, although there were differences noted on visual inspection of the data ($t_{(2)}$=2.646, p=0.188). The levels of iron ranged between 4.38% by the pelvis and 4.75% at the feet, which was noted as significantly different ($t_{(2)}$=41.468, p=0.001), along with the differences in the levels of potassium present ($t_{(2)}$=169.182, p<0.001). The levels of magnesium were found to differ significantly, with ranges between 13.88% at the pelvis and 15.93% at the head ($t_{(2)}$=24.834, p=0.002). When assessing the soil particle analysis results, significant differences were found for clay ($t_{(2)}$=18.351, p=0.003) and silt ($t_{(2)}$=56.792, p<0.001). Although there was no difference identified for the percentage of sand present ($t_{(2)}$=3.344, p=0.079). There were no significant differences identified between the samples when assessing dry and damp soil colour (independent t-tests, p>0.05). Using inverse distance weighted interpolated raster maps, it was possible to visually assess the changes within the grave for skeleton 775 (Figure 3.35).

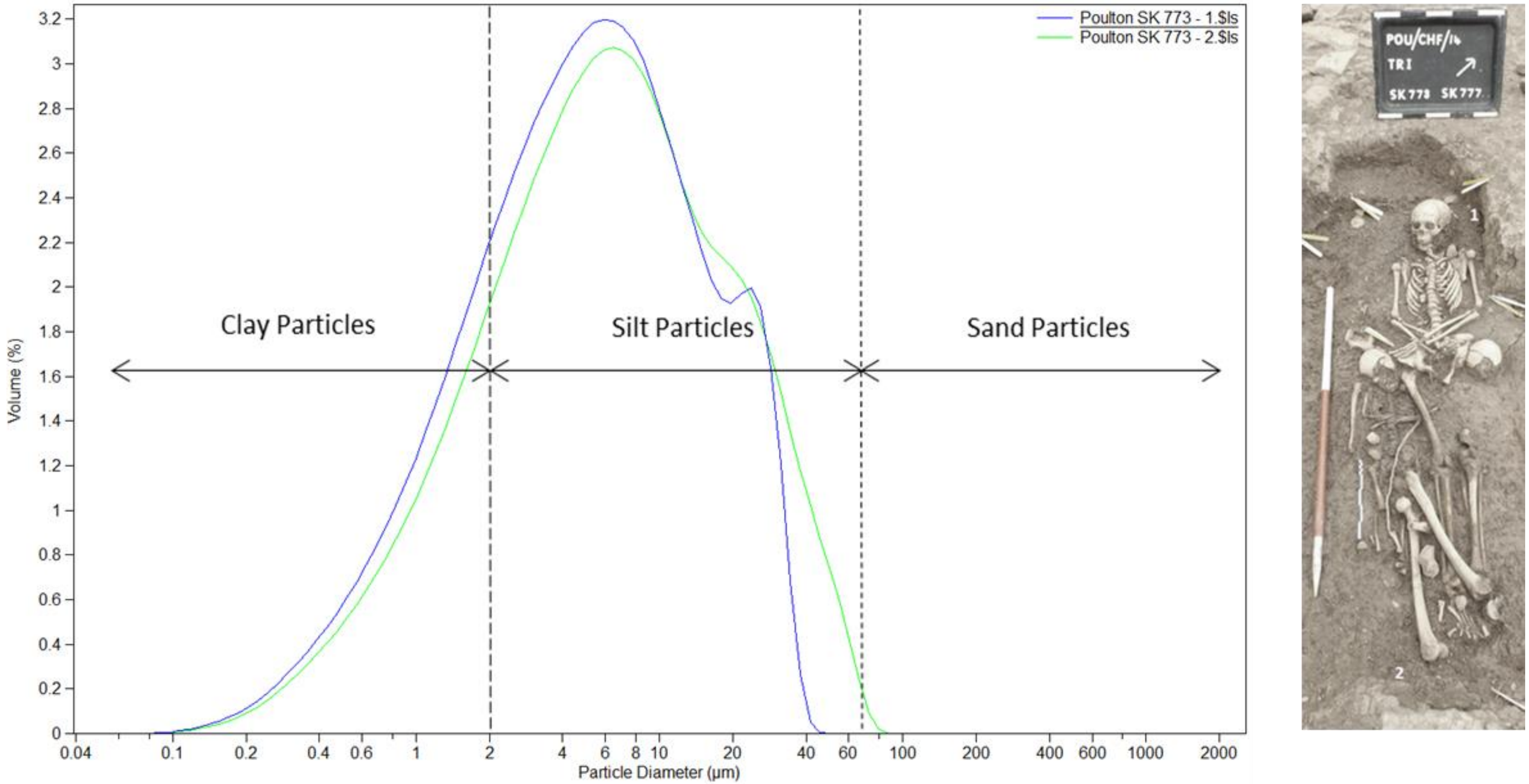

Figure 3.33. Soil particle analysis overlay plot (left) for the two samples collected from the grave of skeleton 773 (right). ©CAL Davenport and Poulton Research Project.

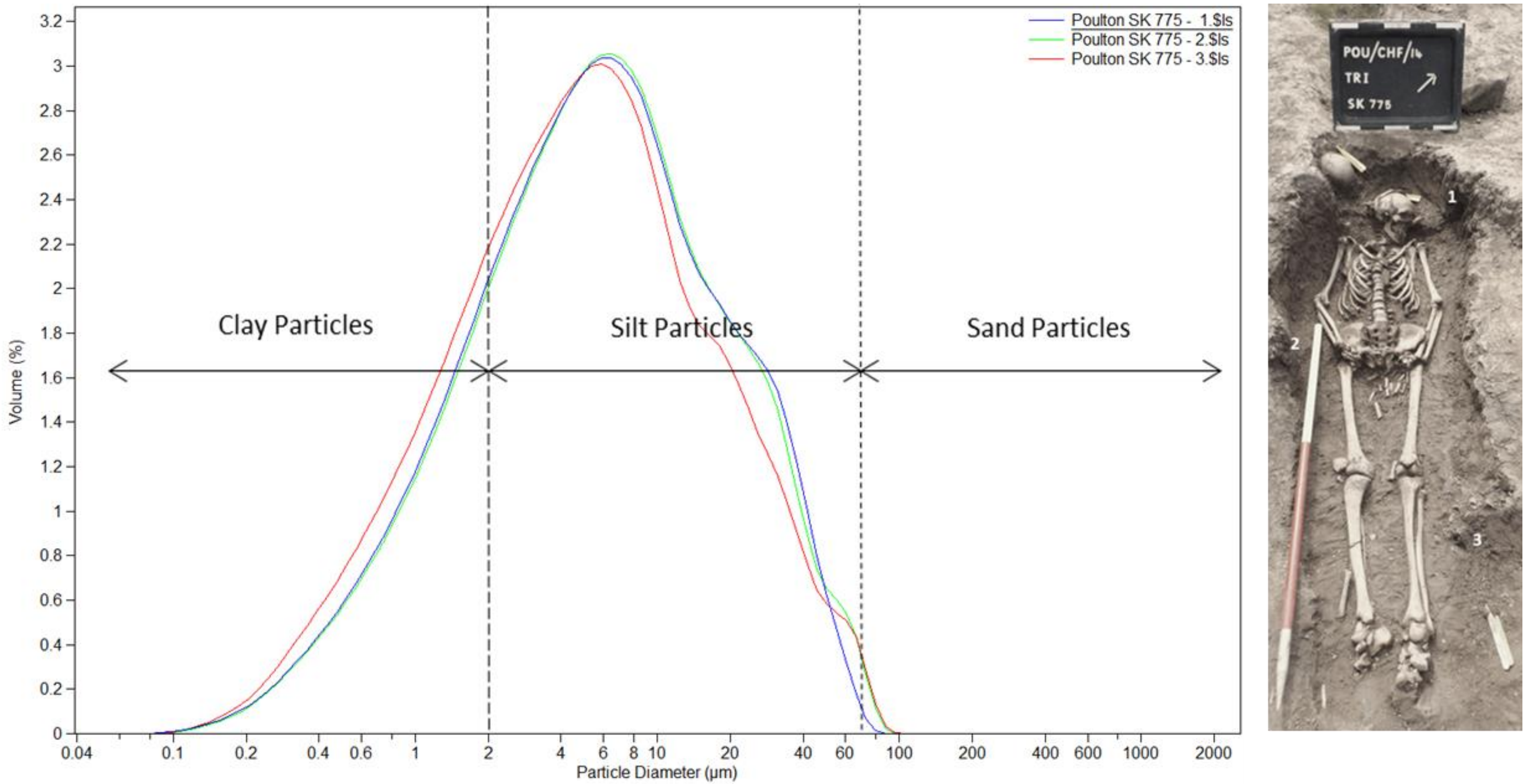

Figure 3.34. Soil particle analysis overlay plot (left) for the three samples collected from the grave of skeleton 775 (right). ©CAL Davenport and Poulton Research Project.

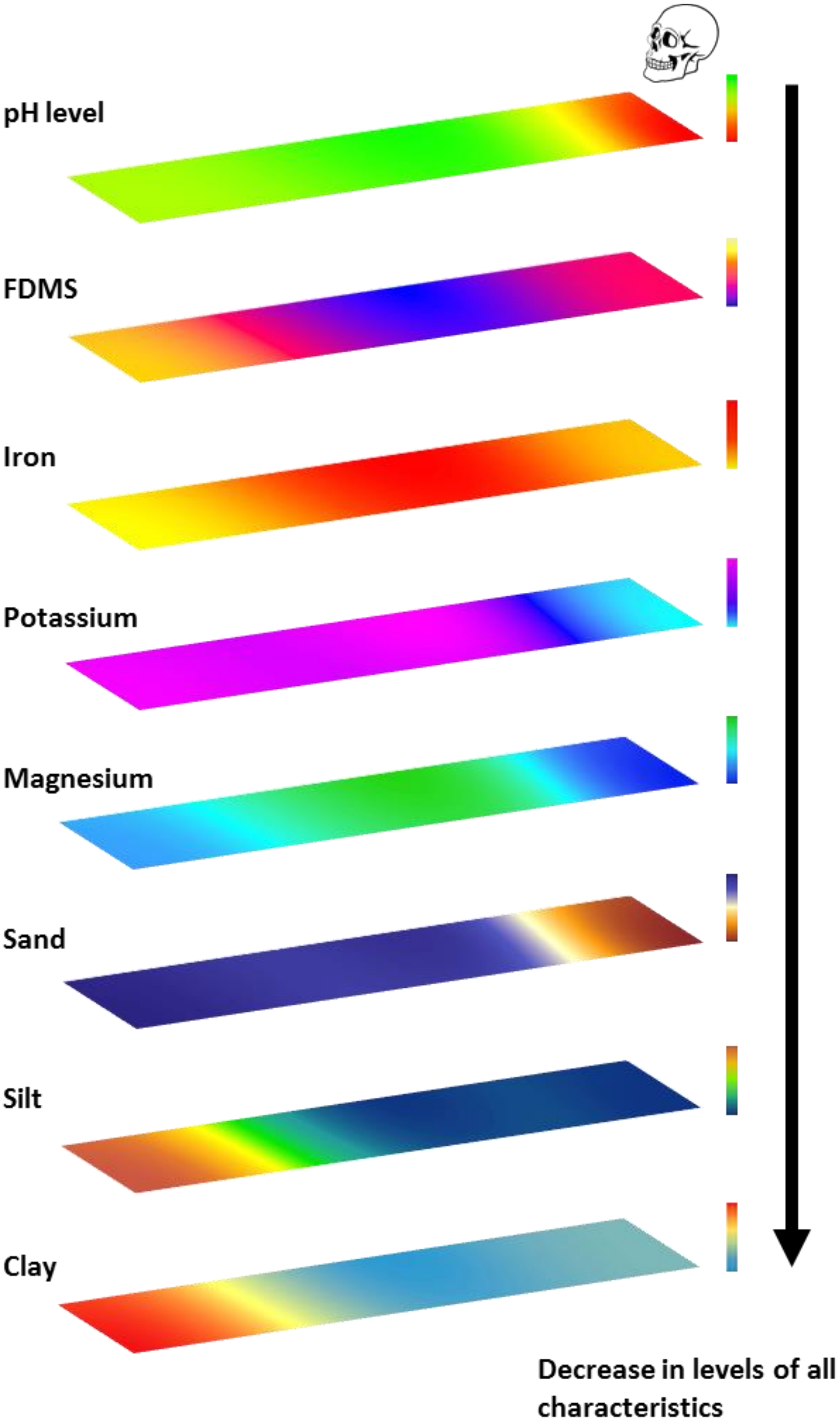

Figure 3.35.Spatial mapping of the soil characteristics of the grave of skeleton 775. Skull indicates the end of the grave the head was placed. Mapped in ArcMAP 10.2.2 using an inverse distance weighted (IDW) interpolated raster. ©CAL Davenport

Table 3.5. The mean soil analysis results for pH, frequency dependent magnetic susceptibility (FDMS), iron (Fe), potassium (K), magnesium (Mg), clay, silt and sand for the three samples collected from the grave of skeleton 775.

Sample	pH	FDMS	Fe %	K %	Mg %	Clay %	Silt %	Sand %
1	5.0	6.818	4.67	1.87	15.93	21.89	77.85	0.27
2	5.5	38.460	4.38	1.90	13.88	21.34	77.81	0.85
3	5.3	-19.300	4.75	1.90	15.32	25.32	73.79	0.89

Skeletons 779 and 781

The contemporary burial of skeletons 779-781 produced six soil samples for analysis (Figure 3.36) of the differences that can occur within a grave. The pH testing showed a range in values of between 5.3 for the samples collected from the right side of the grave, and 6.1 by the left shoulder of skeleton 779, which were significantly different ($t_{(5)}$=46.040, $p<0.001$; Table 3.6). The frequency dependent magnetic susceptibility testing showed that all samples contained virtually no superparamagnetic grains and therefore were not analysed statistically. Both the levels of iron ($t_{(5)}$=9.414, $p<0.001$) and potassium ($t_{(5)}$=11.377, $p<0.001$) were strongly significant, with potassium showing values of between 1.18% at the left shoulder of skeleton 779 and 1.85% by the left knee. Magnesium ranged between 13.96 at the feet of skeleton 781 and 15.20 at the head ($t_{(5)}$=74.549, $p<0.001$). As with skeleton 775, significant differences were found in the percentage of clay ($t_{(5)}$=10.246, $p<0.001$) and silt ($t_{(5)}$=45.105, $p<0.001$) present, but not with sand ($t_{(5)}$=1.597, $p=0.171$). However, as with the previous burials there were no differences identified between the samples when assessing dry and damp soil colour (independent t-tests, $p>0.05$). Using ArcMap, it was possible to visually assess the difference between the results from the soil samples collected from skeletons 779 and 781 (Figure 3.37).

Table 3.6. The mean soil analysis results for pH, frequency dependent magnetic susceptibility (FDMS), iron (Fe), potassium (K), magnesium (Mg), clay, silt and sand for the six samples collected from the graves of skeleton 779 and 781.

Sample	pH	FDMS	Fe %	K %	Mg %	Clay %	Silt %	Sand %
1	5.5	-19.300	3.98	1.21	15.20	14.89	75.72	9.39
2	6.1	-19.300	2.73	1.18	14.66	12.85	87.04	0.10
3	5.5	0.000	4.93	1.85	14.05	21.96	77.68	0.37
4	5.5	-26.900	5.04	1.63	14.84	21.57	77.31	1.12
5	5.3	-28.000	5.06	1.73	13.96	23.61	76.11	0.29
6	5.3	0.000	2.95	1.15	14.73	16.17	81.04	2.78

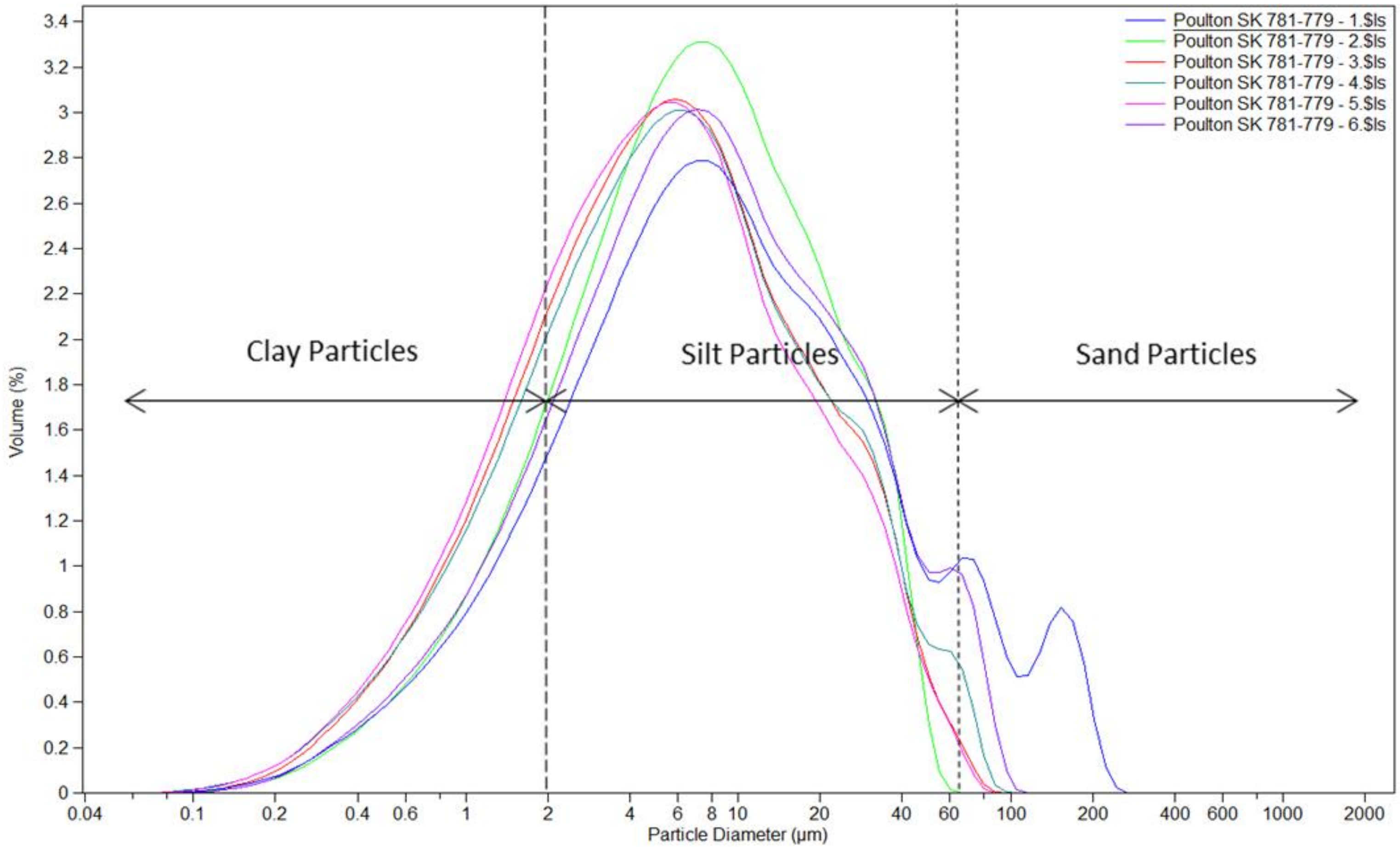

Figure 3.36. Soil particle analysis overlay plot (left) for the six samples collected from the grave of skeletons 779 and 781 (right). ©CAL Davenport and Poulton Research Project.

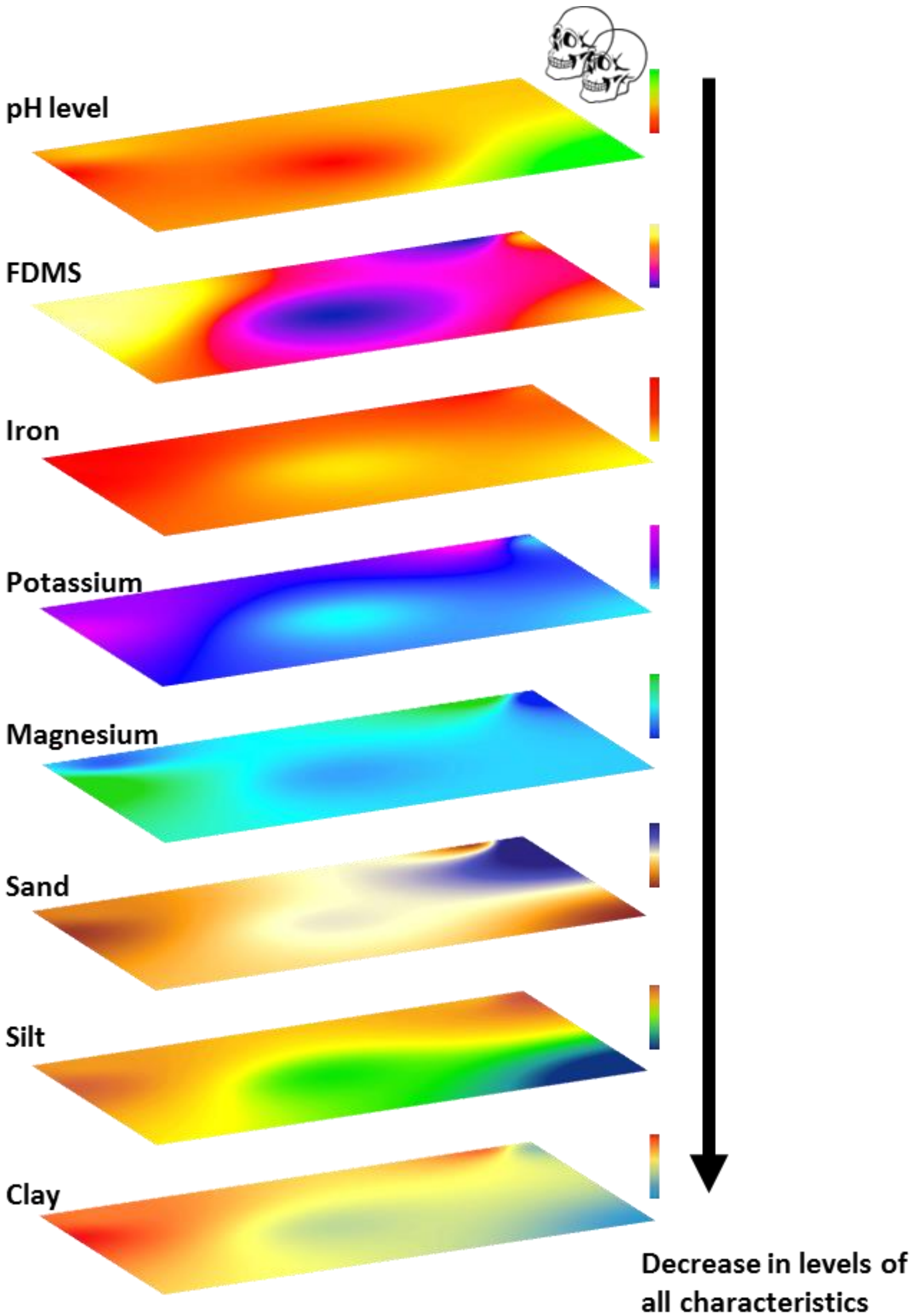

Figure 3.37. Spatial mapping of the soil characteristics of the grave of skeletons 779 and 781. The skulls indicate the end of the grave the heads were placed. Mapped in ArcMAP 10.2.2 using an inverse distance weighted (IDW) interpolated raster. ©CAL Davenport

Skeleton 785

The grave of skeleton 785, a single internment containing a non-adult burial on the north side of the chapel, provided six samples for analysis (Figure 3.38). The pH levels within this grave ranged from an almost neutral 6.8 at the pelvis, to a slightly acidic 5.5 at the cranium, feet and right shoulder ($t_{(5)}$=27.828, p>0.001; Table 3.7). Frequency dependent magnetic susceptibility values mainly contained samples consistent with an admixture of superparamagnetic and non-superparamagnetic grains in the lower portions of the grave, however virtually no superparamagnetic grains were found in the sample from the right knee ($t_{(5)}$=7.000, p=0.001). There were differences identified between the levels of iron ($t_{(5)}$=11.803, p<0.001), potassium ($t_{(5)}$=23.639, p<0.001) and magnesium ($t_{(5)}$=20.414, p<0.001) within the grave. The soil characteristics within this grave varied considerably, with a significant increase in percentage of clay at the left leg ($t_{(2)}$=24.243, p<0.00) and sand at the right shoulder ($t_{(5)}$=5.232, p=0.003). Fluctuating amounts of silt, which ranged between 78.74% at the left leg and 82.15% at the right leg ($t_{(5)}$=155.097, p<0.001) were also recorded. However, as with the previous burials there were no differences identified between the samples when assessing dry and damp soil colour (independent t-tests, p>0.05).

Table 3.7. The mean soil analysis results for pH, frequency dependent magnetic susceptibility (FDMS), iron (Fe), potassium (K), magnesium (Mg), clay, silt and sand for the six samples collected from the grave of skeleton 785.

Sample	pH	FDMS	Fe %	K %	Mg %	Clay %	Silt %	Sand %
1	5.5	-23.500	2.96	1.50	13.22	16.74	81.01	2.25
2	6.1	-14.800	4.96	1.78	16.39	20.67	78.74	0.59
3	5.5	2.702	4.46	1.63	15.46	18.32	79.77	1.91
4	5.8	-18.700	4.27	1.46	18.13	16.95	82.15	0.90
5	6.8	-44.100	3.97	1.32	13.47	16.96	80.80	2.24
6	5.5	0.000	2.97	1.47	15.80	15.55	81.80	2.64

The soil characteristics for the grave were mapped spatially to enable the differences between the soil samples to be observed (Figure 3.39).

Skeleton 787

There were only two soil samples collected from skeleton 787 due to the disturbance to the burial caused by the later interments and the age of the individual (0-2 months), therefore samples were only collected from the left side of the cranium and by the right arm (Figure 3.40). No statistical analysis could be carried out on pH, as the values for both samples were the same (Table 3.8). When visually assessing the values for magnetic susceptibility within this grave, there is a difference, but this was not found to be statistically significant

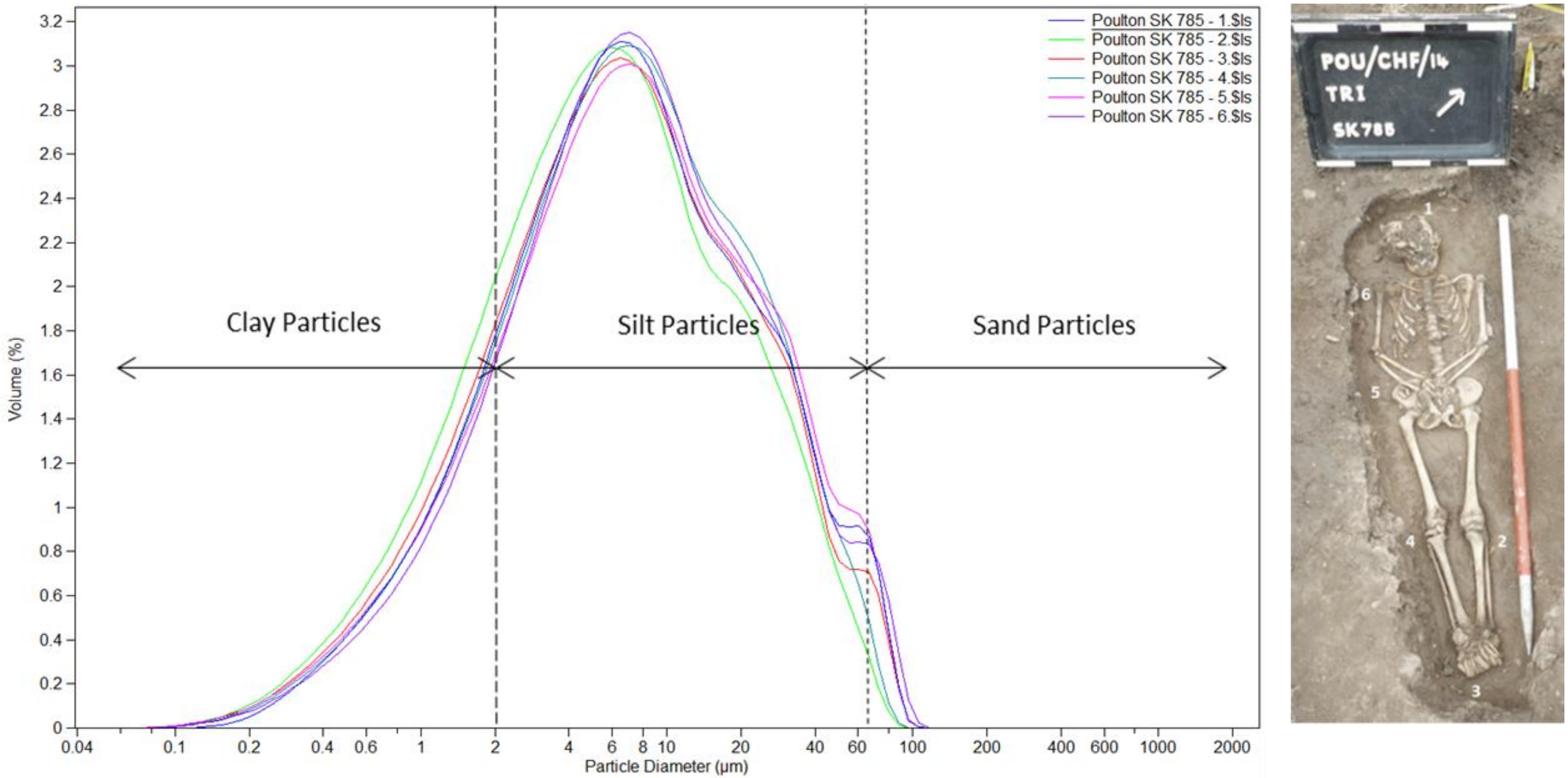

Figure 3.38. Soil particle analysis overlay plot (left) for the six samples collected from the grave of skeleton 785 (right). ©CAL Davenport and Poulton Research Project.

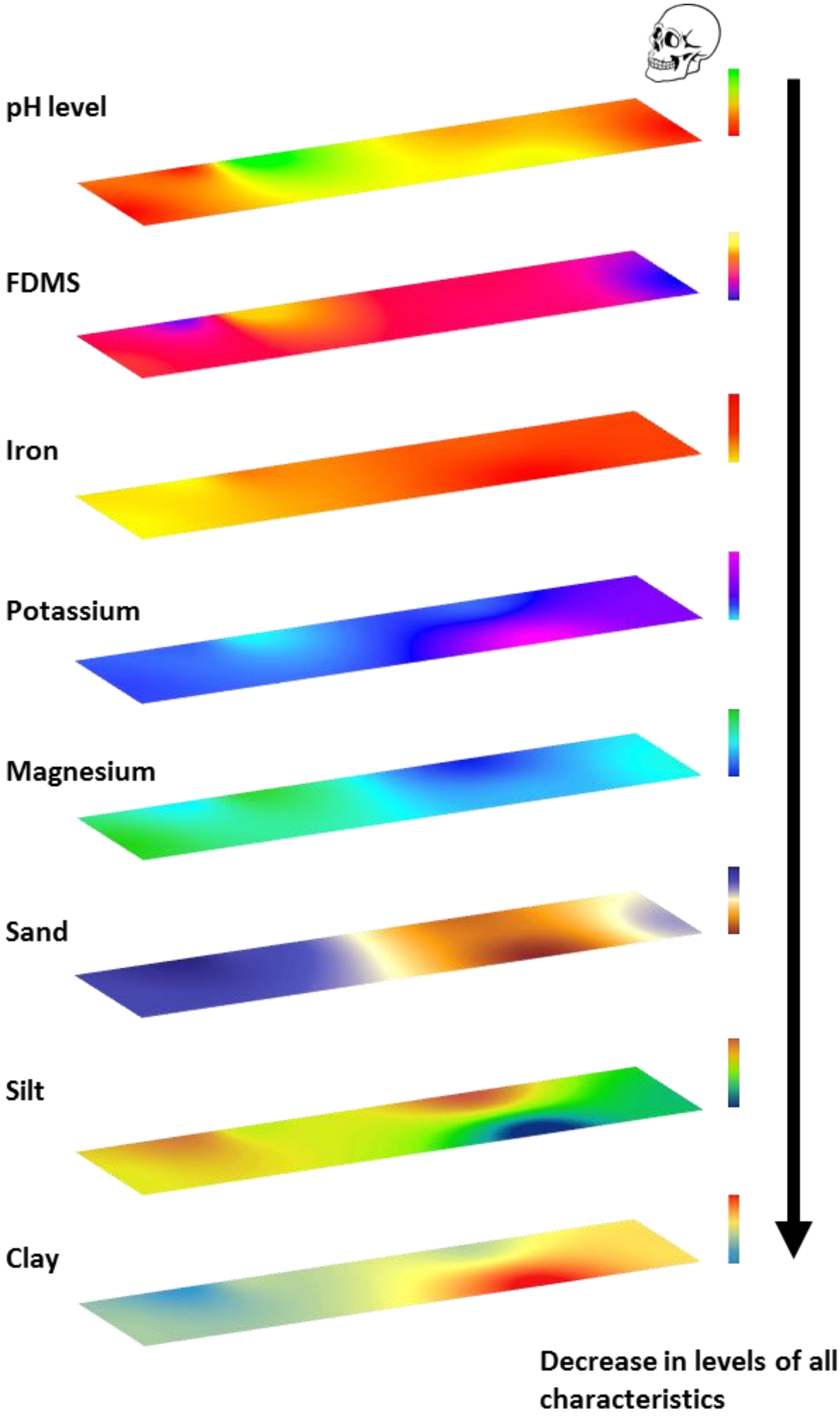

Figure 3.39. Spatial mapping of the soil characteristics of the grave of skeleton 785. Skull indicates the end of the grave the head was placed. Mapped in ArcMAP 10.2.2 using an inverse distance weighted (IDW) interpolated raster. ©CAL Davenport

($t_{(1)}$=1.667, p=0.344). There were significant differences in the levels of iron ($t_{(1)}$=106.690, p=0.006), potassium ($t_{(1)}$=102.040, p=0.006) and magnesium ($t_{(1)}$=452.529, p=0.001). The soil particle analysis gave mixed results, with differences for both clay ($t_{(1)}$=121.624, p=0.029) and silt ($t_{(1)}$=497.938, p=0.001), but similar amounts of sand present ($t_{(1)}$=1.945, p=0.302). There were no significant differences identified between the samples when assessing dry and damp soil colour (independent t-tests. p>0.05).

Table 3.8. The mean soil analysis results for pH, frequency dependent magnetic susceptibility (FDMS), iron (Fe), potassium (K), magnesium (Mg), clay, silt and sand, for the two samples collected from the grave of skeleton 787.

Sample	pH	FDMS	Fe %	K %	Mg %	Clay %	Silt %	Sand %
1	5.8	14.540	4.15	1.62	13.76	17.53	79.51	2.96
2	5.8	1.886	4.23	1.65	13.70	19.23	79.83	0.95

Skeletons 788 and 791

Three soil samples were collected from the grave of skeletons 788 and 791 during the excavation of the skeletal remains (Figure 3.41). There were significant differences in pH for each of the samples ($t_{(2)}$=32.000, p=0.001), with levels ranging between 5.5 at the head of 788 and 5.0 at the head of skeleton 791 (midpoint of samples), before increasing again. (Table 3.9). Frequency dependent magnetic susceptibility was not found to statistically different within the grave, although there were differences noted on visual inspection of the data ($t_{(2)}$=2.000, p=0.184). The levels of iron ranged between 3.73% by the head of skeleton 791 and 5.21% at the head of skeleton 788 ($t_{(2)}$=9.742, p=0.010). The levels of potassium ($t_{(2)}$=9.489, p=0.011) and magnesium were found to differ significantly ($t_{(2)}$=17.032, p=0.003). When assessing the soil particle analysis results, significant differences were found for clay ($t_{(2)}$=9.534, p=0.011) and silt ($t_{(2)}$=42.545, p=0.001), with similar amounts of sand present in each sample ($t_{(2)}$=3.496, p=0.073). There were no significant differences identified between the samples when assessing dry and damp soil colour (p>0.05). The soil samples collected from the graves of skeletons 779 and 781 were mapped using inverse distance weighted interpolated raster maps to allow visual analysis of the differences in the soil characteristics (Figure 3.42).

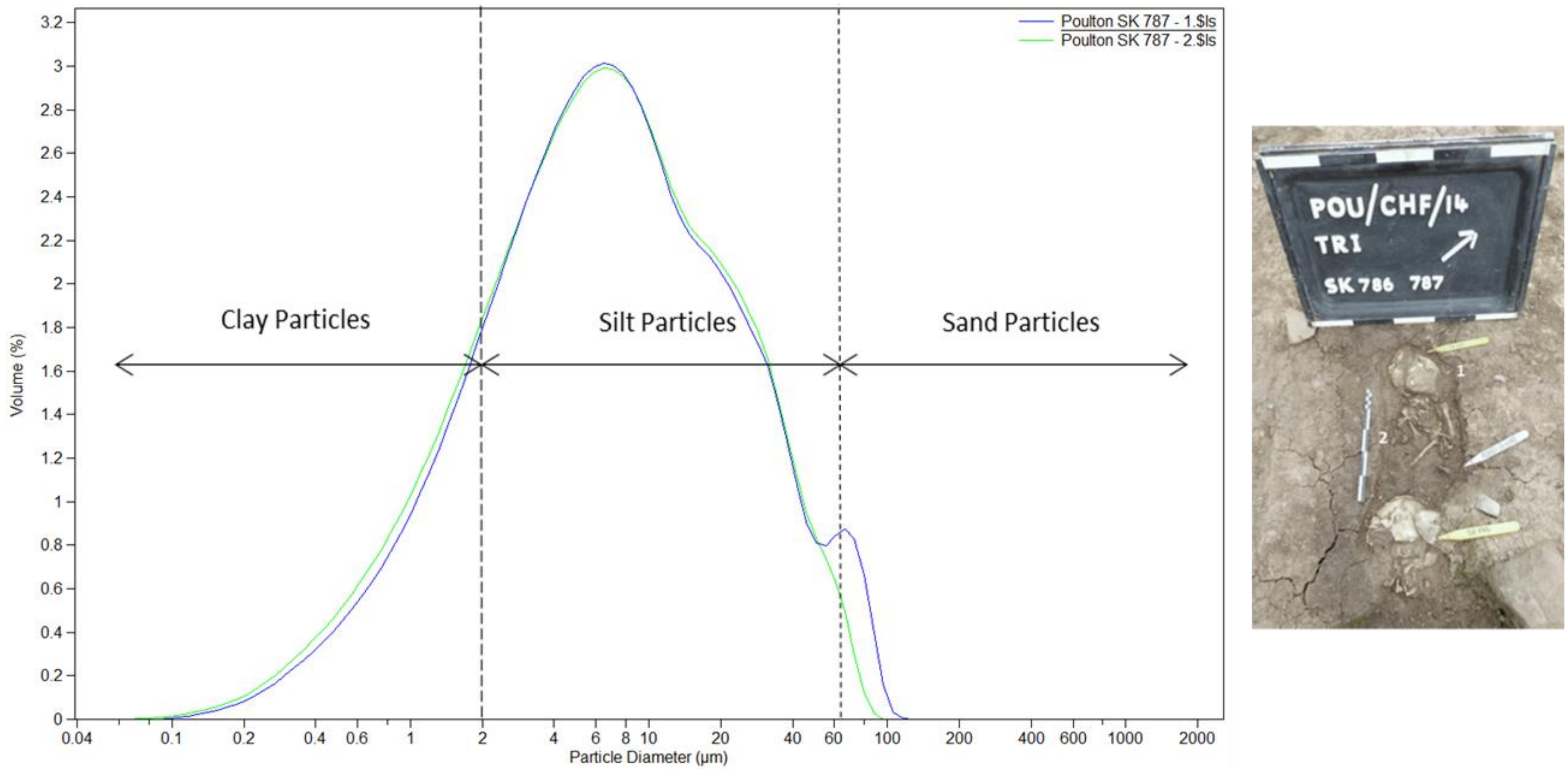

Figure 3.40. Soil particle analysis overlay plot (left) for the two samples collected from the grave of skeleton 787 (right). ©CAL Davenport and Poulton Research Project.

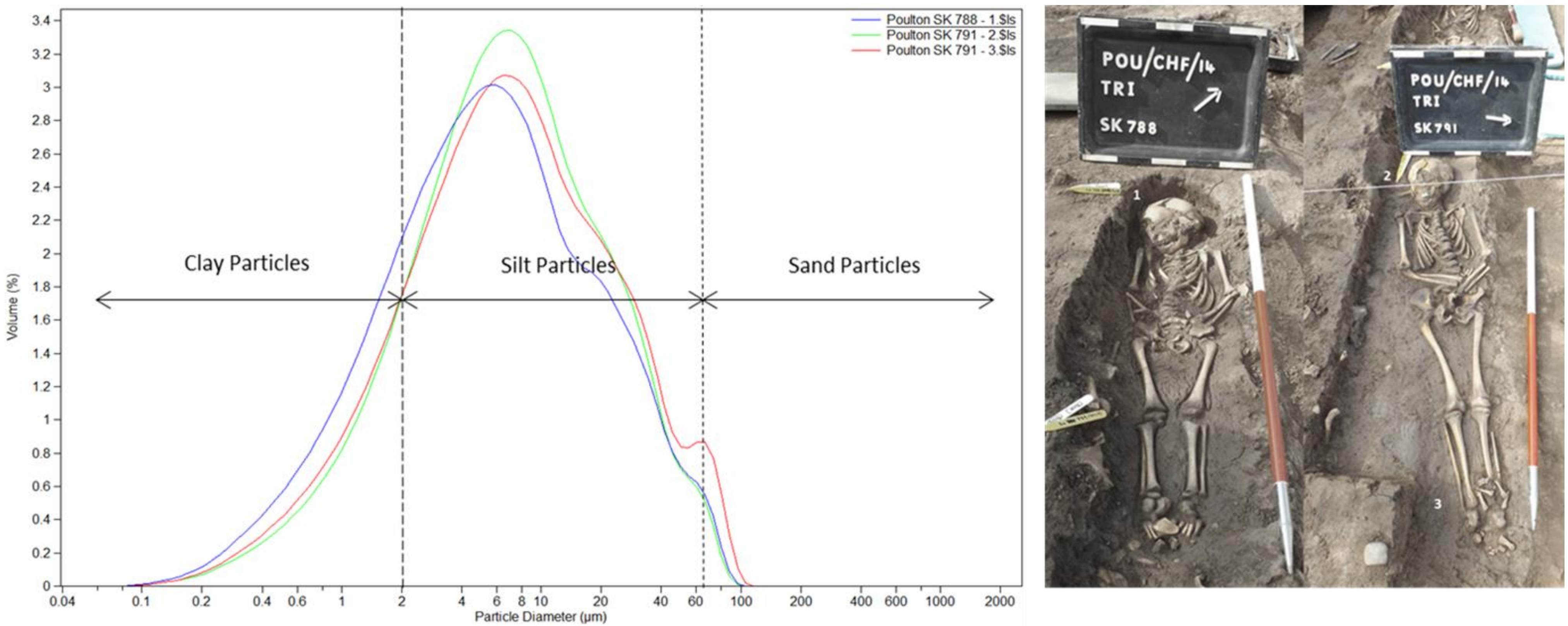

Figure 3.41. Soil particle analysis overlay plot (left) for the three samples collected from the grave of skeletons 788 (middle) and 791 (right). ©CAL Davenport and Poulton Research Project.

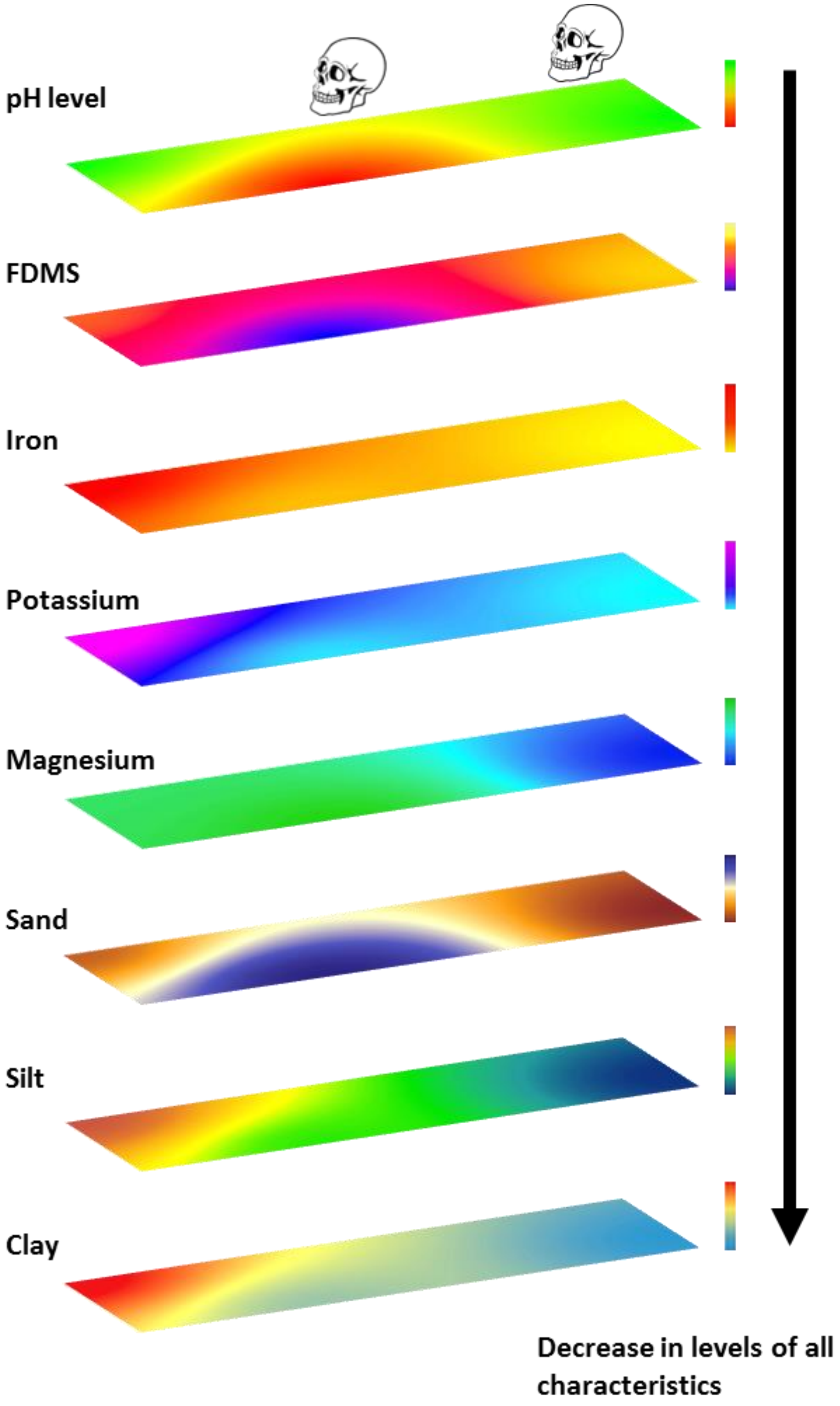

Figure 3.42. Spatial mapping of the soil characteristics of the grave of skeletons 788 and 791. The skulls indicate the head placement within the grave, in this case the head of skeleton 791 was found at the feet of skeleton 788. Mapped in ArcMAP 10.2.2 using an inverse distance weighted (IDW) interpolated raster. ©CAL Davenport

Table 3.9. The mean soil analysis results for pH, frequency dependent magnetic susceptibility (FDMS), iron (Fe), potassium (K), magnesium (Mg), clay, silt and sand for the three samples collected from the graves of skeletons 788 and 791.

Sample	pH	FDMS	Fe %	K %	Mg %	Clay %	Silt %	Sand %
1	5.5	-9.090	5.21	2.03	13.93	21.80	76.80	1.30
2	5.5	-20.500	3.73	1.49	16.25	15.58	83.31	1.11
3	5.0	19.040	4.08	1.51	13.50	16.86	80.50	2.64

Additional grave samples

Seven additional soil samples were collected from the crania of skeletons 793-798, and the grave of skeletons 691 and 692. There were significant differences in pH for each of the samples, with levels ranging between 5.3 and 5.8 ($t_{(6)}$=64.406, p<0.001; Table 3.10). Magnetic susceptibility fluctuated, showing values consistent with an admixture of superparamagnetic and non-superparamagnetic grains for most samples, but virtually no superparamagnetic grains in the cranial samples from 797 and 798 ($t_{(6)}$=9.295, p<0.001). The levels of iron ranged between 3.84% and 4.78%, which was noted as significantly different ($t_{(6)}$=34.172, p<0.001), as were the differences in the levels of potassium ($t_{(6)}$=34.430, p<0.001). The percentage of magnesium present ranged between 10.11% for the sample from skeleton 798 and 16.90% for the grave sample for skeleton 691 and 692 ($t_{(6)}$=16.426, p<0.001). When assessing the soil particle analysis results, significant differences were found for clay ($t_{(6)}$=14.825, p<0.001), silt ($t_{(6)}$=55.172, p<0.001) and sand ($t_{(6)}$=2.764, p=0.033; figure 3.43). There were no differences identified between the samples when assessing dry and damp soil colour (independent t-tests, p>0.05). As the samples come from different areas of the cemetery, rather than one grave, these samples have not been mapped. Please refer to the cemetery mapping to gain a greater understanding of the differences in the burial environment.

Table 3.10. The mean soil analysis results for pH, frequency dependent magnetic susceptibility (FDMS), iron (Fe), potassium (K), magnesium (Mg), clay, silt and sand, for the soil sample obtained from the grave of skeletons 691/692 and those from the crania of skeletons 793-798.

Skeleton	pH	FDMS	Fe %	K %	Mg %	Clay %	Silt %	Sand %
691/692	5.8	5.882	4.78	1.83	16.90	24.65	75.35	0.00
793	5.3	5.882	4.32	1.54	15.53	16.65	82.09	1.26
794	5.5	4.762	3.95	1.58	13.76	16.59	80.99	2.42
795	5.3	4.167	3.91	1.52	13.41	15.43	72.42	12.15
796	5.8	8.333	4.23	1.50	14.17	16.08	73.64	8.56
797	5.8	0.000	3.84	1.61	12.11	17.29	75.28	7.43
798	5.5	0.000	4.18	1.47	10.11	19.94	78.37	1.69

3.7. Site plans

As there is no Harris Matrix for the burials, it has not been possible to examine the relationships present by traditional means. In an attempt to retrieve some of the missing information, the use of ArcGIS spatial analysis software was used to map the burials. This enabled the exploration of the cemetery layout and an investigation into the change in burial practices through the lifespan of the site. Due to the high number of disturbed burials present at the site, only articulated burials (n=591) were mapped. Of these, 18 did not provide coordinates for burial and were not included in the map or statistical analysis.

Spatial distribution of the burials of the map revealed no set pattern to the placement of the adult and non-adult burials present at Poulton Chapel (Figure 3.44). The north of the cemetery shows an area where fewer non-adults were located, however for the rest of the cemetery the burials are mixed by age group. Using SPSS v. 23, Spearman's correlations were carried out to determine whether there was a statistical relationship between the location of the burial and the age of an individual. The results concluded that there was a positive relationship for both Eastings and Northings, however this result was weak ($r_{s(566)}=0.136$, $p<0.001$ and $r_{s(566)}=0.110$, $p=0.009$ respectively). When location was compared to the age categories assigned during biological, Eastings continued to display a significant weak correlation ($r_{s(528)}=0.147$, $p=0.001$), but not for northings ($r_{s(528)}=0.079$, $p=0.070$). There was no relationship identified for the distribution of skeletons for which sex was determined for either the Eastings ($r_{s(315)}=0.049$, $p=0.389$) or Northings ($r_{s(315)}=0.046$, $p=0.415$).

It was apparent when looking at the spatial analysis that the North and East sides of the cemetery may be causing a bias with the statistical analysis. As these areas of the cemetery have not been fully excavated, it could change as the excavations continue and will need re-evaluating once the excavations are complete. However, at present there is no pattern to the location of the burials when considering age and/or sex enabling the assumption that there was no significance in the positioning of burials based on these two factors alone.

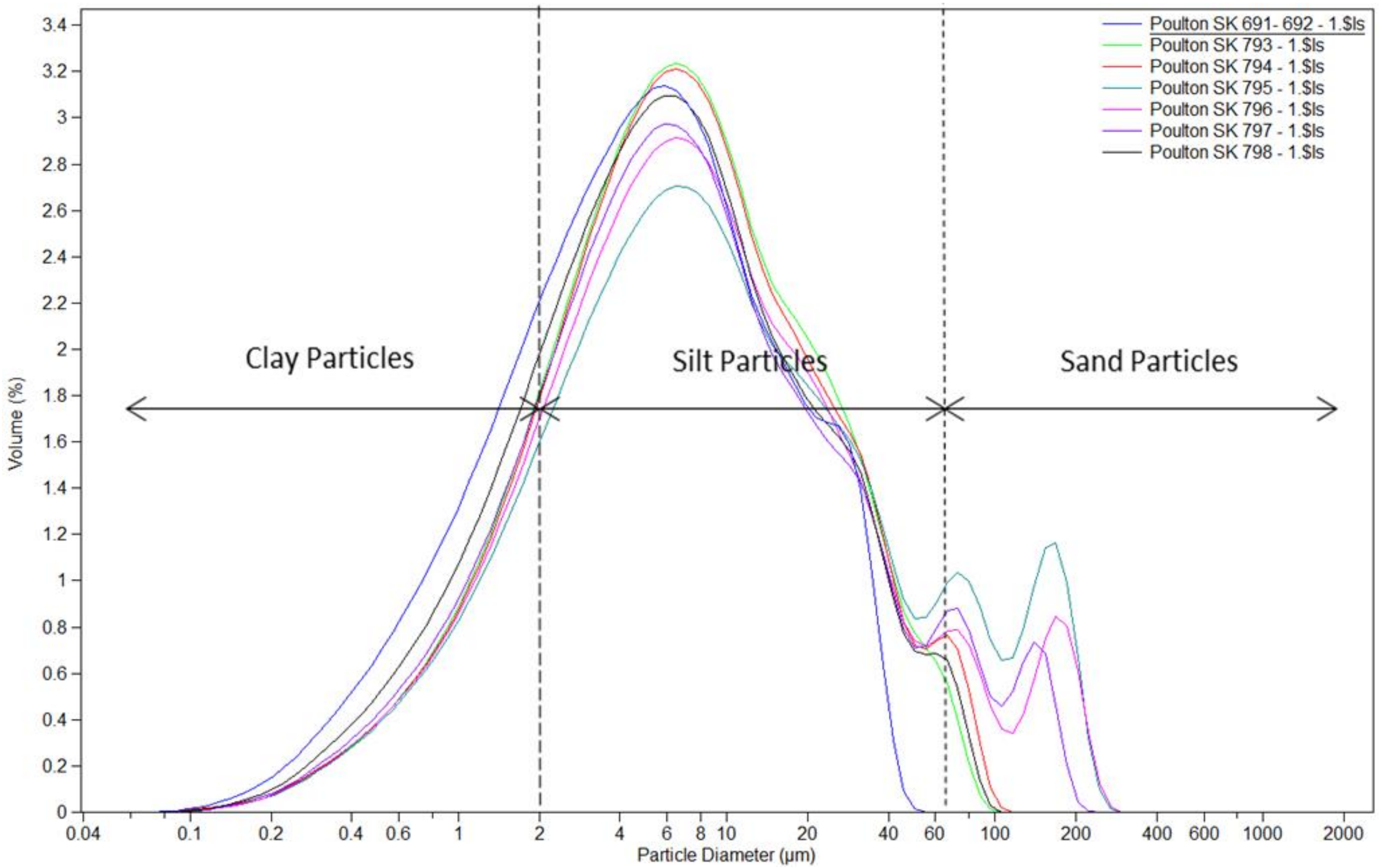

Figure 3.43. Additional grave soil sample from the grave of skeletons 691-692 and cranial soil samples from skeletons 793-798. ©CAL Davenport

3.8. Archaeothanatology

All articulated skeletons (n=591) were assessed to determine the position of the arms during internment (see figure 2.1, page 46 for arm position reference). Of these, 127 (21.5%) skeletons did not provide sufficient information for analysis. A further 18 articulated burials did not have coordinate information to plot spatially, but could be included in the statistical analysis for all other variables. Each arm position assessed for its relationship with the location of the burial, age and sex of the skeleton (Table 3.11). The spatial distribution for each arm position was plotted using ArcMap 10.2.2.

Table 3.11. Arm position codes assigned to the Poulton Chapel articulated burials giving overall percentage, along with sample breakdowns for the individual arm positions.

Arm Position Code			**Sample breakdown by arm position (%)**			
	N	**%**	**Male**	**Female**	**Non-adult**	**Unknown**
1	108	23.5	12.1	14.0	73.8	-
2	176	40.3	29.5	28.4	41.5	0.6
3	112	25.0	34.8	33.9	28.6	2.7
4	22	5.0	54.5	31.8	9.1	4.5
5	1	0.2	100.0	-	-	-
6	2	0.4	50.0	-	50.0	-
7	16	3.5	37.5	18.8	43.8	-
8	5	1.1	-	60.0	40.0	-
9	5	1.1	40.0	60.0	-	-
Total	**446**	**100.0**	-	-	-	-

There was no relationship identified between arm position and burial alignment, or burial type (Spearmans rank correlations, $p>0.05$), indicating that certain positions and alignments were not habitually practiced together. There were no significant differences between burial alignments or burial type when grouped by arm position (Spearmans rank correlations, $p>0.05$). There was a significant positive relationship identified between burial practice and arm position ($r_{s(446)}=0.175$, $p<0.001$). This would be expected due to the amount of space present around a corpse within a coffin during decomposition. As the articulations holding the skeleton in place break down, the bones will shift from their original position due to the lack of soil matrix preventing movement of the bones. This would lead to increased variation in arm positions within coffin burials, resulting in a significant difference in the median values for burial practice ($\chi^2_{(8)}=12.248$, $p=0.002$). Further analyses of burial practices at Poulton are planned, with the information gained from this study indicating that arm positions may assist in identifying further coffin burials.

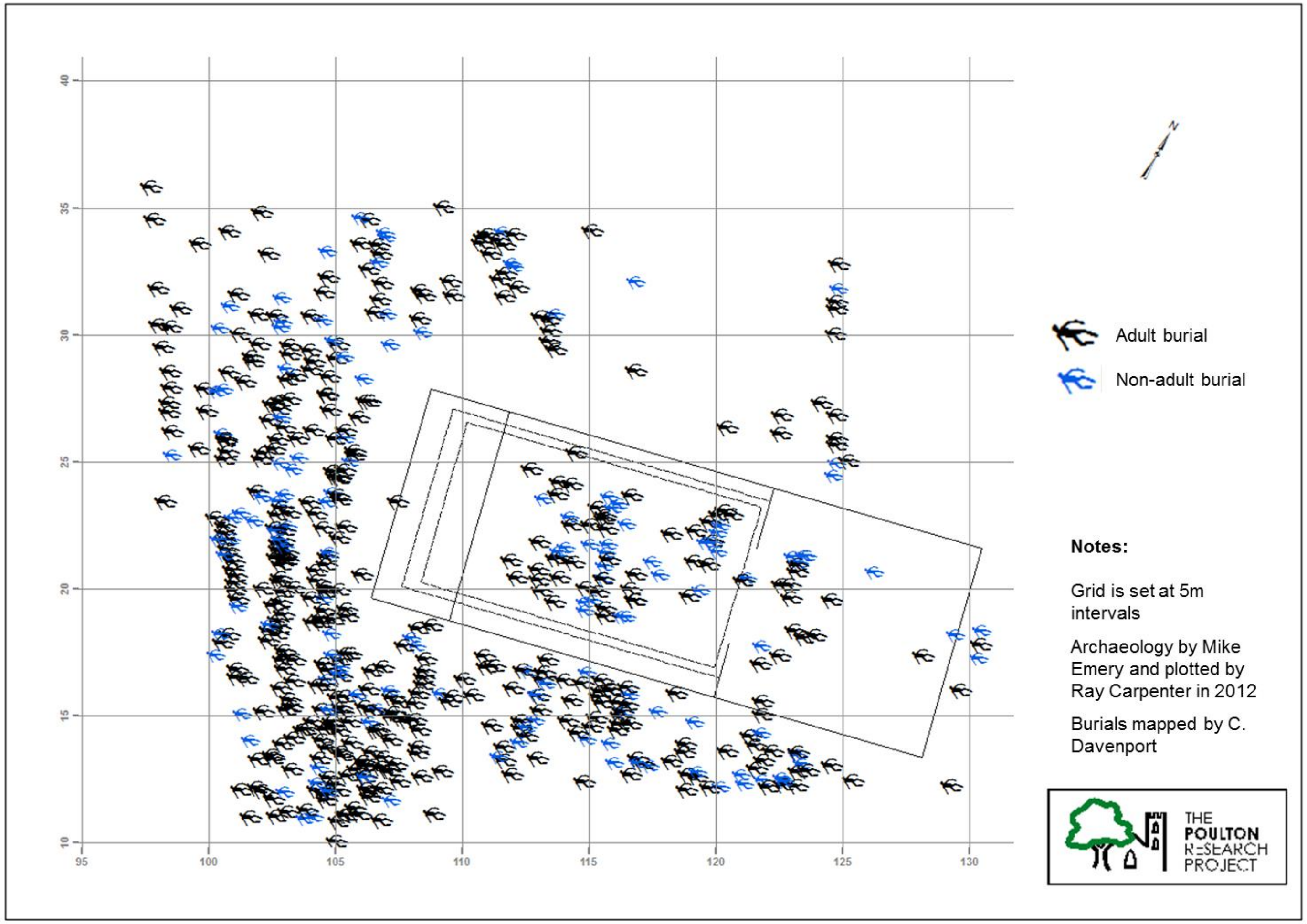

Figure 3.44. Overall plot of the Poulton Chapel articulated burials with available coordinates (n = 573). Plotted using ArcMap 10.2.2. ©CAL Davenport

Although the number of males and females are relatively equal in arm positions 1-3, there is a marked difference in the number of individuals represented by each sex for arm position four. Arm positions coded from 5-9 comprise smaller numbers of individuals, which may bias any analysis done on these burials (Figure 3.45). Significant positive correlations were found between arm position and burial practice ($r_{s(464)}$=0.116, p=0.019) indicating that the arm positions are linked to the method of internment of an individual at Poulton Chapel.

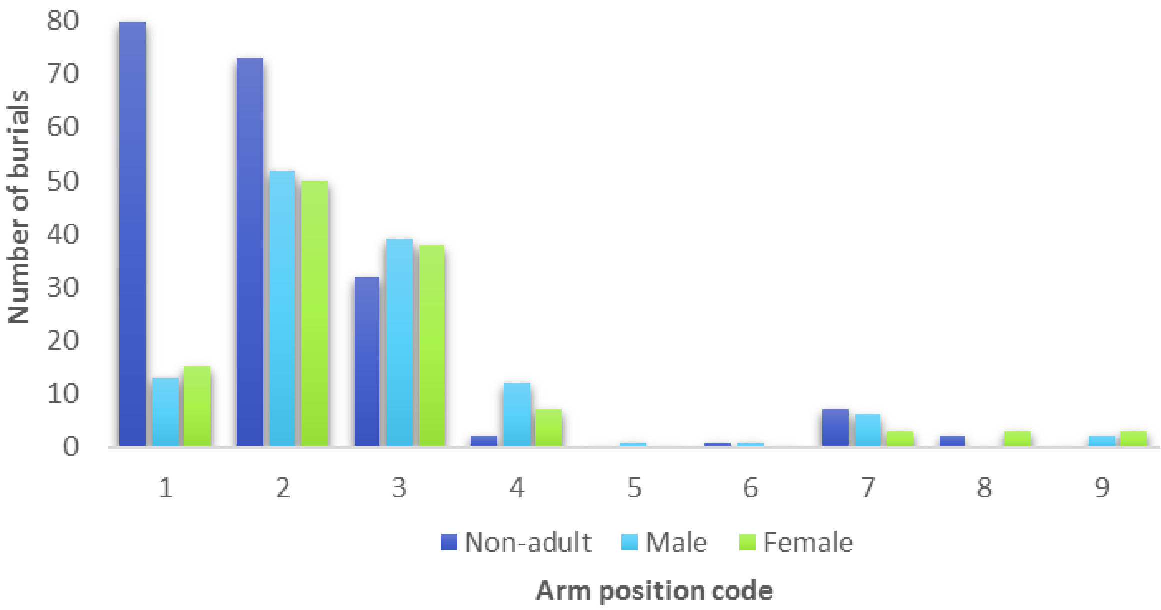

Figure 3.45. Frequencies of non-adult (n=196), male (n=129) and female (n=116) arm position codes for the skeletons at Poulton Chapel.

When examining the sample breakdown and spatial analysis, it was evident that non-adults comprise the majority of burials in arm position one ($r_{s(446)}$=0.229, p<0.001; Figure 3.46), whereas the adult burials are the majority in other arm positions represented by a larger sample size ($\chi^2_{(8)}$ =40.981, p <0.001; Figures 3.47-3.50). Further analysis into the relationship between location and arm position showed that arm position codes increased as the location moved further north ($r_{s(446)}$=0.243, p<0.001), or further west ($r_{s(446)}$=-0.121, p=0.010). This variation in arm position may be due to the relatively high number of non-adults excavated on the west and south sides of the Chapel when compared to the North and East sides. As the excavation is not complete, it is recommended that age, arm position and location is reassessed once all information is available to enable accurate interpretation of the burial distribution.

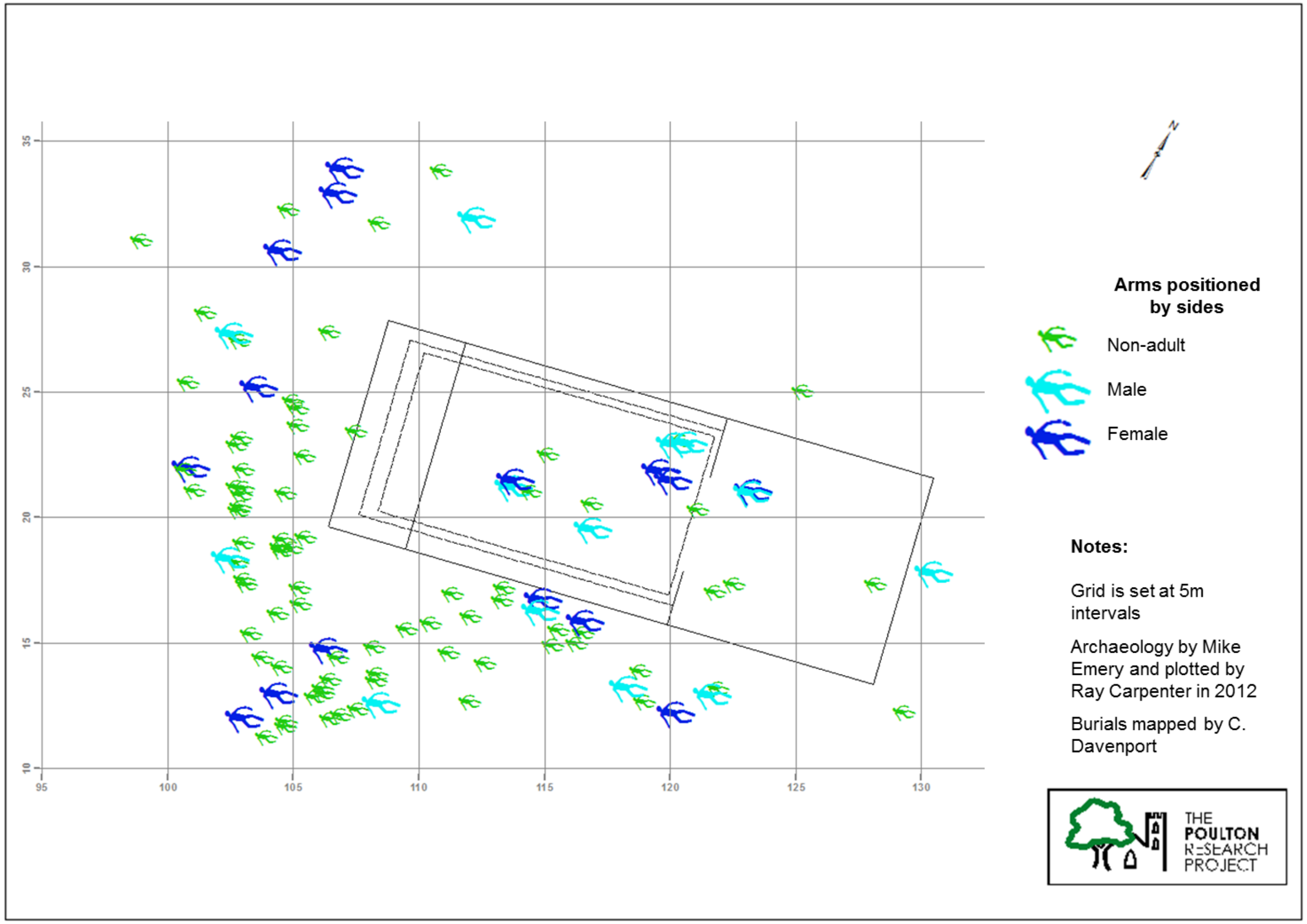

Figure 3.46. Distribution of the articulated burials at Poulton Chapel, buried with the arms placed by the sides of the body (arm position 1, n=109). Plotted using ArcMap 10.2.2. ©CAL Davenport

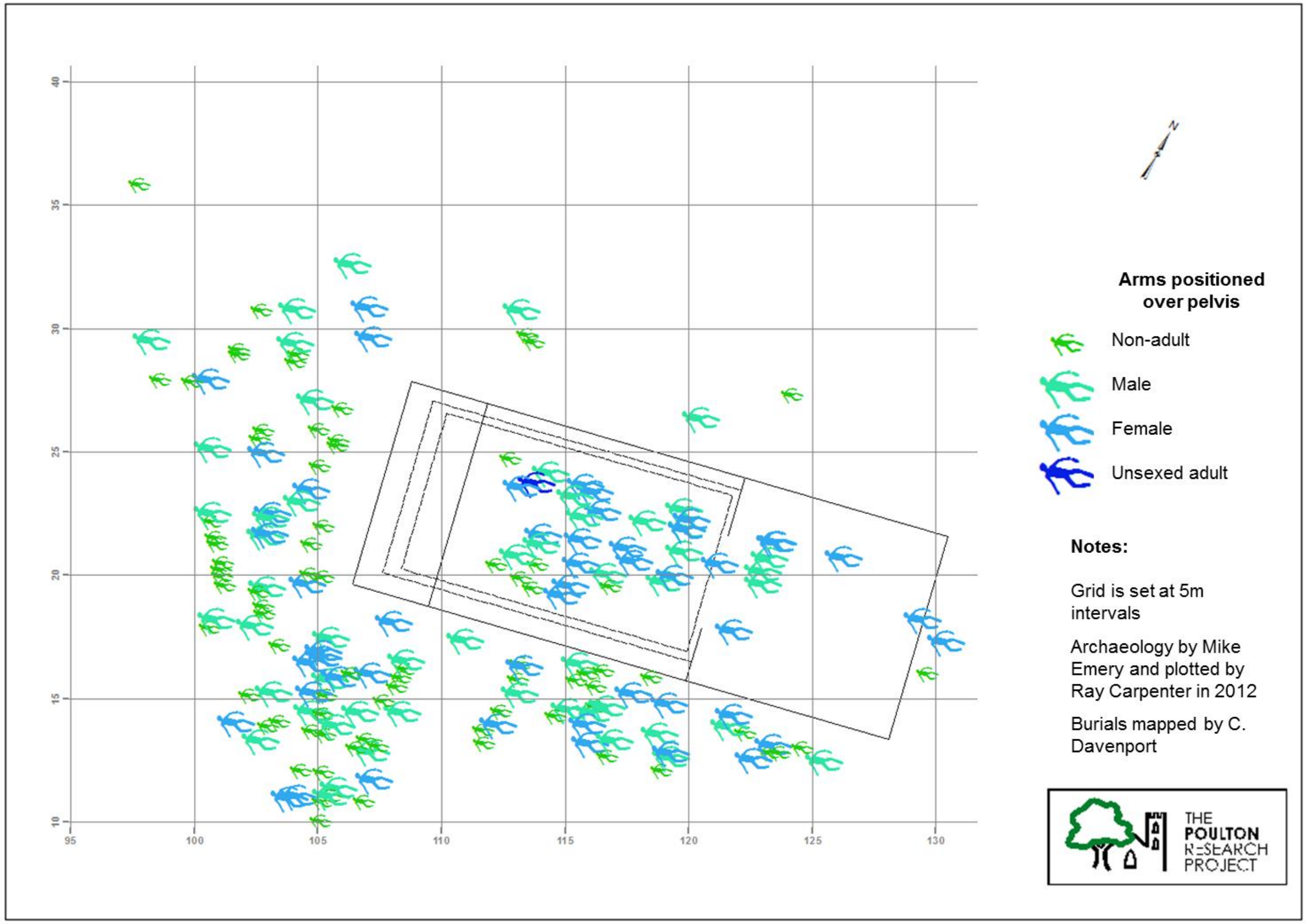

Figure 3.47. Distribution of the articulated burials at Poulton Chapel, buried with the hands placed over the pelvis (arm position 2, n=187). Plotted using ArcMap 10.2.2. ©CAL Davenport

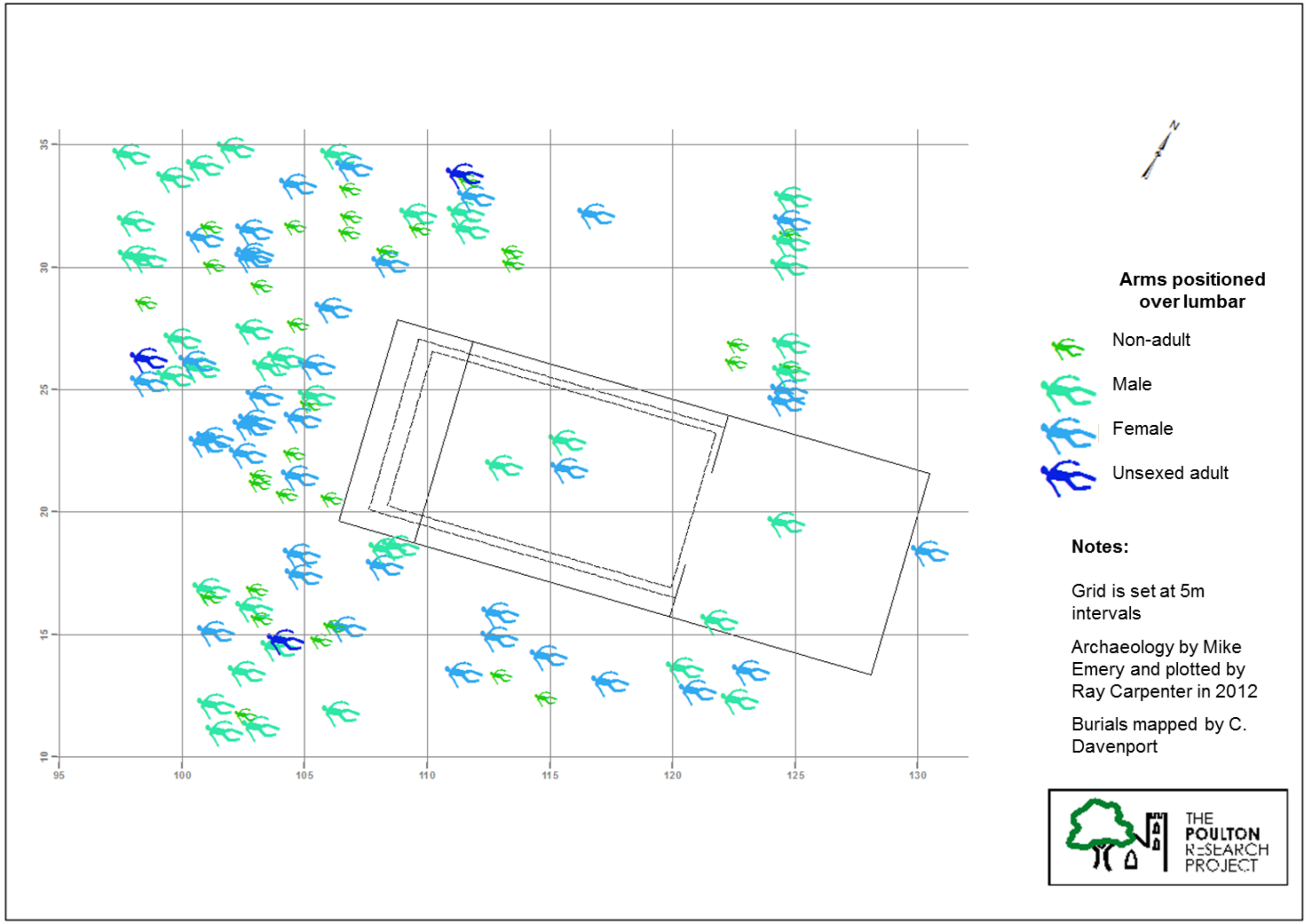

Figure 3.48. Distribution of the articulated burials at Poulton Chapel, buried with the arms folded over the lumbar region (arm position 3, n=116). Plotted using ArcMap 10.2.2. ©CAL Davenport

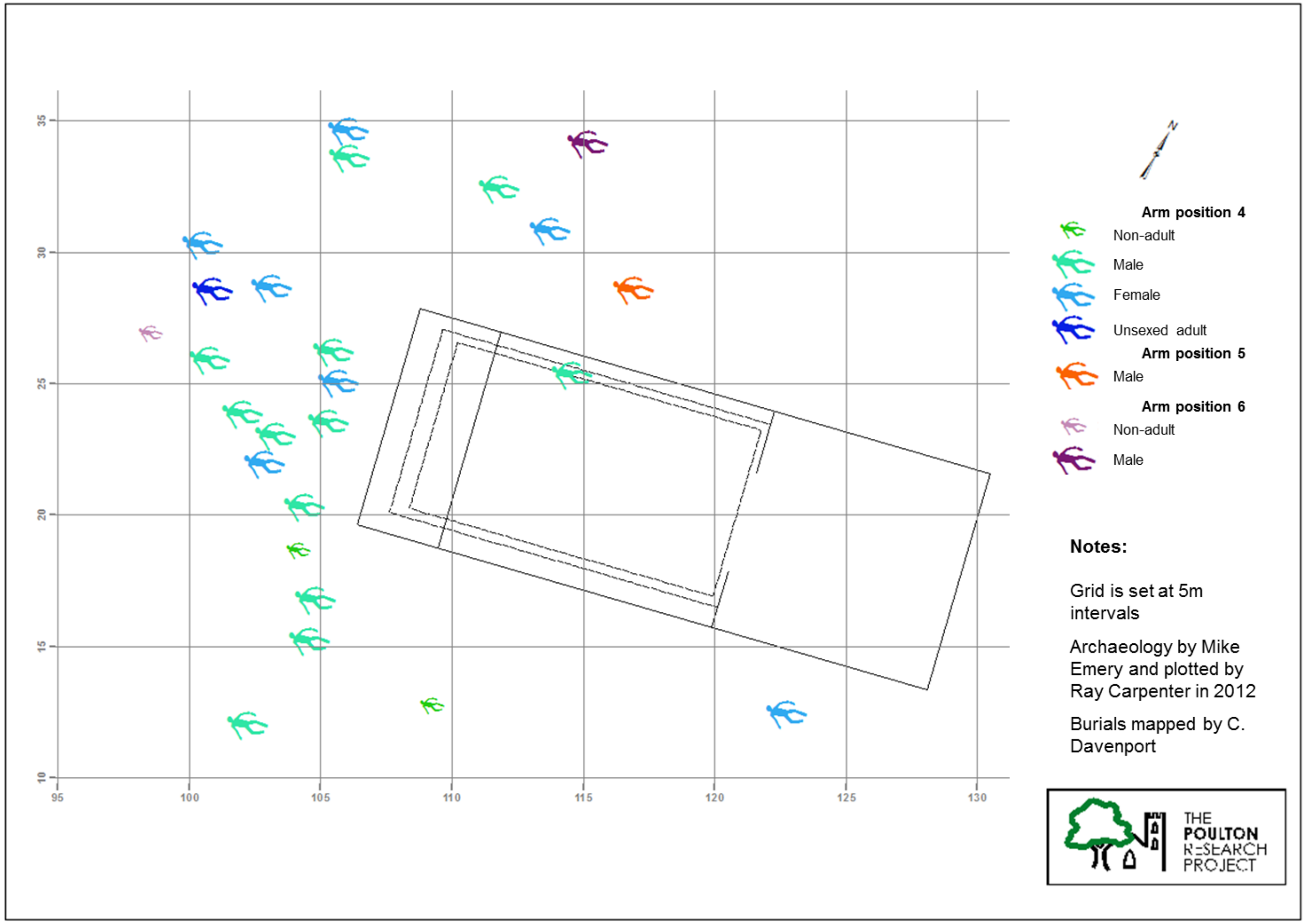

Figure 3.49. Distribution of the articulated burials at Poulton Chapel, buried with the arms crossed over the chest (arm position 4, n=23), arms in prayer position (arm position 5, n=1) and one arm at the side, one crossed over the chest (arm position 5, n=2). Plotted using ArcMap 10.2.2. ©CAL Davenport

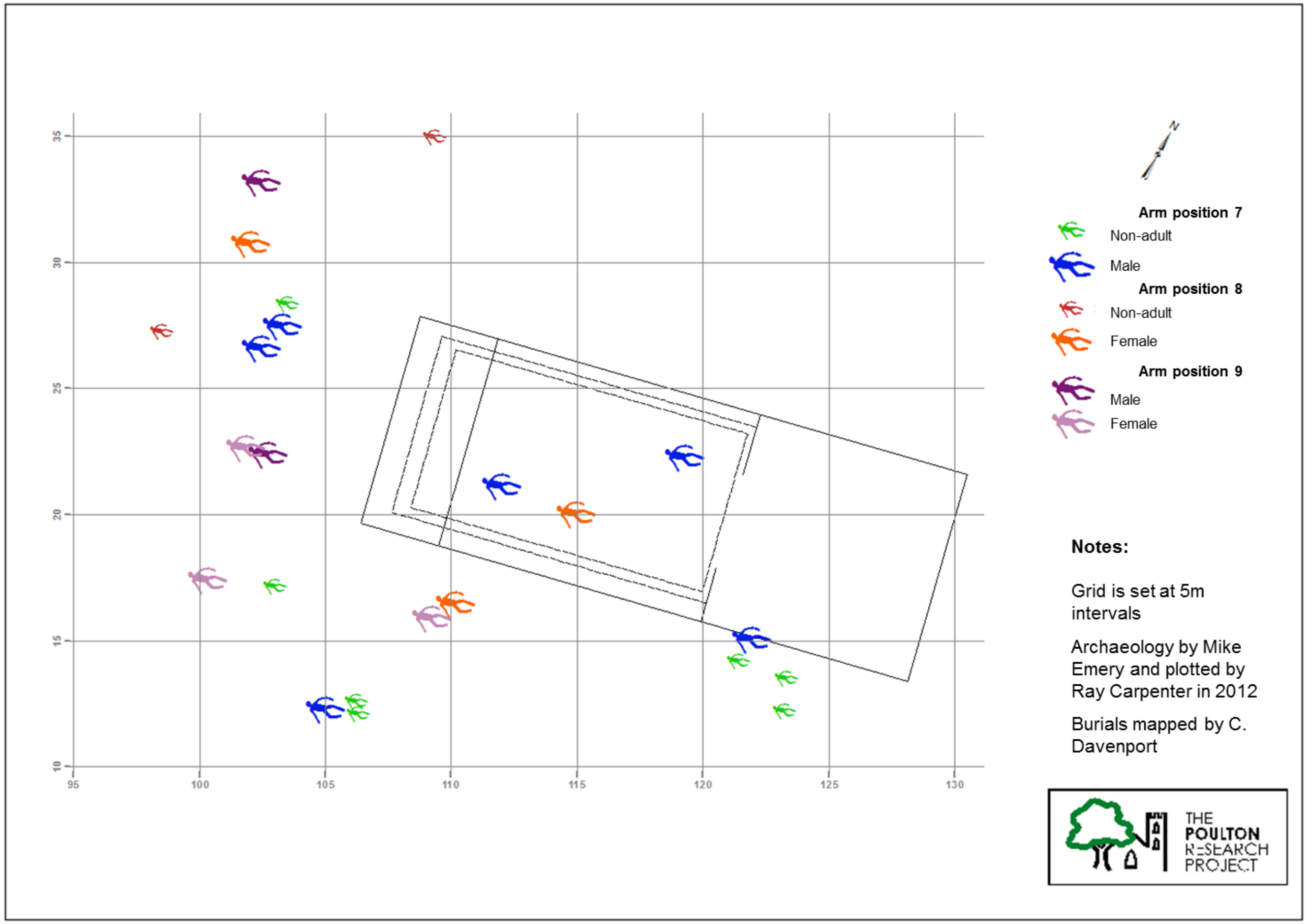

Figure 3.50. Distribution of the articulated burials at Poulton Chapel, buried with one arm by side, one over pelvis (arm position 7, n=16), one arm across lumber, one over the pelvis (arm position 8, n=5) and one arm across lumbar, one crossed over the chest (arm position 9, n=5). Plotted using ArcMap 10.2.2. ©CAL Davenport

The skeletons (n=473, 18 did not provide spatial information) were interred on a west/east alignment (head to the west and feet to the east) bar three individuals that were on an east/west alignment (head to the east, feet to the west). The three east/west burials were identified as an adult male and adult female, along with one adolescent male (15-18 years), all of which were positioned with the arms folded across the stomach. The location of the burials within the cemetery varied, as did the burial practices (one each of shrouded, non-shrouded and coffin respectively), giving no immediate indication of the relevance of this particular burial alignment. Due to the minimal variation in the alignment at Poulton Chapel, no meaningful statistical analyses could be carried out.

All articulated skeletons (n=591) were assessed to determine the burial practice observed during internment. Of these, 156 (26.40%) skeletons did not provide sufficient information for analysis. The remaining 435 burials were predominantly assessed for markers that would distinguish shrouded from non-shrouded individuals, except in the cases where further material evidence was discovered to support the classification of coffin burial. Material evidence for Poulton consisted of coffin nails present with the remains during excavation (figure 3.51), the position of the remains alone was not enough to classify as a coffin burial. Each coffin nail was assigned a finds number and the bag labelled with the associated skeleton number.

Figure 3.51. Coffin nails (n=7) discovered during the excavation of skeleton 852 (excavated in 2016, therefore not included in this thesis) at Poulton Chapel. Finds numbers arranged from left to right, 688-694. ©CAL Davenport

The majority of the non-adult sample were non-shrouded, whereas the male and female adult samples were a mix of non-shrouded or shrouded burials (Figure 3.52). The relationship between burial practice and sex was explored further, but showed no significant difference in the medians for each sample, indicating that the number of male and female adult articulated burials was fairly consistent across all burial practices ($\chi^2_{(2)}$= 1.172, p=0.279).

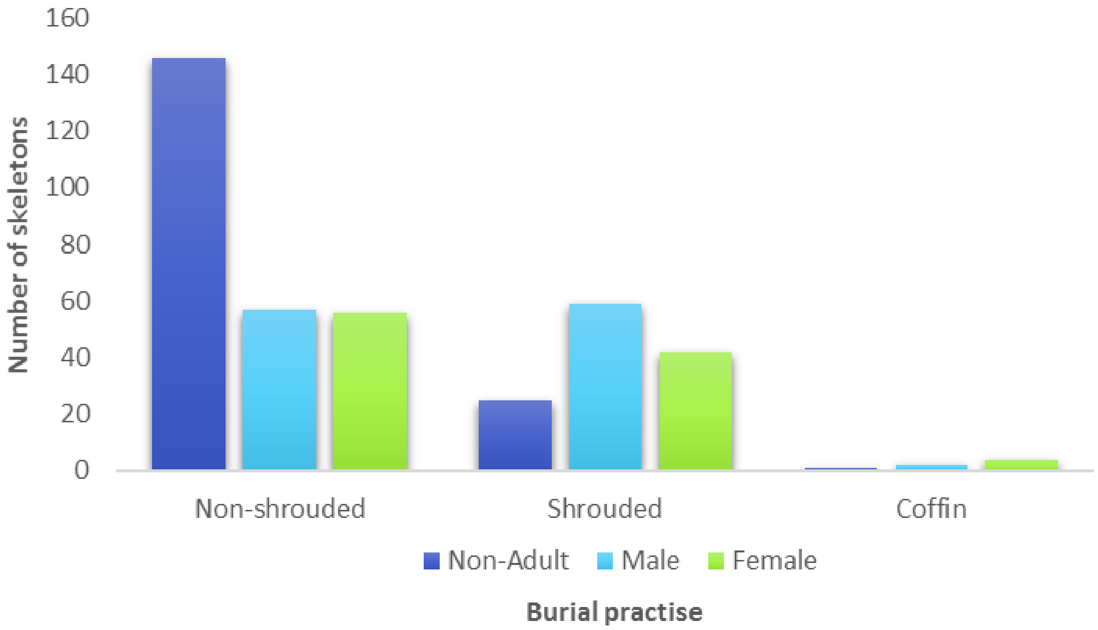

Figure 3.52. Frequencies of the non-adult (n=194), male (n=134) and female (n=113) skeletons exhibiting the different burial practices at Poulton Chapel.

Arm position showed a significant difference across the groups ($\chi^2_{(1)}$ = 31.388, p<0.001), which demonstrated a tendency for non-shrouded individuals to be interred with the arms placed by the sides. This pattern closely follows that of the age distributions, as non-adults comprised 73.8% of the burials interred with the arms placed at the sides. Therefore, it could be inferred that the preference when interring non-adults was to place them directly into the ground with the arms placed by the sides (Friedman test: $\chi^2_{(2)}$=384.443, p<0.001).

The distribution of the burials relative to burial practice is shown in figure 3.53). The spatial distribution shows that there are no identified coffin burials on the North side of the chapel, with the overall coffin burial sample totalled only 1.61% of the overall sample. There were no relationships identified between burial practice and burial alignment, burial type or completeness of recovered remains (Spearmans rank correlation; p>0.05). There was a significant positive correlation identified for age, sex and arm position when compared with burial practice (p<0.001). When assessing the relationship between the medians for adult vs. non-adults individuals, there were significant differences ($\chi^2_{(1)}$ =44.477, p<0.001) indicating that the non-adult skeletons were more likely to be non-shrouded.

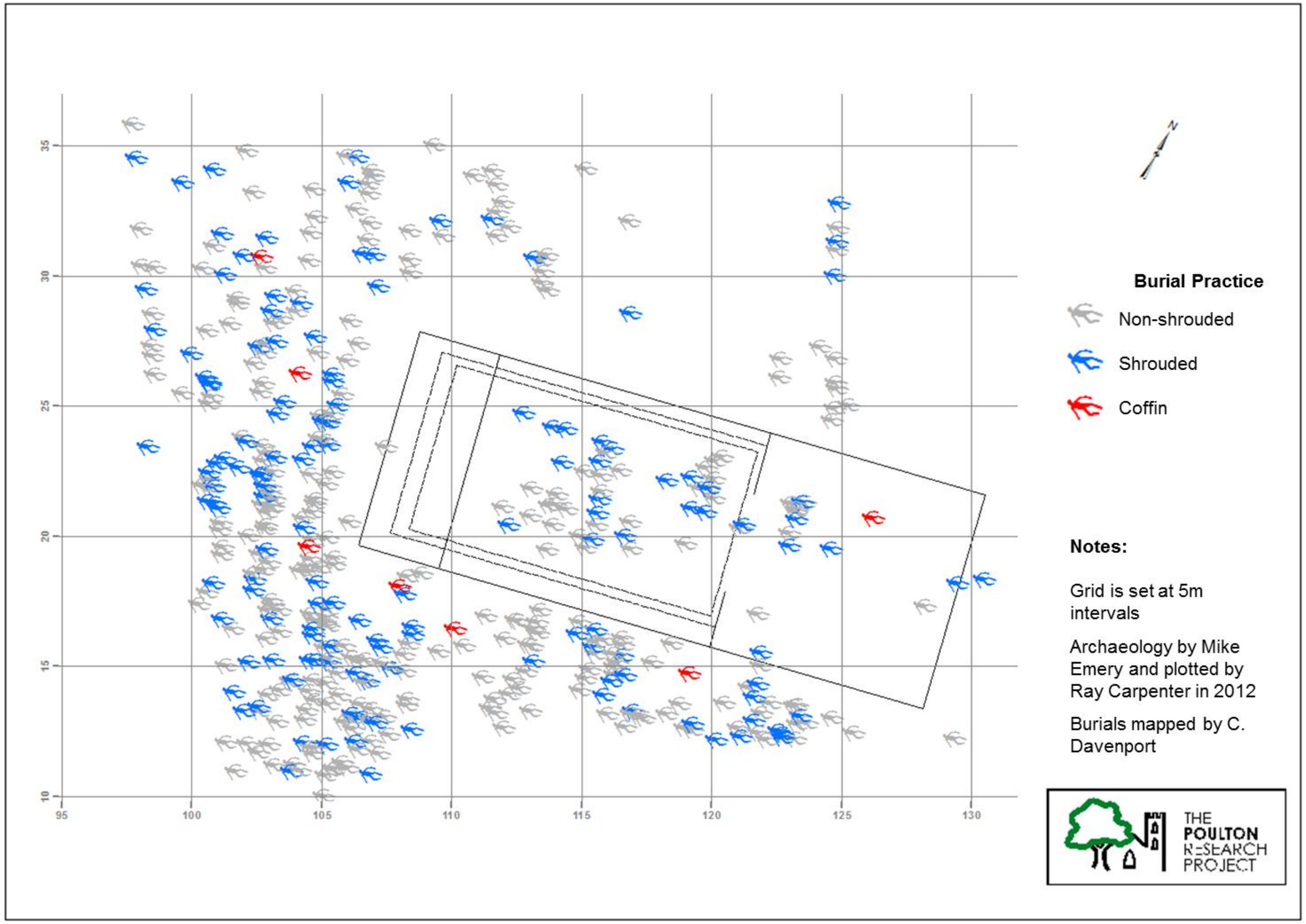

Figure 3.53. Map of the articulated burials at Poulton Chapel showing the distribution of each of the identified burial practices: non-shrouded (n=290), shrouded (n=138), and identified coffin burials (n=7). Plotted using ArcMap 10.2.2. ©CAL Davenport.

The skeletons from Poulton Chapel (n=591) were primarily prone burials, with exception of six individuals, which were buried in a flexed position. Frequency distributions (figure 3.54) show that of the non-adult burials, three were found with arm position one, with the remaining two individuals found with arm positions two and six. The remaining burial was an adult burial found with the arms folded across the body (arm position three). The flexed burials were found at several locations across the site, giving no indication of any pattern for the burial of individuals in this way (Figure 3.55). Due to the small sample of flexed burials, it was not possible to carry out meaningful statistical analyses. However, it can be inferred that a flexed burial from Poulton is likely to be non-shrouded, with the arms placed by the sides and a non-adult.

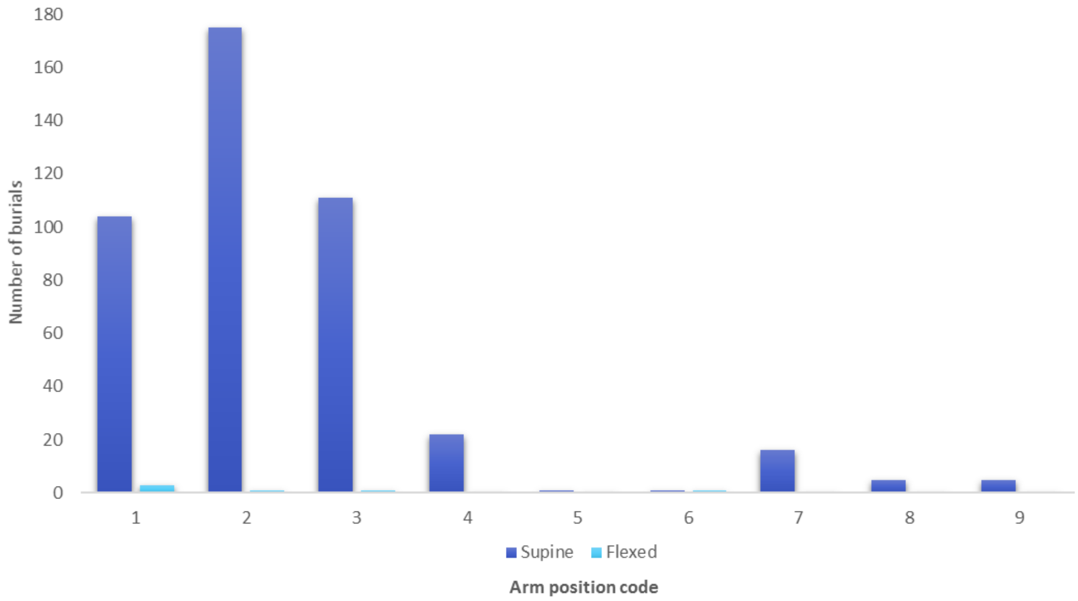

Figure 3.54. Frequencies of supine (n=585) and flexed (n=6) burials for each arm position code at Poulton Chapel. Flexed burials were identified with arm positions 1 (n=3), 2 (n=1), 3 (n=1) and 6 (n=1).

3.9. Cemetery sample analysis

To the end of the excavation season in 2015, 591 articulated and 160 disturbed human burials were recovered from Poulton Chapel and were available for assessment for this thesis. Of the articulated burials, 321 were adult and 272 were non-adult. A further 68 boxes of disarticulated material, including three boxes of charnel pit skeletal material were also recovered during this period. All articulated skeletons (n=591) were assessed to determine the completeness of the material retrieved during excavation (Table 3.12). There were no relationships identified between completeness and sex, age, location, burial practice, type or alignment (Spearmans rank correlations, p >0.05). However, there was a significant

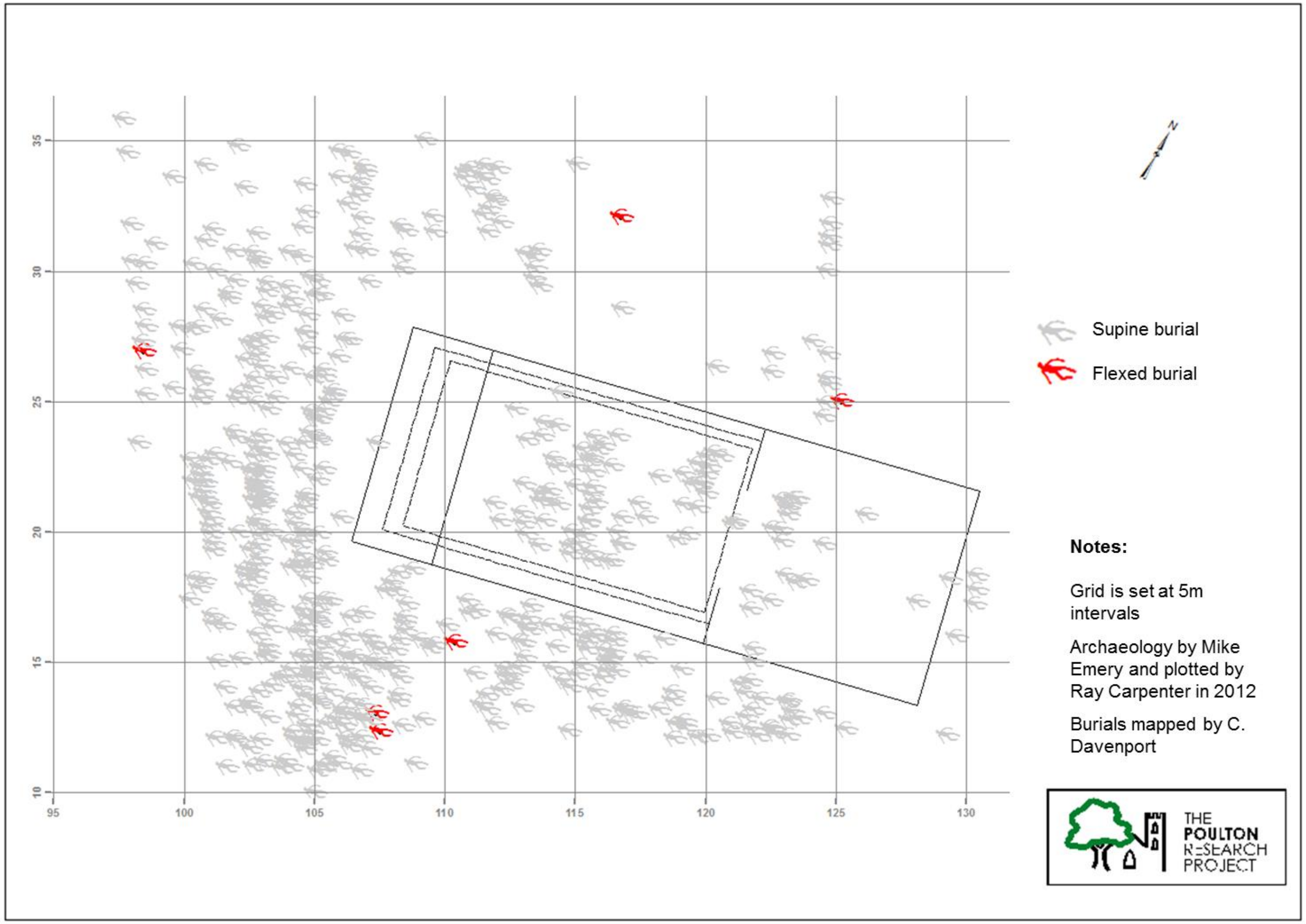

Figure 3.55. Map showing the distribution of the six flexed articulated burials identified at Poulton Chapel. Plotted using ArcMap 10.2.2. ©CAL Davenport

positive correlation with arm position ($r_{s(464)}$=0.098, p=0.036) identified when assessing only those that could provide information on arm position.

Table 3.12. Approximate skeletal completeness of the articulated burials recovered from Poulton Chapel.

	>75%	50-75%	25-50%	<25%	Total
n	247	115	113	116	591

This correlation changed to a stronger significant negative correlation, when those that could not provide the information were also included ($r_{s(591)}$=-0.401, p<0.001). This is most likely due to the number of individuals that were less than 25% complete not having the elements present to assess arm position. By including those with no information present in the analysis, it is possible to see that this data has led to a bias, which is seen in figure 3.56.

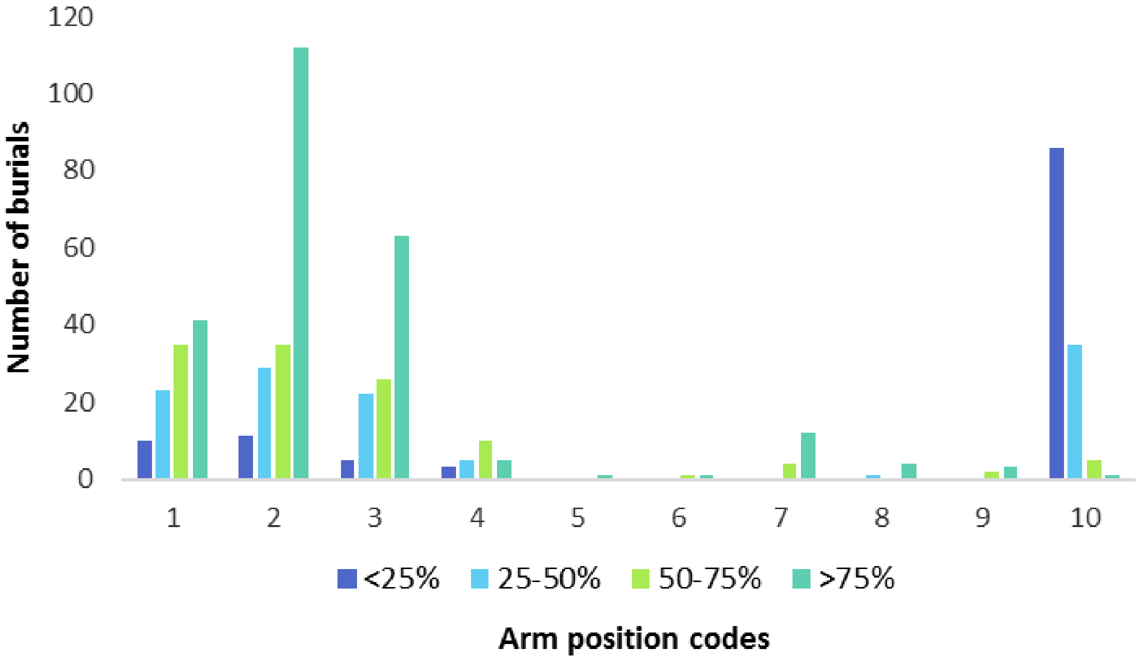

Figure 3.56. Burials identified by arm position and completeness, showing the bias given when including the individuals that had no arm data available (arm position 10).

When assessing the median distribution for the burials providing information on arm position, a significant difference was identified between the groups ($\chi^2_{(8)}$=25.843, p=0.001). This is due to the large number of burials that were more than 75% complete recovered displaying arm positions two and three. It is likely that positions where the arms are crossed over the pelvis or chest cover a smaller surface area and therefore minimise the potential for truncation during later internments. The skeletons were plotted using ArcGIS (Figure 3.57) to explore the spatial relationship of the burials when taking into account the completeness of the remains. The map shows a cluster of burials showing >75% completeness in the North East corner of the cemetery. However, this is not supported by

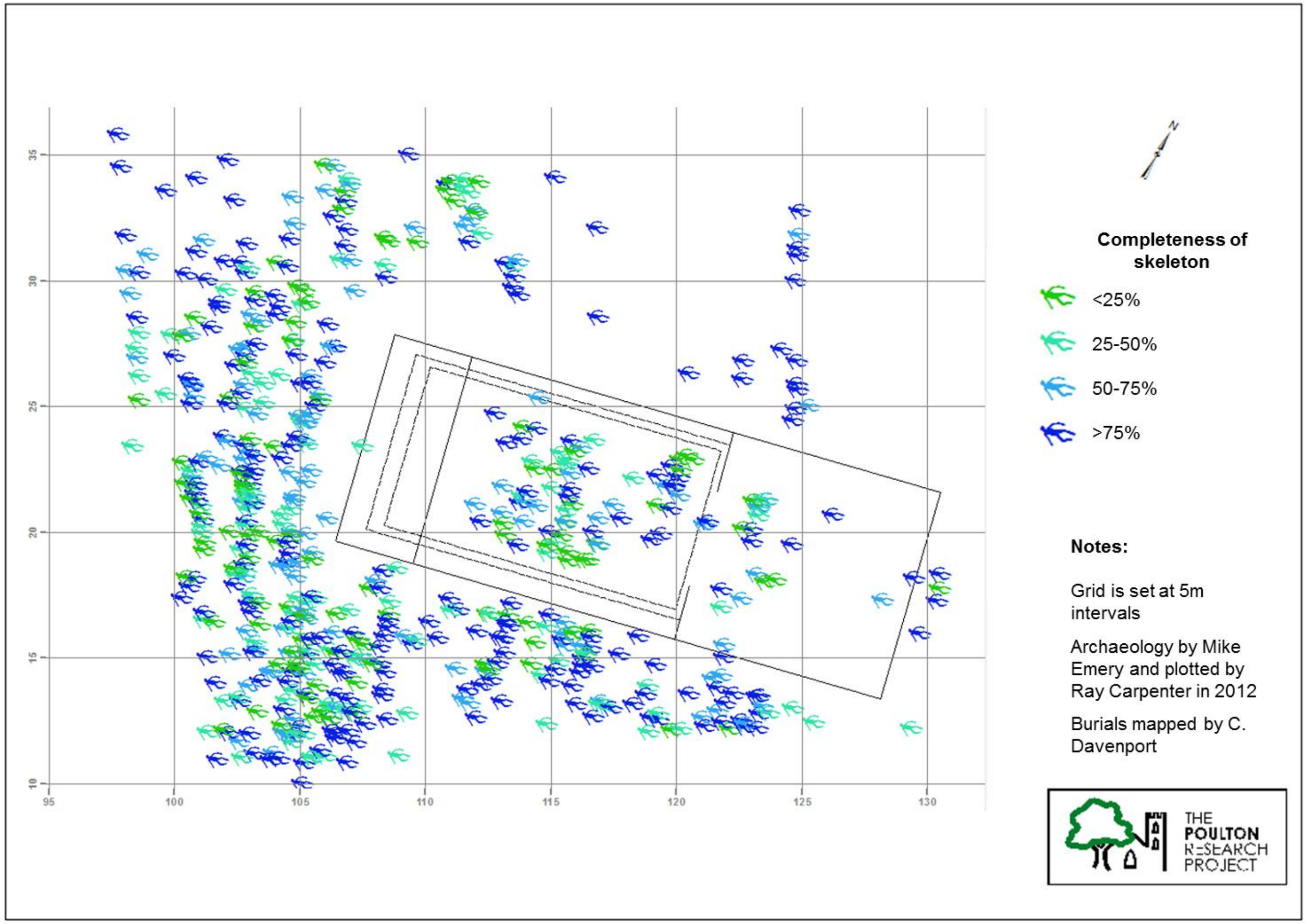

Figure 3.57. Map of the articulated burials at Poulton Chapel showing the distribution of each of the identified grades of completeness. Plotted using ArcMap 10.2.2. ©CAL Davenport

the statistical analysis when comparing the relationship between skeletal completeness and eastings ($r_{s(573)}$=0.072, p=0.086) or northings ($r_{s(573)}$=-0.016, p=0.710).

When assessing biological profiling characteristics, a weak but statistically significant relationship between the degree of erosion to the cortical surface of the bone and the sex of the adult remains ($r_{s(312)}$=0.142, p=0.012) was identified, with a higher frequency of males scoring lower on the scale than females ($\chi^2_{(6)}$=13.727, p=0.033). There was no relationship identified between the degree of erosion and adult/non-adult groupings ($r_{s(591)}$=-0.007, p=0.866), and no differences identified in the frequencies of the two age groupings ($\chi^2_{(6)}$=4.337, p=0.631). This is shown in figure 3.58, with similar numbers of both adult and non-adult individuals in each erosion category.

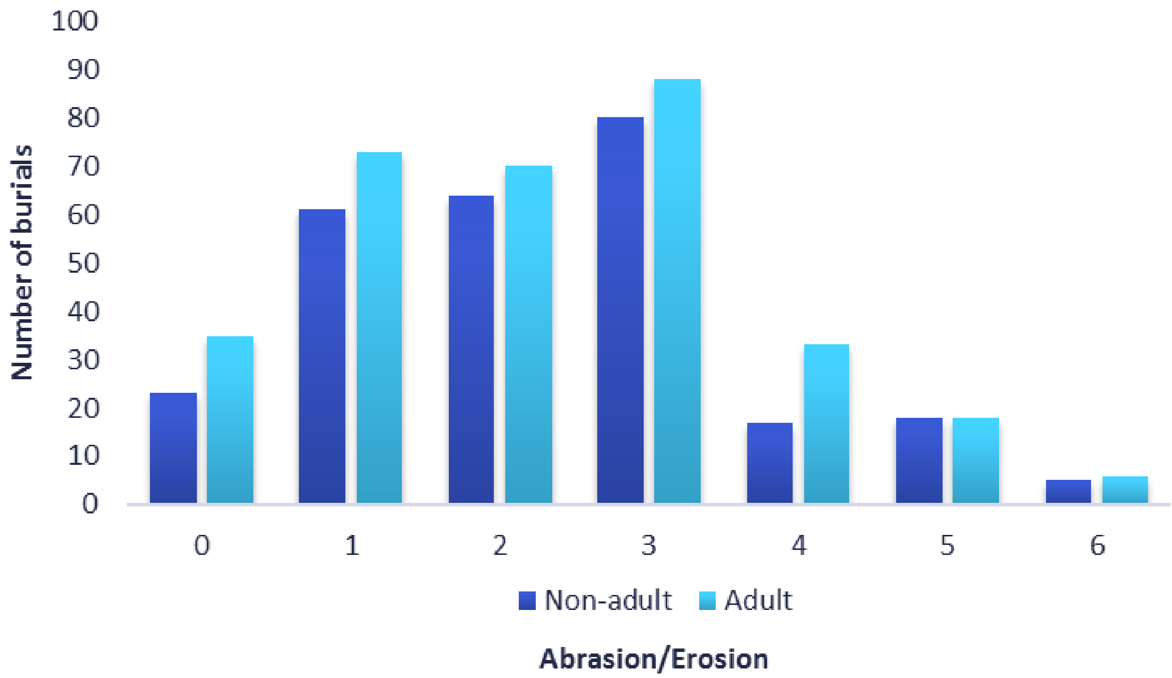

Figure 3.58. Post-mortem preservation of the Poulton Chapel articulated skeletal material following excavation using a system adapted from Brinkley and McKinley (2004).

There was a significant negative relationship between skeletal completeness and the degree of abrasion/erosion to the cortical surface of the remains ($r_{s(591)}$=-0.481, p<0.001), which showed that the more complete the skeleton, the lower on the abrasion score it scored ($\chi^2_{(18)}$=173.785, p<0.001). There was a significant positive relationship with the degree of fragmentation ($r_{s(591)}$=0.704, p<0.001), with those with minimal fragmentation having less surface erosion ($\chi^2_{(24)}$=582.959, p<0.001; figure 3.59). No relationships were identified between abrasion/erosion and arm position, burial type, burial practice or alignment (Spearmans rank correlations, p>0.05). However, the frequency of arm positions 1-4 were typically found at the lower end of the abrasion/erosion scale ($\chi^2_{(48)}$=68.374, p=0.028).

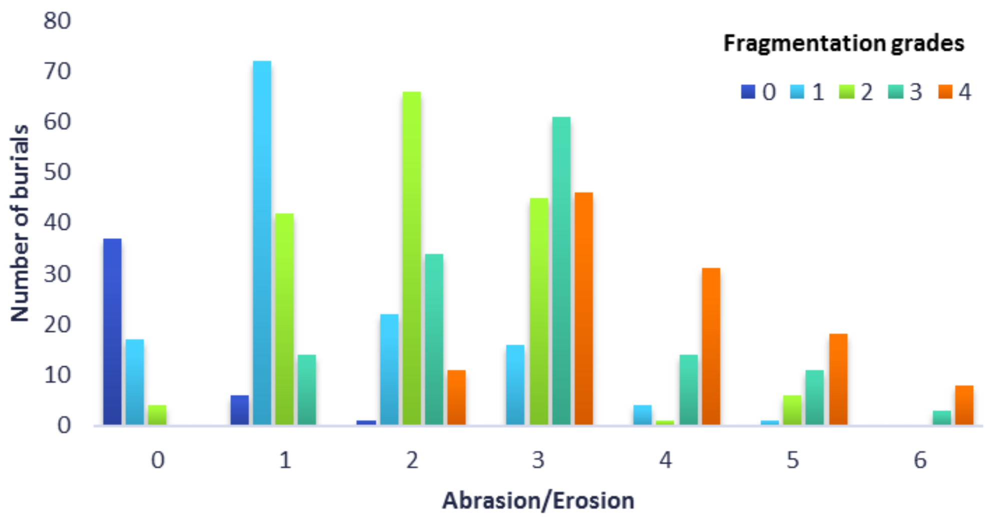

Figure 3.59. Abrasion/erosion rates split by the degree of post-mortem fragmentation of the human skeletal remains from Poulton Chapel.

The abrasion/erosion and fragmentation grades assigned to the burials were mapped in ArcMap 10.2.2 using an inverse distance weighted interpolated raster map (Figures 3.61 and 3.62). There was a significant positive relationship identified for the location (eastings and northings) of a burial, with the abrasion/erosion grade increasing as the burial location moved west across the site ($r_{s(573)}$=-0.118, p=0.005) and to the south ($r_{s(573)}$=0.262, p<0.001). When assessing the relationships between biological factors and fragmentation, no relationship was identified for sex ($r_{s(312)}$=0.087, p=0.124). A weak significant positive relationship was identified between the adult and non-adult burials ($r_{s(591)}$=0.118, p=0.004), indicating that the adult burials tended to have a higher degree of fragmentation ($\chi^2_{(4)}$=12.979, p=0.011). The relationship between fragmentation and the age of the skeletal remains is apparent when visually verifying the relationship (Figure 3.60).

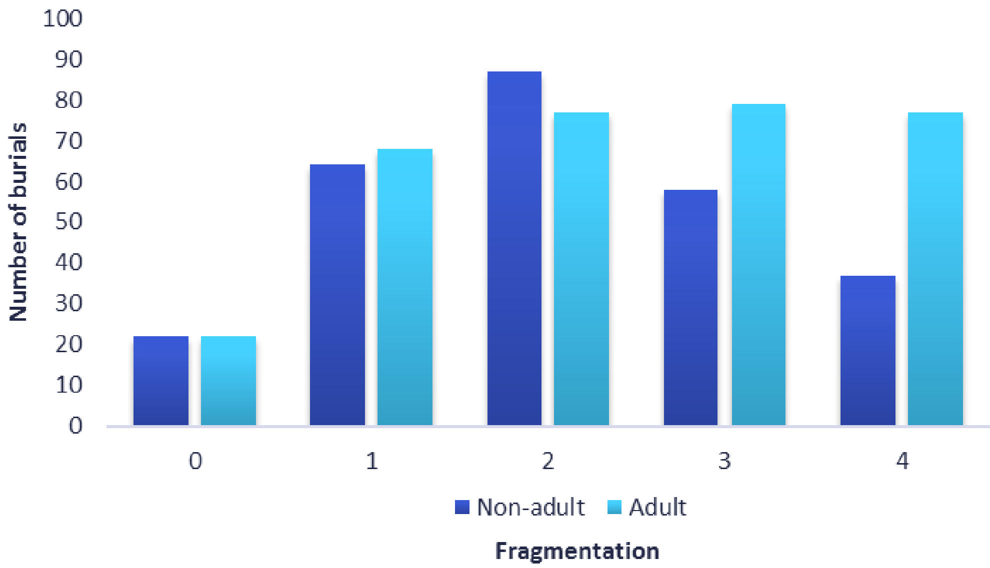

Figure 3.60. Post-mortem fragmentation of the Poulton Chapel articulated skeletal material following excavation.

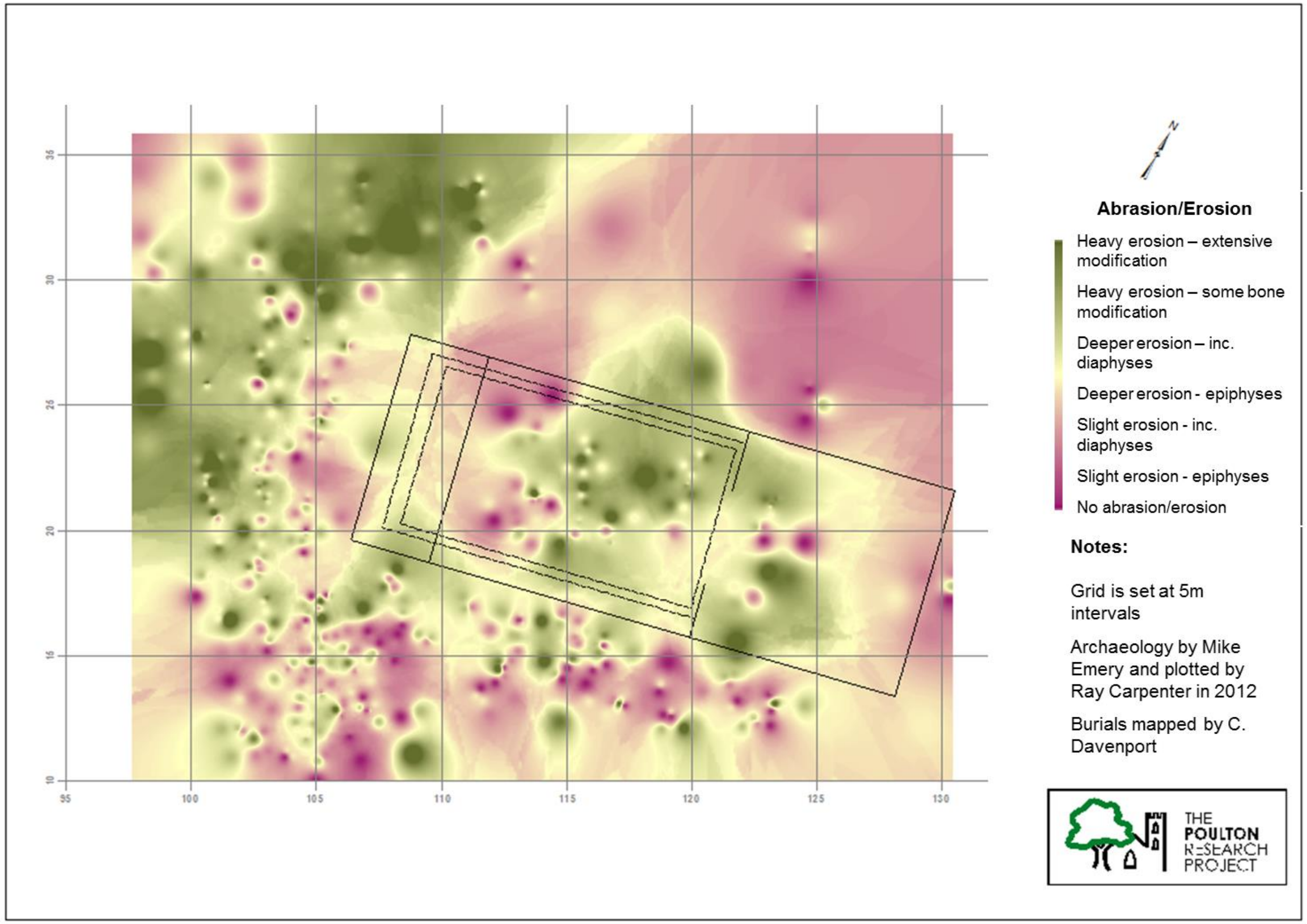

Figure 3.61. Map of the articulated burials at Poulton Chapel showing the distribution of each of the identified grades of abrasion/erosion. Plotted using an IDW interpolated raster map in ArcMap 10.2.2. ©CAL Davenport

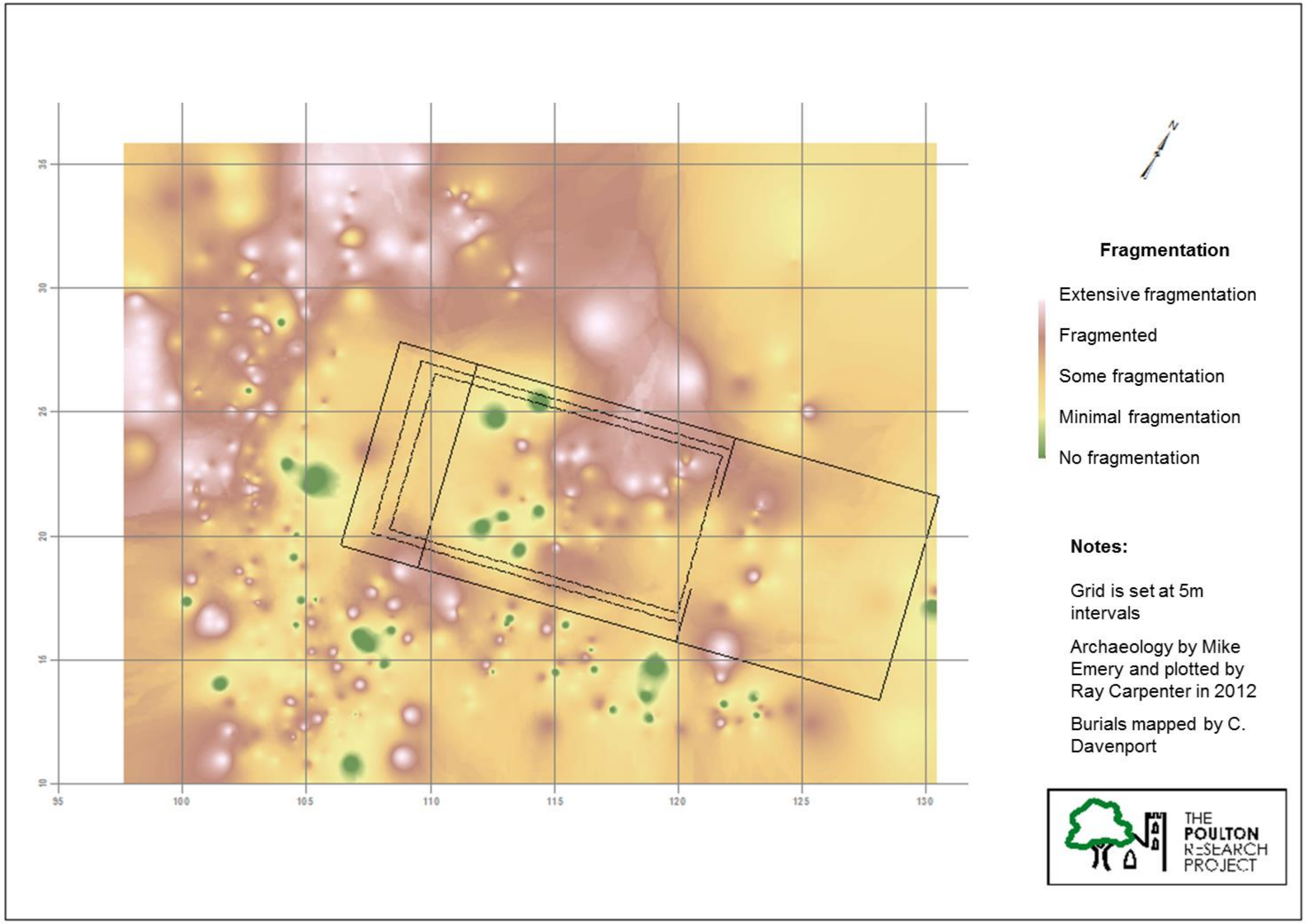

Figure 3.62. Map of the articulated burials at Poulton Chapel showing the distribution of each of the identified grades of fragmentation. Plotted using an IDW interpolated raster map in ArcMap 10.2.2. ©CAL Davenport

A higher frequency of burials that were >75% complete had minimal fragmentation ($\chi^2_{(12)}$=48.781, p<0.001). However, this relationship was weak ($r_{s(591)}$=-0.246, p<0.001), as all completeness grades were represented at all fragmentation levels. There was a weak relationship identified between arm position and degree of fragmentation ($r_{s(591)}$=-0.246, p<0.001), with high number of individuals interred with arm positions 1-3 having some fragmentation, and positions 4 and 7 regularly exhibiting severe fragmentation ($\chi^2_{(32)}$=58.398, p=0.003). There was a significant positive relationship identified for the location (eastings and northings) of a burial, with the fragmentation grade increasing as the burial location moved west across the site ($r_{s(573)}$=-0.128, p=0.002) and to the south ($r_{s(573)}$=0.280, p<0.001).

Collagen extraction was carried out on rib fragments from 17 skeletons, with the locations of each of skeleton shown in figure 3.63. Of the skeletons tested, five did not yield collagen of a measureable amount (skeletons 522, 524, 691, 775 and 781). The remaining 12 skeletons produced collagen yields of between 1.44 and 9.84% (Table 3.13), which were above the cut-off limit for further analysis (Van Klinken, 1999).

Table 3.13. Successful collagen extraction skeletons and associated yields.

Skeleton	Bone	Bone weight (g)	Collagen weight (g)	Collagen yield (%)
750	Rib	0.68	0.06	8.82
773	Rib	0.68	0.02	2.94
785	Rib	0.69	0.01	1.44
787	Rib	0.65	0.03	4.61
788	Rib	0.53	0.01	1.89
791	Rib	0.61	0.06	9.84
793	Rib	0.64	0.01	1.56
794	Rib	0.74	0.02	1.48
795	Rib	0.69	0.03	4.35
796	Rib	0.60	0.04	6.67
797	Rib	0.66	0.06	9.09
798	Rib	0.66	0.02	3.03

There were significant differences identified between the abrasion/erosion groups and collagen yield ($\chi^2_{(7)}$=23.671, p=0.001), indicating that lower yields were associated with higher rates of erosion to the cortical surface. Severely fragmented remains also produced lower collagen yields ($\chi^2_{(7)}$=21.453, p=0.003). The spatial distribution shows that collagen yield reduces as the burials selected move further north (Figure 3.64; $r_{s(19)}$=-0.626, p=0.004). It was noted that the collagen yield tended to decrease as the depth of the burial increased, although the strength and significance of this relationship is not very strong, suggesting that further testing should be carried out ($r_{s(18)}$=-0.478, p=0.045).

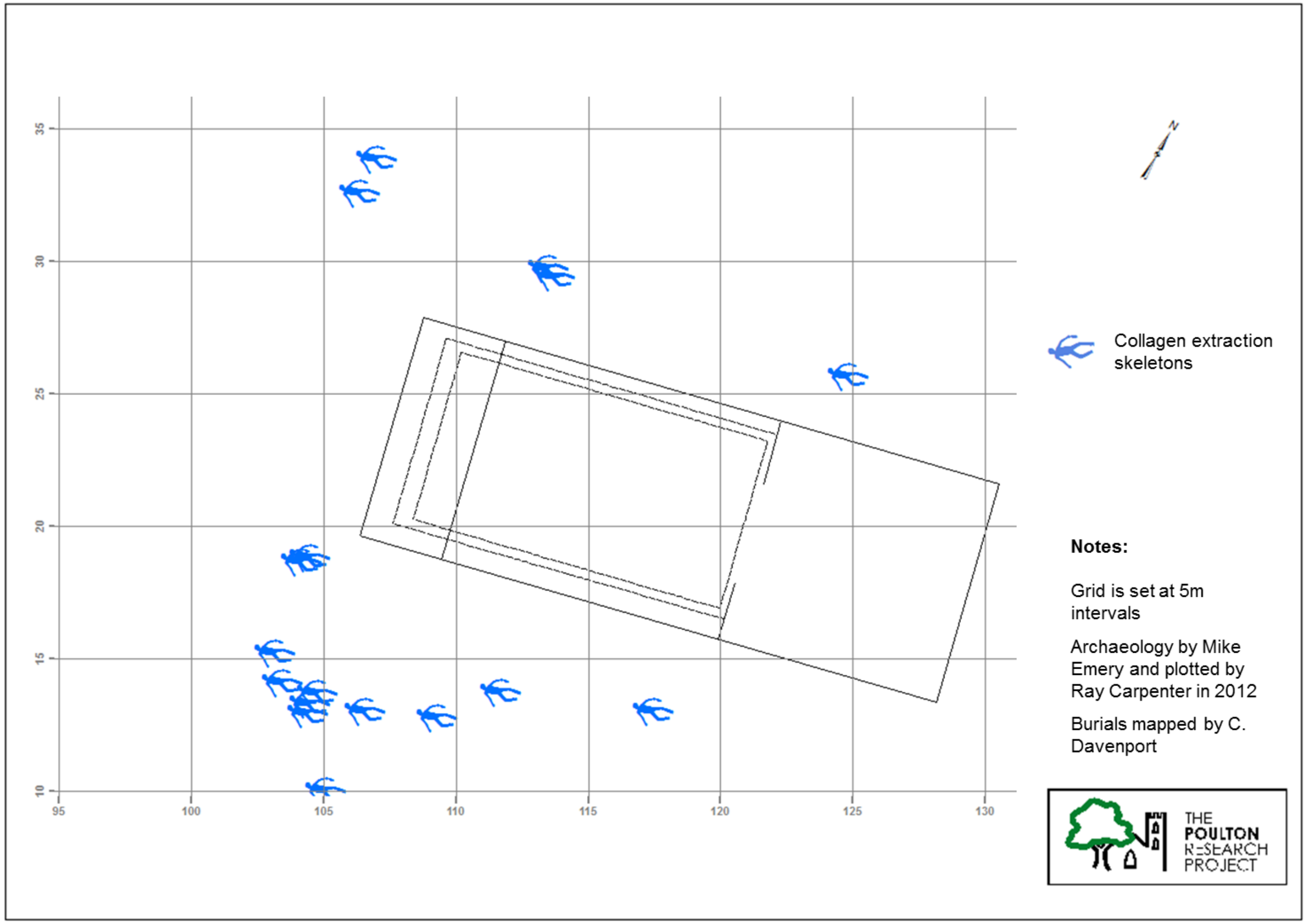

Figure 3.63. Locations of the skeletons providing rib fragments for collagen extraction (n=17). ©CAL Davenport

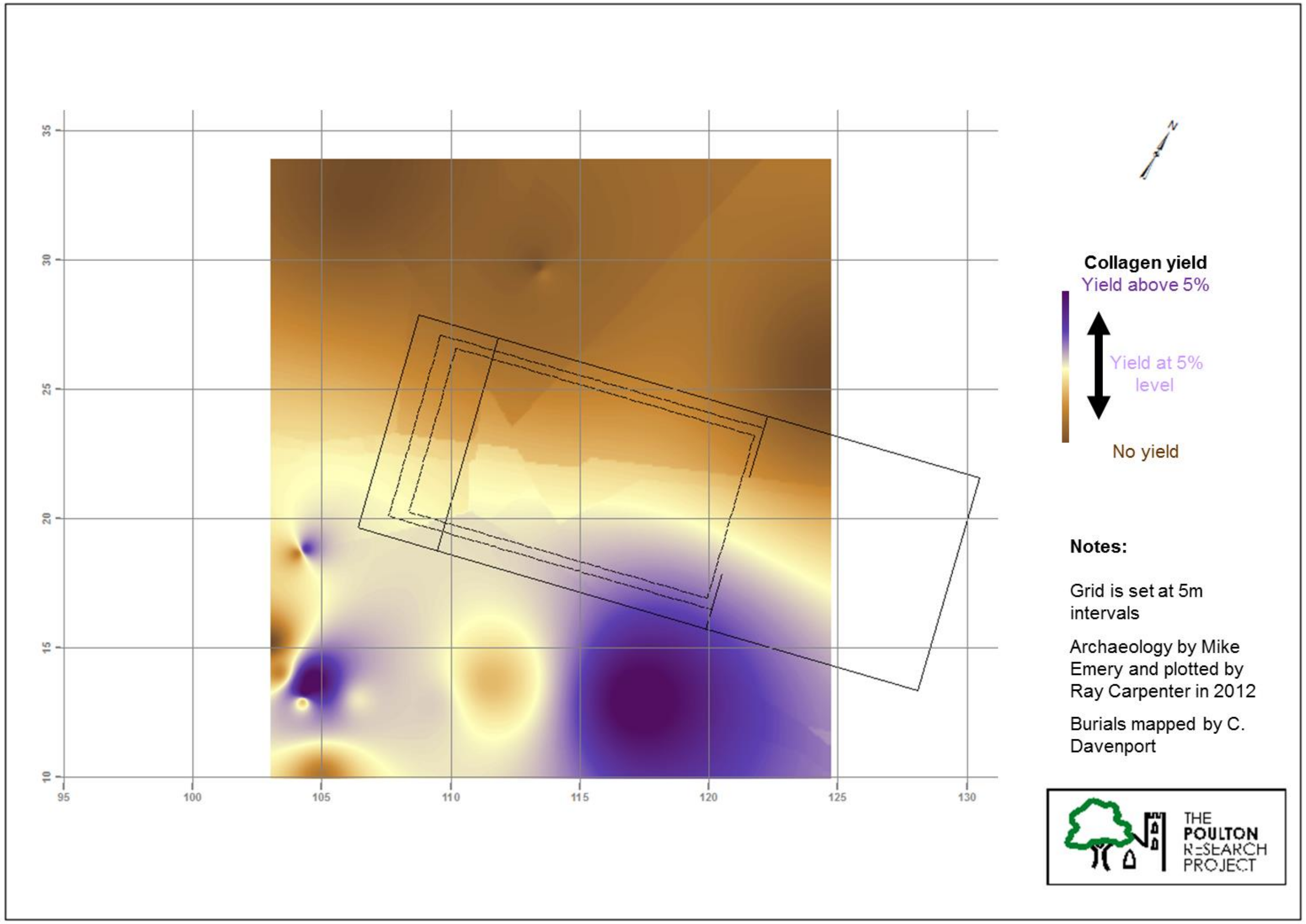

Figure 3.64. Collagen yield levels for Poulton Chapel showing the areas that provided usable data. Mapped in ArcGIS 10.2.2 using an inverse distance weighted (IDW) interpolated raster. ©CAL Davenport

Field portable x-ray fluorescence on bone

The skeletal material from Poulton Chapel was analysed using Field Portable X-Ray Fluorescence to determine if there were any differences in the bone mineral components. The percentage of iron in the bone was shown to increase in shallower burials ($r_{s(16)}$=0.602, p=0.014), and those that were located to the east end of the cemetery ($r_{s(16)}$=0.515, p=0.041), though there was no relationship identified with northings (p>0.05). An increase in the iron levels correlated with an increase in magnesium levels ($r_{s(16)}$=0.501, p=0.048), however, this relationship was weak and the significance was borderline. The magnesium levels in the bone tended to decreased with age, with the adult levels being lower than those observed in non-adults ($r_{s(16)}$=-0.570, p=0.021). However, this may be due to the magnesium levels present in the soil, as the levels present in the bone are far higher than expected for human bone samples (Walden *et al,* 2017), and reflect the surrounding burial matrix. The results from the bone XRF were compared to the geological conditions to see if this would lend any further insight into the conditions affecting the levels of elements in the bones. The pH level in the soil was found to have an impact, with more neutral pH resulting in lower phosphorous levels in the bone ($r_{s(15)}$=-0.664, p=0.007). It was noted that as the level of clay increased, the percentage of magnesium present in the bone decreased ($r_{s(15)}$=-0.704, p=0.003). However, an increase in silt would result in a decrease in potassium levels in the bone ($r_{s(15)}$=-0.516, p=0.048).

Preservation influences

The soil samples from the graves (n=35) were tested against the preservation parameters for the burials: collagen extraction, abrasion/erosion, and fragmentation. A weak, but significant relationship was noted when assessing the impact of soil pH, demonstrating the environment becomes more neutral, collagen yield increases ($r_{s(36)}$=0.362, p=0.030). When compared with the grain size analysis, clay and sand were found to have an impact on the amount of collagen obtained, with the yield appearing to increase as the amount of clay present in the soil increased ($\chi^2_{(7)}$=14.702, p=0.040) and sand ($\chi^2_{(7)}$=14.655, p=0.041). However, there was no relationship identified between the variables ($r_{s(35)}$=0.016, p=0.927 and $r_{s(35)}$=0.218, p=0.207 respectively). When assessing the preservation of the remains the abrasion/erosion and fragmentation grades were lower when the iron levels increased ($r_{s(35)}$=-0.350, p=0.039 and $r_{s(35)}$=-0.353, p=0.038 respectively). There were significant increases in abrasion and erosion on the bone as the amount of clay decreased ($r_{s(35)}$=-0.607, p<0.001), and silt and sand quantities increased ($r_{s(35)}$=0.334, p=0.05 and $r_{s(35)}$=0.492, p=0.003 respectively). Fragmentation appeared to increase as the size of the particles increased, but this relationship was only identified for clay ($r_{s(35)}$=-0.572, p<0.001) and silt ($r_{s(35)}$=0.428, p=0.010).

Weak relationships were present between burial depth and location, with the shallower burials found towards further north ($r_{s(564)}$= 0.181, p<0.001), and to the east of the site ($r_{s(564)}$= 0.103, p=0.014). It should be noted that the burials depths were calculated from the topographic readings from the site. Therefore, burial depth is based on the depth below ground level, not on the reduced level, which would not take into account the slope of the site. Non-adult burials were found at greater depths than the adults were ($r_{s(564)}$= 0.179, p<0.001), which is in contrast to the theory that younger individuals were less important in the community (Lucy, 1994). However, it was noted that as burial depth increased, the level of abrasion/erosion to the bone also increased, though this relationship was also very weak ($r_{s(564)}$=0.106, p=0.012).

3.10. Skeletal analysis – biological profiling

Sex determination

Of the 332 articulated adult burials assessed, there were 162 males, 150 females and 20 unknown adult individuals (Figure 3.65). The ratio of males to females at this site was even ($\chi^2_{(1)}$ = 0.462, p=0.497), showing no skewing of the sexes as seen with other medieval sites (Bardsley, 2014).

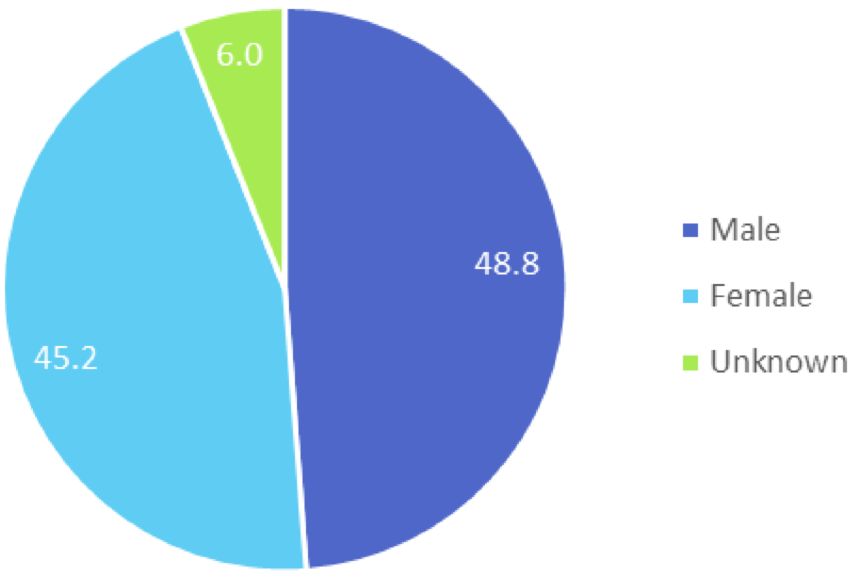

Figure 3.65. Sex determination distribution for the adult skeletons analysed from Poulton Chapel (n=332).

Sex could not be determined for 7% of the articulated adult individuals due to the traits required for sex determination not surviving, or the morphological characteristics having been damaged by post deposition processes. The most commonly available pelvic element for sex determination was the greater sciatic notch, which led to high survivability of the pre-auricular sulcus. Of the individuals that were recovered with a pelvis, over 50% retained the pubic traits required for sex determination. However, this was often detached from the rest of the innominate, leading to the complete obturator foramen not being observable in all cases (Figure 3.66).

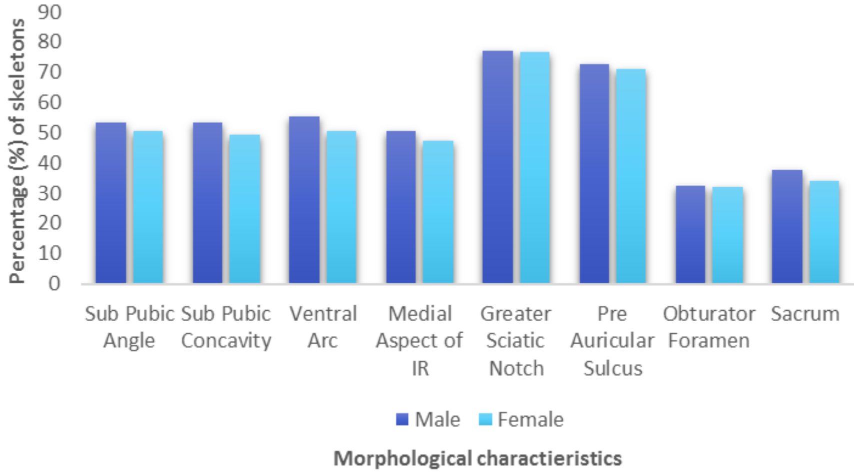

Figure 3.66. Preservation rates of the pelvic morphological characteristics from the male (n=154) and female (n=146) Poulton Chapel burials.

The survivability of the elements did not differ significantly between males and females, leading to a similar number of techniques being available for each sex ($t_{(16)}$=-0.080, p=0.937). However, a large percentage of skeletons did not have any pelvic traits available for use, which meant that cranial morphology and metric measurements were used for sex determination in these cases. The most commonly available cranial element for sex determination was the mastoid process due to its robusticity. The mandible was available for analysis in over 60% of the individuals, with all three traits available for analysis (Figure 3.67). The position of the mandible in the grave protects the bone from post-mortem damage, helping to preserve the traits and contributing the high survivability of the bone.

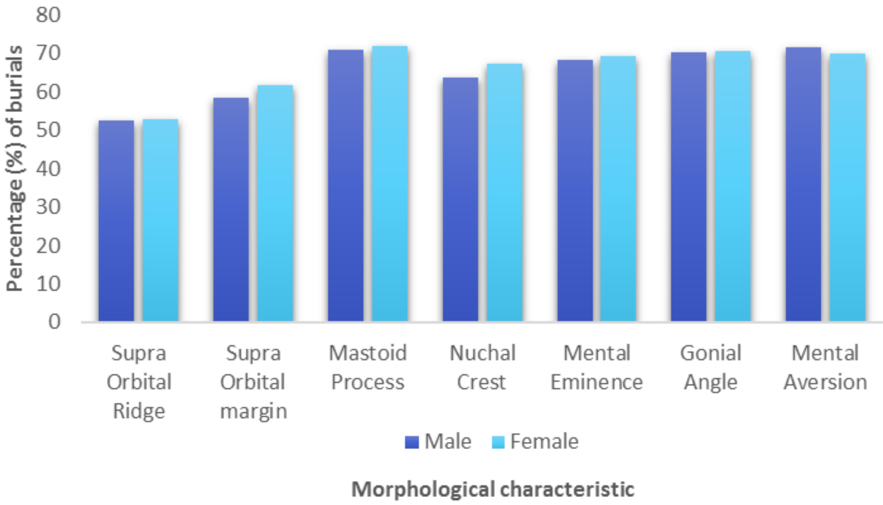

Figure 3.67. Preservation rates of the cranial and mandibular morphological characteristics from the male (n=162) and female (n=150) Poulton Chapel burials.

The survivability of the elements did not differ significantly between males and females leading to a similar number of techniques being used to for determination of each sex ($t_{(14)}$=-0.124, p=0.903). Of the skeletons that could be assessed using the cranium and mandible, over 34% of males and 36% of females provided elements for all seven sex determination techniques. The most commonly available metric measurement for sex determination was the femoral head (59% of the adult sample), with the humeral head being present in 56% of the total adult sample. The proximal ends of both the femur and humerus form ball and sockets joints, which provide some protection to the cortical surface of the bone. In turn, this aids the preservation of this element and the potential for metric measurements to be taken. The analysis of the burial position demonstrated that elements that are proximal to the torso are more likely to be preserved. Of those that could be assessed for sex, the percentage of burials preserving elements providing metric measurements for analysis are shown in figure 3.68.

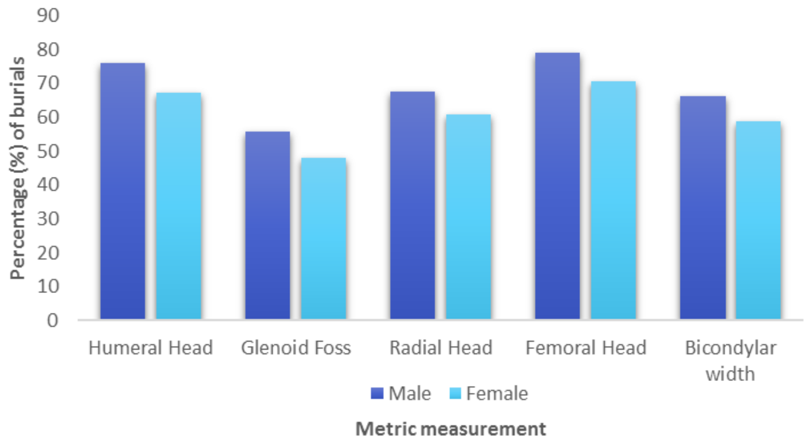

Figure 3.68. Preservation rates of the anatomical structures providing metric measurements from the male (n=162) and female (n=150) Poulton Chapel burials.

The survivability of the elements did not differ significantly between males and females leading to a similar number of techniques being used to for determination of each sex ($t_{(10)}$=-0.105, p=0.918). Of the skeletons that could be assessed using metric measurements, over 35% of males and 26% of females provided elements for all five sex determination techniques. The pre-auricular sulcus was examined for all adult skeletons where the landmark was preserved (n=219) to determine whether it was a groove of pregnancy (GP) or groove of ligament (GL). There were 21 males (10%) who exhibited a pre-auricular sulcus, all of which were identified as a groove of ligament (Figure 3.73). It was possible to observe a pre-auricular sulcus on 92 females, with 25 identified as a groove of pregnancy.

Age estimation

There were 591 articulated burials (332 adults, 259 non-adults) available for assessment of age, with 534 providing characteristics required for the estimation. Of those that could not be placed into age categories (9%), 44 were classified as adult and 13 as non-adult. The age-at-death distribution (Figure 3.69) shows the high number of non-adult individuals in this sample, with 47% of the articulated burials under 20 years old.

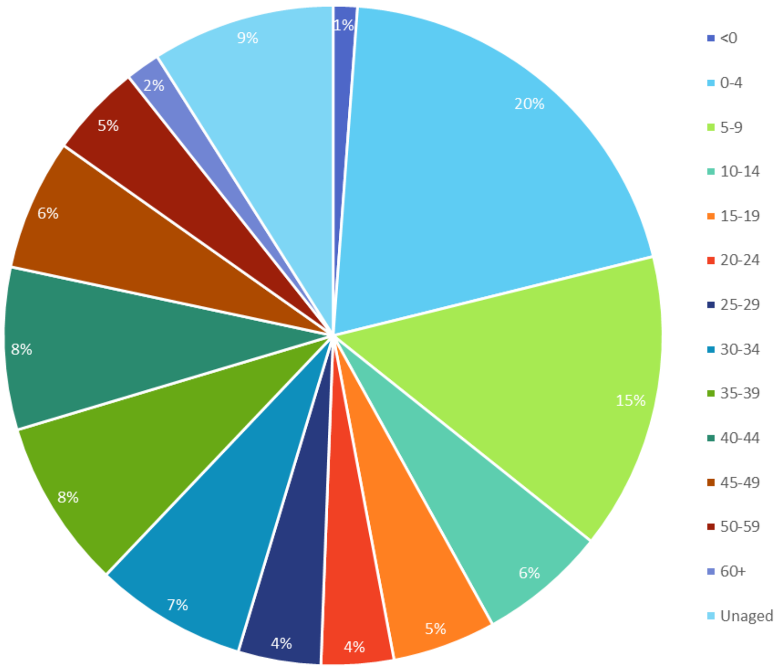

Figure 3.69. Age-at-death distributions for the Poulton Chapel articulated burials (n=591)

The preservation of the elements for age assessment did not vary significantly between males and females (Figure 3.70; $t_{(12)}=0.513$, $p=0.617$), with both sexes similarly having poor preservation of the pubis and ribs. Although the cranium survived in many cases, heavy fragmentation of this region prevented the observation of the sutures. Of the techniques available, only eight individuals used all seven, with the majority (23%) of individuals using five techniques. The auricular surface was the most commonly used method due to the robusticity of this element.

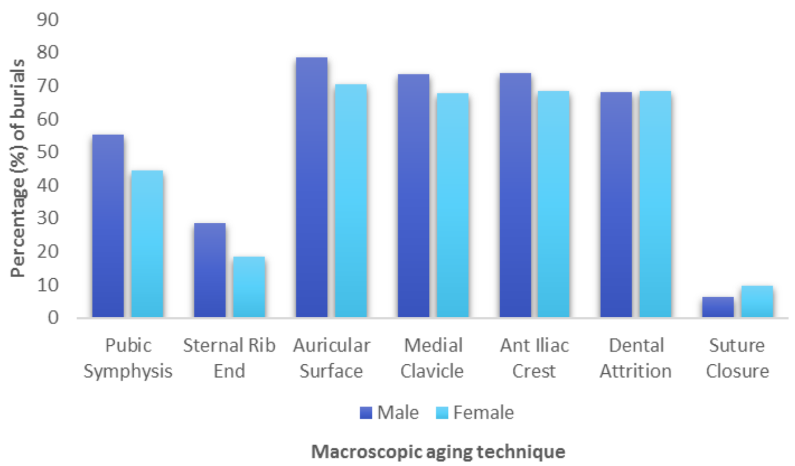

Figure 3.70. Preservation rates of the anatomical regions enabling assessment of the macroscopic aging techniques from the adult male (n=154) and female (n=146) Poulton Chapel burials.

Non-adult age estimation

The non-adult age-at-death estimation was based on dental calcification (through radiographs) and eruption, fusion and in some cases ossification of the epiphyses, and skeletal measurements (Figure 3.71). The percentage of burials using each technique was high, most likely due to the increased number of elements available for use in each case.

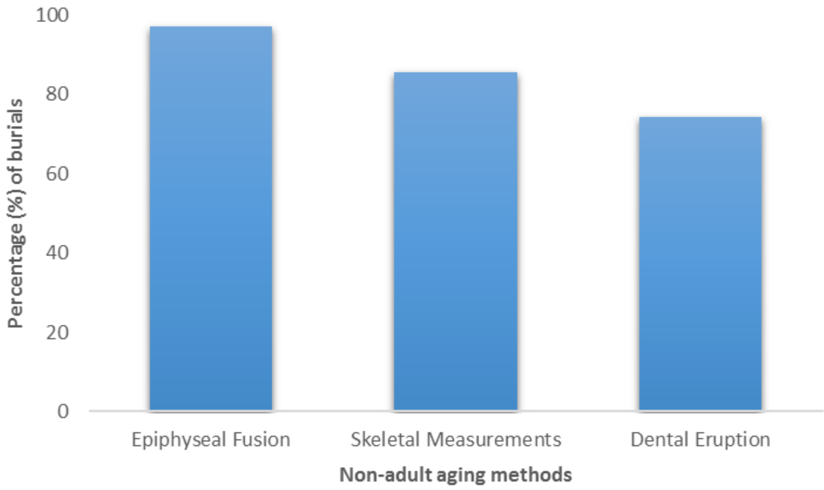

Figure 3.71. Preservation rates of the anatomical structures enabling assessment of age from the non-adult Poulton Chapel burials (n=259).

The non-adult skeletal elements showed preservation comparable to the adult sample ($\chi^2_{(6)}$=4.337, p=0.631), which conflicts with previous literary evidence stating that non-adults are under-represented in the archaeological record (Molleson 1991; Crawford 1991; 1993). The majority of articulated burials (66%) were able to use methods from all three age estimation techniques, with only 3% of burials using only one. Of the 3%, skeletal measurements could not be taken from any of the burials.

Stature estimation

All articulated adult burials (n=321) were assessed for long bone length, with all available measurements recorded. Of those assessed for sex, 240 produced measurements from at least one long bone for the estimation of stature (figure 3.72). To ensure consistency, maximum femur length was used to estimate stature for the Poulton Chapel burials. Average femur length for males was 45.23 ± 2.27cm (n=91) and for females was 42.00 ± 2.12cm (n=61), demonstrating the sexual dimorphism present within the sample ($\chi^2_{(72)}$=102.338, p=0.011). Female stature ranged from 151.61cm to 178.74cm, with female mean height (161.37 ±5.06cm) greater than expected for the period, which has been estimated at around 158.60cm for the medieval period (Cafell and Holst, 2005). Male stature ranged from 150.18cm to 181.60cm, with a mean male stature of 165.87 ± 5.78cm, which was significantly higher than female ($\chi^2_{(89)}$=151.000, p<0.001). The mean male stature falls below those given for British samples in the 12th century (168.4m; Munter 1928) and 13th-

14th centuries (171.8m; Huber 1968; Steckel, 2005); and further below the lower than the overall male mean for Northern Europe (172.1m; Steckel, 2005).

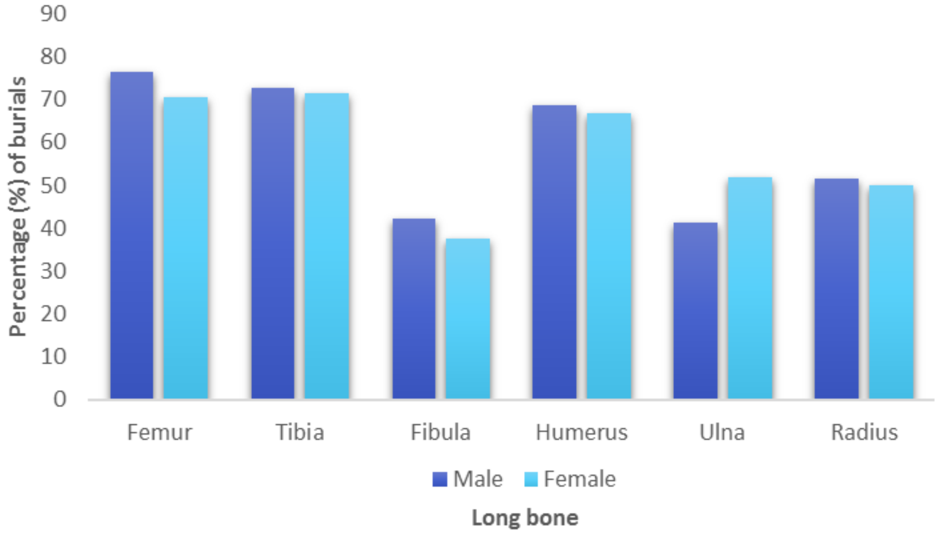

Figure 3.72. Preservation rates, given as a percentage, of the complete long bones available for stature estimation from the adult male (n=128) and female (n=112) Poulton Chapel burials.

Fragmentary femora landmarks were measured on the complete femora to assess whether the regression equations produced by Simmons *et al.* (1990) could be used on the Poulton sample for stature estimation. By comparing the landmarks measurement stature estimations against the complete long bone estimations, it provided a direct comparison between the methodologies. It should be noted, that due to there being no known stature information for this sample, it is not possible to explore the accuracy of the resultant regression equations. The technique was assessed on both male (n=51) and female (n=44) individuals.

Male measurements

Correlations showed that the individual fragmentary measurements correlated with femoral length/stature, however the relationships between the measurements were not very strong (VHD - $r_{(51)}$=0.517, p<0.001; VHA - $r_{(51)}$=0.590, p>0.001; LCH - $r_{(51)}$=0.516, p<0.001). Using scatterplots, it was apparent that 26.7% of the variation in stature was due to the variation in vertical head diameter measurements, 34.8% of stature variation was due to proximal femoral breadth (VHA) and 26.7% was due to lateral condyle width (Figure 3.73).

The stature estimations from complete femoral length were tested against the stature estimations derived using the formulae by Simmons *et al* (1990). The estimations provided using vertical head diameter were not significantly different from those given using complete femoral length ($t_{(197)}$=-1.916, p=0.057). However, those for proximal femoral breadth and lateral condyle height differed significantly ($t_{(149)}$=-3.273, p=0.001 and $t_{(149)}$=-4.000,

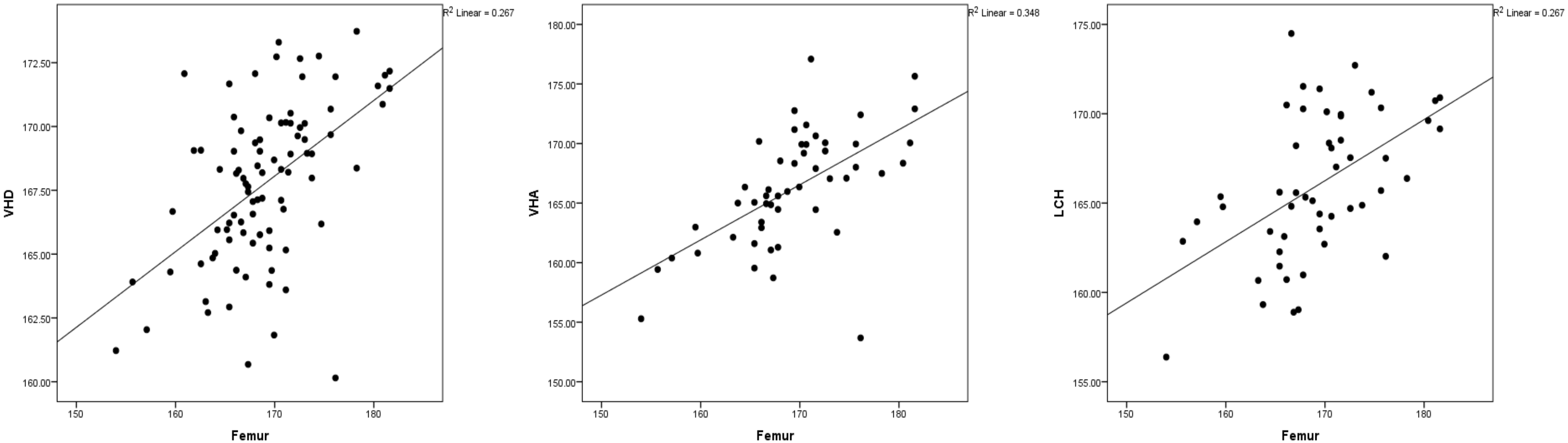

Figure 3.73. Scatterplots showing the variation for each measurement (R^2 linear) for the Poulton adult male sample.

p<0.001), suggesting that the formulae need to be adjusted for this sample. Linear regression was carried out on both vertical head diameter and lateral condyle height, with both the ANOVA and coefficients indicating a strong linear relationship (p<0.001). The revised regression equations for the estimation of male stature using proximal femoral breadth and lateral condyle height at Poulton Chapel are presented in table 3.14.

Table 3.14. Suggested regression equations for estimating stature from proximal femoral breadth and lateral condyle height of the Poulton Chapel males.

	Slope		Intercept
Predictor variable: VHA			
White Males	0.59 x	VHA	+ 111.61
Predictor variable: LCH			
White Males	1.15 x	LCH	+ 123.33

Female measurements

Correlations showed that the individual fragmentary measurements correlated with femoral length/stature, however the relationships between the measurements were not very strong (VHD – $r_{s(61)}$=0.468, p<0.001; VHA – $r_{s(45)}$=0.576, p>0.001; LCH – $r_{s(44)}$=0.501, p=0.001). Using scatterplots, it was apparent that 25.2% of the variation in stature was due to the variation in vertical head diameter measurements, 37.5% of stature variation was due to proximal femoral breadth (VHA) and 29.9% was due to lateral condyle width (Figure 3.74).

The stature estimations from complete femoral length were tested against the stature estimations derived using the formulae by Simmons *et al* (1990). The estimations provided for all measurements were significantly different from those given when estimating stature using complete femoral length (VHD - U=1508.000, p<0.001; VHA - U=697.000, p<0.001; LCH - U=757.000, p<0.001), suggesting that the formulae need to be adjusted for this sample. Linear regression was carried out on all landmark measurements, with both the ANOVA and coefficients indicating a strong linear relationship (p<0.001). The resultant regression equations for the estimation of female stature using vertical head diameter, proximal femoral breadth and lateral condyle height are presented in table 3.15.

Table 3.15. Suggested regression equations for estimating stature from proximal femoral breadth and lateral condyle height of the Poulton Chapel females.

	Slope		Intercept
Predictor variable: VHD			
White Females	0.92 x	VHD	+ 120.70
Predictor variable: VHA			
White Females	0.59 x	VHA	+ 109.39
Predictor variable: LCH			
White Females	1.16 x	LCH	+ 119.68

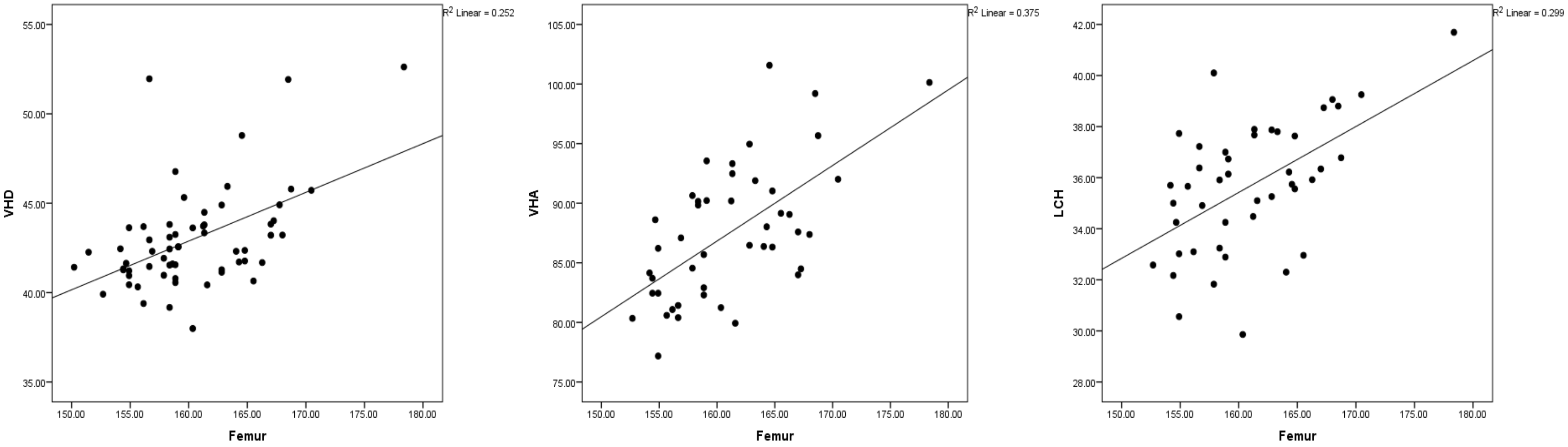

Figure 3.74. Scatterplots showing the variation for each measurement (R^2 linear) for the Poulton adult female sample

Inter-observer error

Cohen's κ coefficient was carried out to determine if there was agreement between the two observer's sex assessments for 100 skeletons from Poulton. All individuals included in this study were ones for which a category could be assigned for age and/or sex. According to the benchmarks set out by Landis and Koch (1977), there was almost perfect agreement on the determination of sex, $\kappa = 0.875$, $p < 0.001$. The differences in the statistical analysis arise from three individuals being sexed as adults by the author that had been classified as non-adult by the independent observer. An individual identified as male by the author had been classified as female by the independent observer, along with four individuals classed as female by the independent observer that were identified as male by the author. One individual was not sexed by the independent observer but was identified as non-adult by the author. This is most likely due to the skeletons in question being incomplete and a reduced number of factors being accounted for by the independent observer.

Cohen's κ coefficient was carried out to determine if there was agreement between the two observer's age assessments for 100 skeletons from Poulton Chapel. Age estimations provided from each study fell into a five-year age range for adolescents and adults, with one-year age ranges given for those under ten years of age. According to the benchmarks set out by Landis and Koch (1977), there was moderate agreement on the estimation of age, $\kappa = 0.502$, $p < 0.001$. Both observers agreed on the age range produced in 53 cases, with a further 31 cases falling within one age category. Of the remaining cases, eight fell within two age ranges and two fell within 4 age ranges. The final individual was identified as an unaged non-adult by the author and placed into an age category by the independent observer.

Several factors could have affected the results from this analysis, including the availability of radiographs in the early stages of the research. As the inter-observer analysis was based on the individuals assessed prior to the radiographs being taken, the age assessments produced by the independent observer using fewer age markers may have produced slightly different assessments. Adult age estimation is based on senescence and not development, making it more difficult to carry out age estimation, which can lead to bias within age estimations. Further studies on bias in adult age estimation have determined that is often the case when assessing age in skeletal remains that non-adults tend to be over-aged and adults under-aged (Merritt, 2013). Without known age-at-death for the individuals at Poulton Chapel, it is not possible to determine whether either observers were biased when aging human skeletal remains.

Intra-observer error

Cohen's κ coefficient was carried out to determine if there was agreement between the sex determination observations taken by the author for 100 skeletons from Poulton. According to the benchmarks set out by Landis and Koch (1977), there was almost perfect agreement on the determination of sex, $\kappa = 0.953$, $p < 0.001$. The differences in the statistical analysis arise from three individuals being given sex classifications during the first assessment, but due to age (15-19 year age category), were classified as non-adult in the second assessment. This is due to the division between adult and non-adult becoming clearly defined as part pf this research in the later stages of data collection. Therefore, all individuals in the 15-19 year category were later classified as non-adult unless they could provide a tighter age estimate (18-19 years).

Cohen's κ coefficient was carried out to determine if there was agreement between the age estimation observations for 100 skeletons from Poulton Chapel. According to the benchmarks set out by Landis and Koch (1977), there was almost perfect agreement on the estimation of age, $\kappa = 0.947$, $p < 0.001$. Both assessments produced the same age range in 96 cases, with the remaining four cases being within one age range.

The differences noted in the age range assessments fell into both adult and non-adult categories, with two individuals present in each. The non-adult initial non-adult age estimates did not include dental radiographs, leading to a more extensive analysis during the second assessment. The difference within the adult categories most likely occurred as adult age estimation is based on senescence and not development. This can often lead age estimations to be subject to a greater degree of interpretation, especially when fewer skeletal elements are present when assessing the age range. For this analysis, both adult cases produced younger age estimates on re-examination, suggesting a slight tendency to over-estimate age (Merritt, 2013).

3.11. Geochemical studies on human skeletal material

Radiocarbon dating

There are currently five radiocarbon dates from four skeletons at Poulton Chapel. Two of the radiocarbon dates were attained from skeleton 53, which was excavated from the nave in 1999 and thought to be the remains of Sir Nicholas Manley due to the proximity of the burial to the chancel. The first carbon date was requested as part of BBC Television documentary series ‘Meet the Ancestors’ but produced inconclusive results, so a second radiocarbon date was requested in 2012. The results from this second test provided a date range of 1450AD to 1640AD from a two sigma-calibrated result obtained from tooth collagen. The second radiocarbon date was requested for skeleton 535 after it was found with an arrowhead inside the chest cavity. The arrowhead was identified as a Type M7 bodkin arrowhead which were in use from the end of the thirteenth century (Jessop, 1996) and the burial was dated from 1280AD to 1390AD (Canavan, 2014). Further burials have since been discovered with arrowheads (skeletons 719 and 836), with research on the arrowheads and skeletons planned. Skeletons 463 and 750 were radiocarbon dated in December 2015 by Beta Analytical in an attempt to determine the start and end dates of the cemetery. The shallowest (skeleton 750) and deepest (skeleton 463) burials from the Poulton cemetery were selected, with second molars extracted and sent to Beta Analytical for preparation and testing. Skeleton 750 was dated from 1285AD to 1385AD and skeleton 463 was dated from 1275AD to 1390AD, both of which are very similar to each other and to the date from skeleton 535.

Stable isotopes

There had been very little stable isotope work carried out at Poulton Chapel since the start of the excavations with only one unpublished research dissertation undertaken (Curtis, 2008). With the commencement of several projects at Liverpool John Moores University, there has been the opportunity to increase the amount of information about the lifestyle of this rural sample. Using both traditional and novel methods, an understanding of the paleodiet of this rural sample has been gained.

Dental collagen

Two skeletons (Skeletons 463 and 750) provided dental collagen samples for carbon and nitrogen stable isotope testing, to provide an insight into the paleodiet at Poulton during the medieval period. The samples were sent to Beta Analytical in December 2015. The plot obtained from the analysis for skeletons 463 and 750, along with dietary mean faunal values (Müldner and Richards, 2007a; 2007b; Müldner et al, 2009), are given in figure 3.75.

The mean δ13C values (-20.05 ±0.71‰) for the Poulton chapel collagen samples were consistent with a diet focused on C3 plants. Mean δ15N values (11.70 ± 0.14‰) were consistent with a shift of 1-2 trophic levels (5.89‰) above the herbivore baseline (5.81 ± 1.48‰, n=61); indicating that the diet contained animal and marine sources, along with an occasional intake of omnivore or freshwater fish protein. As the village of Poulton provided the lay community for the abbey grounds, those assisting in the upkeep of the estate would have had access to the fishponds, as well as the River Dee, providing access to freshwater fish species. Chester Weir was built in 1093 for the first Earl of Chester, to provide ample water for the mills placed along the river (Historic England, 1998). It also encompassed a salmon leap, which is still present today, suggesting that there was access to this anadromous fish species.

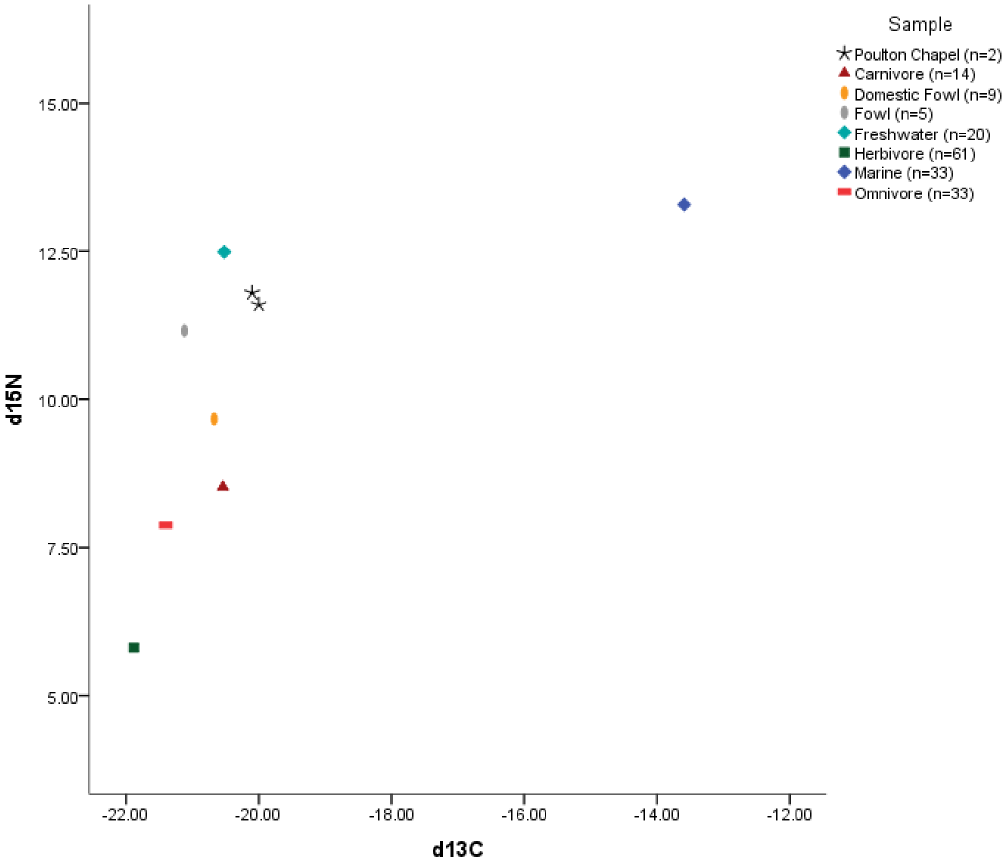

Figure 3.75. Isotope data for the Poulton Chapel burials in comparison with faunal, freshwater and marine values available from the medieval period (Müldner and Richards, 2007a; 2007b; Müldner *et al,* 2009).

Dental calculus

Twenty-eight dental calculus samples were obtained from randomly selected adult human skeletons at Poulton (Figure 3.76). The dental calculus samples were assessed before and after acid extraction, with the results plotted against those for the dental collagen shown in figure 3.77. The mean δ13C values (-21.51 ±0.47‰) for the Poulton Chapel calculus samples were consistent with a diet focused on C_3 plants. Mean $\delta^{15}N$ values (11.84 ± 1.0‰) were consistent with a shift of 1-2 trophic levels (6.03‰) above the herbivore baseline (5.81 ± 1.48‰, n=61); indicating that the diet contained animal and marine sources. There were no significant differences identified between the $\delta^{15}N$ values retrieved from the calculus samples and dental collagen samples retrieved from Poulton chapel ($t_{(14.3)}$=0.629, p=0.539). However, the $\delta^{13}C$ calculus values showed a significant decrease of approximately 1.5‰ when compared with the dental collagen values ($t_{(12.5)}$=-14.361, p<0.001). This is most likely due to calculus being a biofilm and therefore comprising of food remains, bacteria and DNA (Salazar-García *et al*, 2014). Further differences in the results will be due to the dental collagen providing an assessment of the diet consumed during tooth formation, rather than the continuous build up and wear of the calculus over the lifespan of the individual (Salazar-García *et al*, 2014). Due to the presence of food particles and other materials derived from

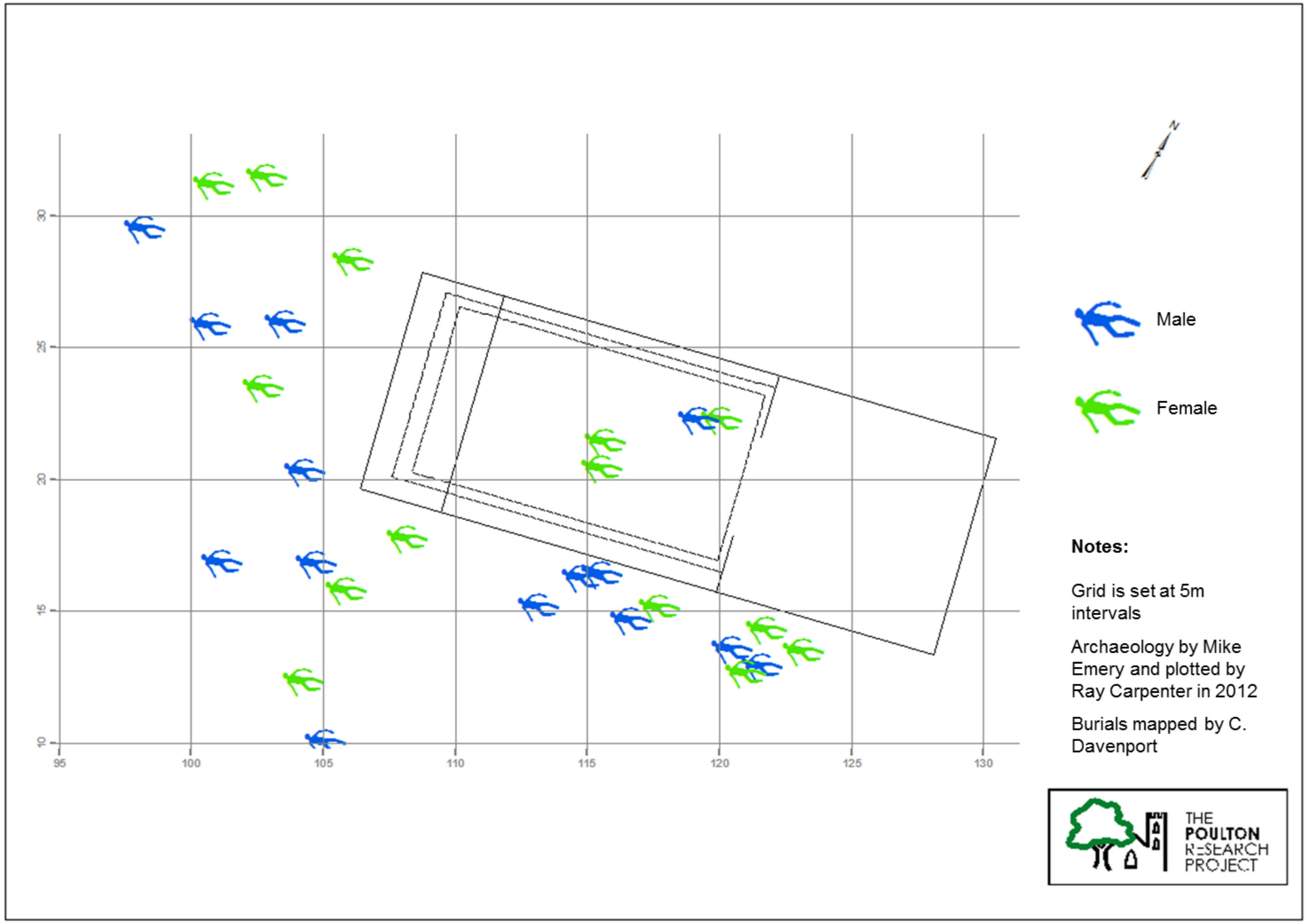

Figure 3.76. Map demonstrating the distribution of male and female burials selected from the cemetery for calculus stable isotope testing. Included for reference is the outlines of Poulton Chapel. Map produced using in ArcMap 10.2.2 and ArcScene 10.2.2. ©CAL Davenport

plant material being trapped in the calculus and C_3 plants materials having a $\delta^{13}C$ value of approximately -26‰ (Mays, 1997); it is likely that this has contributed to the lowered values. The acid extraction adjusted the $\delta^{13}C$ further, showing that that it is approximately 2‰ lighter when considering just the organic carbon content. This is to be expected as the carbonate (inorganic) component of the $\delta^{13}C$ is isotopically heavier that the organic component (*pers. comms* Simon Poulson).

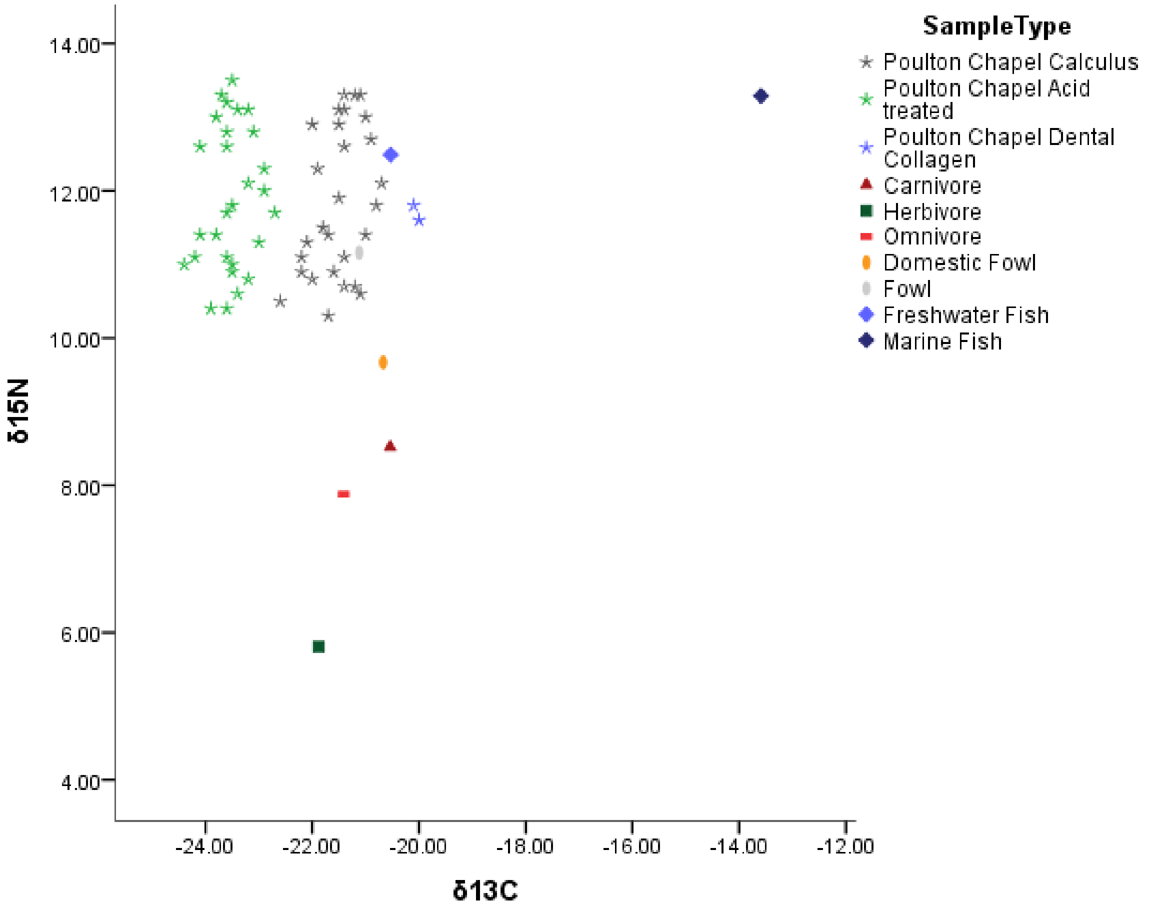

Figure 3.77. The Poulton Chapel calculus samples (n=28) plotted alongside the dental collagen samples (n=2), demonstrating the shift in values between isotopic source materials and the acid treated calculus sample.

3.12. Demographics

Age estimations were obtained from 628 burials. However, as both articulated burials and skull only were included in this number, there was an issue of individuals being included twice. Therefore only articulated burials have been included in the demographic analysis for Poulton Chapel (n=534). Almost 40% of the sample did not survive past 10 years of age (Table 3.16). Conversely, those who survived to ten years of age could expect to live a further 25 years on average based on the demographic analysis, although life expectancy gradually decreases from this age onwards.

Table 3.16. Simplified standard life table displaying the demographics for the Poulton Chapel articulated burials.

Age x	Individuals dx	Survivorship lx	% of Deaths	Mortality Qx	Expectation of Life ex
0	125	534	23.41	0.23	22.53
5	87	409	16.29	0.21	23.66
10	38	322	7.12	0.12	24.37
15	30	284	5.62	0.11	22.30
20	20	254	3.75	0.08	19.64
25	26	234	4.87	0.11	16.10
30	42	208	7.87	0.20	12.80
35	49	166	9.18	0.30	10.41
40	45	117	8.43	0.38	8.72
45	35	72	6.55	0.49	7.60
50	28	37	5.24	0.76	7.43
60	9	9	1.69	1.00	5.00
Sum	**534**				

Although the survivorship curve shows a sharp decrease in the sub-adult sample at the start, the rate of death decreases considerably until approximately 30 years old, when the rates starts to increase again (Figure 3.78). The mortality curve gives an indication of the ages at which mortality peaks, in this case, following the high rates of mortality during childhood, the next peak in mortality is at 35 years of age (Figure 3.79).

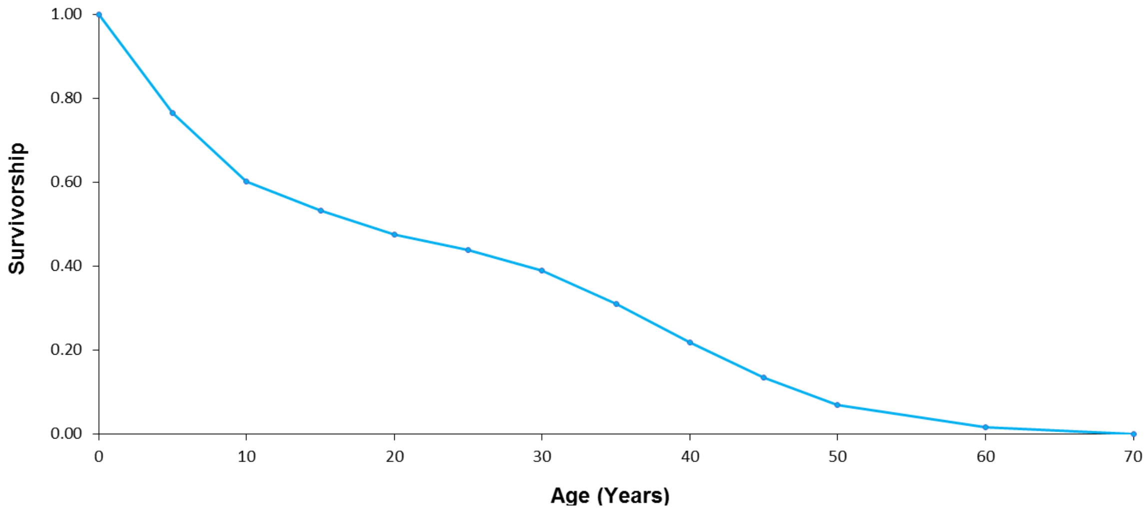

Figure 3.78. Survivorship curve for the Poulton Chapel articulated burials (n=534).

The crude mortality rate for estimated from life expectancy at birth (22.53 years) based on the 534 individuals in the demographic analysis was 44 death per 1000 within this sample. The length of time the cemetery was in use has been estimated at 343 years, based on the midpoint of the construction of the abbey in 1150 and the date the Manleys took over the site and made it a private chapel. The last 26 years until the last known burial have not been included in this estimate, as burials during this time may have ceased. As there is no documented evidence of members of the Manley family being buried at this site, with the exception of Nicholas Manley's request in his will, the cemetery lifespan has been estimated at 343 years. Until radiocarbon dating confirms the presence of burials prior to 1150 and/or after 1493, all sample estimates will be based on this figure. The sample size required to sustain the current number of burials over the lifespan of the cemetery is approximately 35 individuals (35.08).

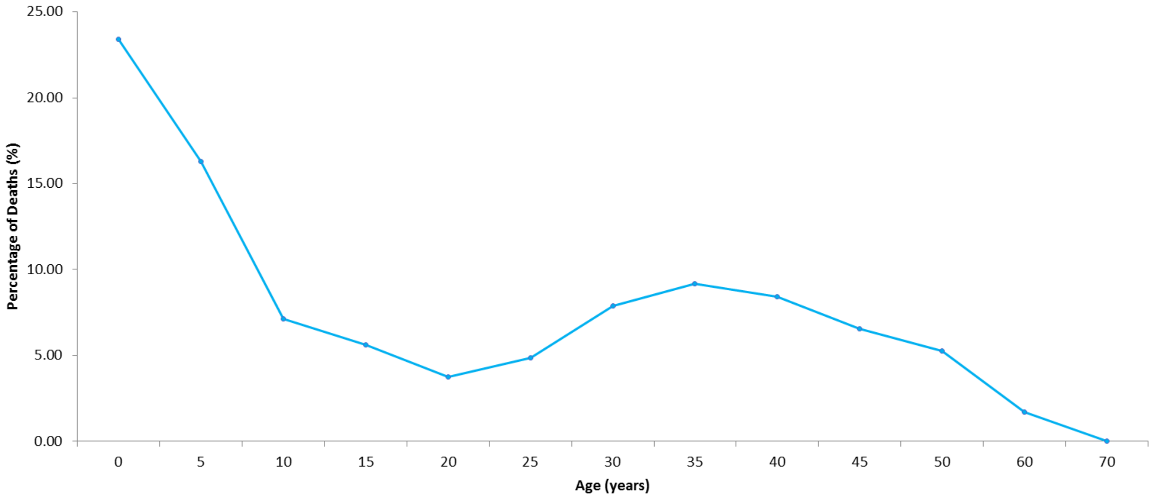

Figure 3.79. Mortality curve for the Poulton Chapel articulated burials (n=534).

The overall demographics give an insight into the samples as a whole, but do not take into account the different risk factors that can affect the sexes. During the time the Abbey was founded and in the years that followed, the lay community would help with construction and farming. During times of conflict between England and Wales, the lay community would also help defend the village or assist with looking after soldiers that would be billeted there. During the medieval period, due to the high mortality rates, it was common for women of childbearing age to be pregnant often. However, this increased the risk of the mother not surviving the pregnancy or childbirth, with post-partum infections also being common. Therefore, demographic analysis has been carried out on the articulated adult males and females separately to determine any difference in the profile between the sexes.

Male demographics

The male articulated burials (n=146) were represented in all age categories, with the majority (23%) providing estimates in the category of 40-44 years at death. The rise in mortality at this age compares with the overall demographics, which showed that the survivorship rate began to decrease at a slightly faster rate at this time. The life expectancy for the adult articulated burials is only given from 15 years of age due to the lack of information regarding non-adult sex estimation, with males having a life expectancy of 22.8 years once they reach this age (Table 3.17). The life expectancy decreases gradually as an individual reaches each five-year age group, with a peak in mortality seen at 40-44 years of age.

Table 3.17. Simplified standard life table displaying the demographics for the male articulated burials (n=146) from Poulton Chapel.

Age x	Individuals dx	Survivorship lx	% of Deaths	Mortality Qx	Expectation of Life ex
15	13	146	8.90	0.09	22.79
20	7	133	4.79	0.05	19.77
25	12	126	8.22	0.10	15.73
30	24	114	16.44	0.21	12.13
35	27	90	18.49	0.30	9.69
40	30	63	20.55	0.48	7.78
45	16	33	10.96	0.48	7.58
50	13	17	8.90	0.76	7.35
60	4	4	2.74	1.00	5.00

The survivorship curve showed a slow decrease in sample at the start of the curve (Figure 3.80), with the rate of death increasing from approximately 30 years old, before slowing down again at around 45 years of age. The mortality curve also illustrates this drop in the rate of death in the late teens, prior to rising by the age of 25 years until it reaches its peak mortality rate at approximately 40 years (Figure 3.81).

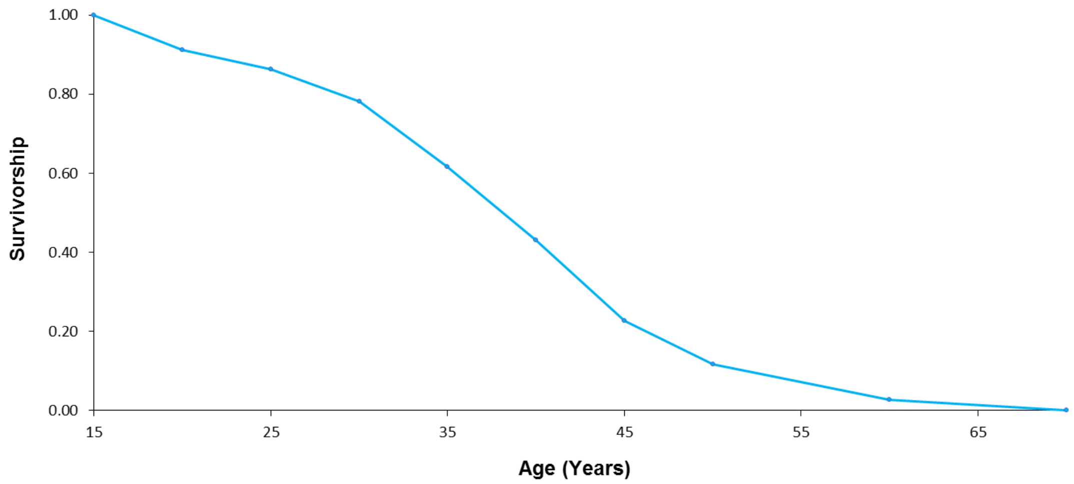

Figure 3.80. Survivorship curve for the male Poulton Chapel articulated burials (n=146).

For the Poulton articulated males, following the high rates seen during early childhood, a peak in adolescence (8.09%) is seen as the individual takes a more active role within the community. The next peak in mortality for males is seen at around 40 years of age, with a loss of 20.55% of the adult male sample. This could be due to the number of dependents able to undertake duties in the home environment enabling the males to assist in protecting the surrounding areas during times of war. Although men of all ages would be recruited into the war, those with a young family would be reluctant to leave the home undefended on the English-Welsh border due to frequent crossings by the Welsh. It could also be due to the average life expectancy being shorter in the medieval period due to the lack of medical care available in modern times. Age related illnesses would likely go untreated resulting in a shorter lifespan.

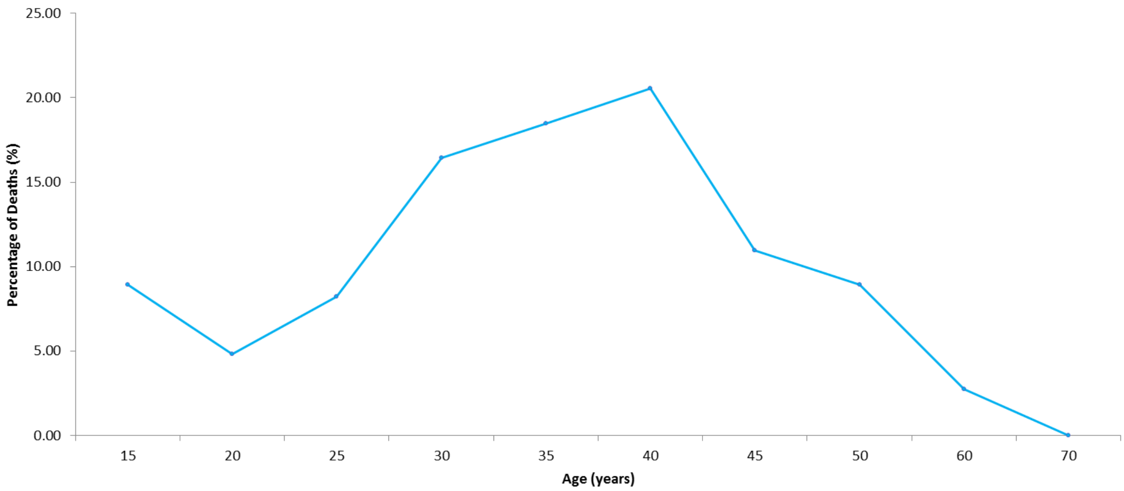

Figure 3.81. Mortality curve for the male Poulton Chapel articulated burials (n=146).

Female demographics

The female articulated burials (n=135) were represented in all age categories, with the majority (17%) providing estimates in the categories of 35-39 years and 45-49 years of age. As with the male demographics from Poulton Chapel, the rise in mortality at this age compares with the overall demographics, which showed a rise in mortality at 35 years and again at 45 years. The life table indicates that the females from the Poulton Chapel sample had a slightly higher life expectancy than the males (Table 3.18). Females could expect to live for another 23.3 years once they reached 15 years of age. As with the males, life expectancy decreases gradually as an individual reaches each five-year age group, with peaks in mortality seen at 35 and 45 years of age.

Table 3.18. Simplified standard life table displaying the demographics for the female articulated burials (n=135) from Poulton Chapel.

Age x	Individuals dx	Survivorship lx	% of Deaths	Mortality Qx	Expectation of Life ex
15	9	135	6.67	0.07	23.33
20	14	126	10.37	0.11	19.82
25	11	112	8.15	0.10	16.99
30	20	101	14.81	0.20	13.56
35	21	81	15.56	0.26	11.30
40	17	60	12.59	0.28	9.38
45	22	43	16.30	0.51	7.09
50	17	21	12.59	0.81	6.90
60	4	4	2.96	1.00	5.00

The slow decrease in sample is evident at the start of the survivorship curve, with the rate of death increasing from approximately 30 years old, before slowing down again at around 50 years of age (Figure 3.82). For the Poulton articulated females, following the high mortality rates seen during early childhood, the peak seen in adolescence in the males is not present, with lower rates of mortality at this age (Figure 3.83; 6.67%). However, the female articulated burials have a peak at twenty years, which could coincide with the first obstetric event. Pregnancy carried many risks during the medieval period, with less access to medical care and unsanitary conditions cited as common factors in loss of the mother and/or child during labour.

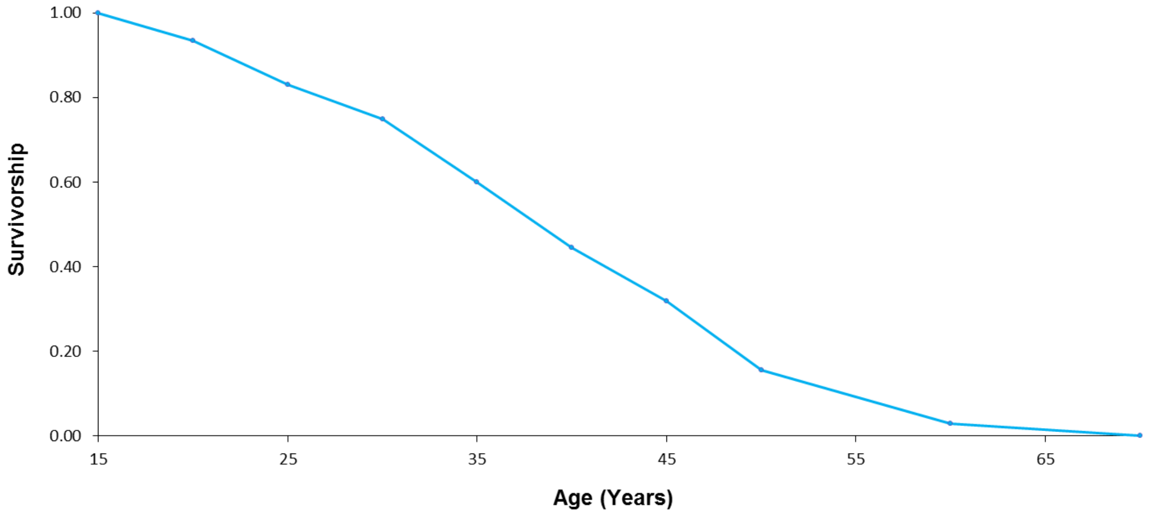

Figure 3.82.Survivorship curve for the female Poulton Chapel articulated burials (n=135).

The next peak in mortality for females is seen at 35 years of age with a loss of 15.56% of the adult female sample, most likely due to the risks associated with pregnancy starting to increase again at this point. Although considerably less than the decline in the male sample at this point (18.49%), when combined with the third peak in female mortality at 45 years, 44% of the adult female sample is lost within a 15 year span. This sharp decline in the female sample highlights the increased risk of pregnancy faced by the female sample during childbearing years. From the age of 45 years, the mortality rate of the adult female sample is comparable to that of the males, lending further support to the theory that the decrease in survivability after this point is due to old age.

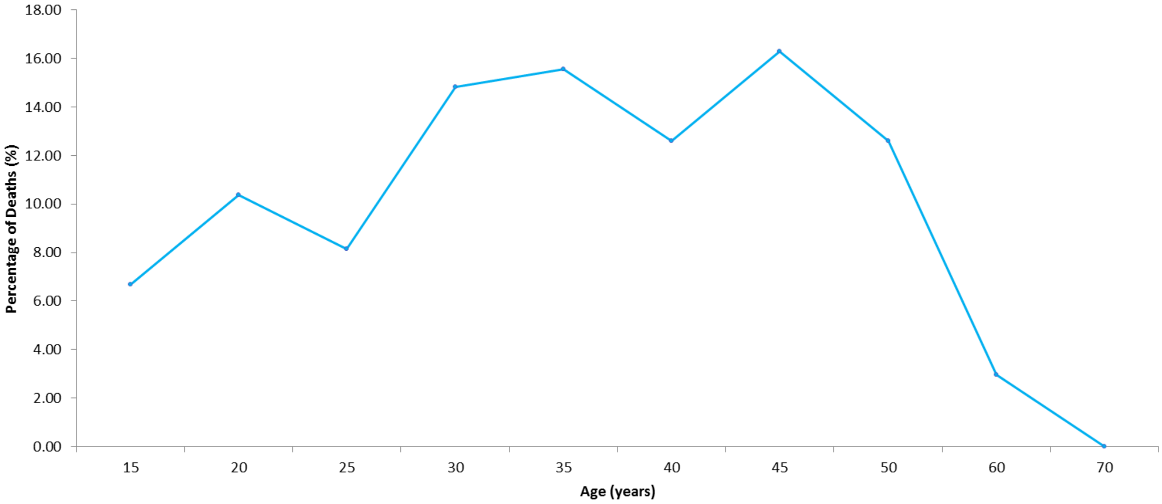

Figure 3.83. Mortality curve for the female Poulton Chapel articulated burials (n=135).

3.13. Summary of site results

The site of the medieval Chapel was in use by the local community at Poulton for approximately 343 years, after which it became a private place of worship for the Manley family. Evidence for previous occupation at the site has been provided by the ongoing excavations, but until now, there has been no investigations into how this has affected the preservation of the human skeletal remains within the cemetery.

The osteological analysis of the remains recovered from the cemetery up until the end of the 2015 excavation season produced 591 articulated burials (332 adults, 259 non-adults), with an average life expectancy of 22.53 years at birth. The mortality profiles show that almost 40% of the overall sample did not survive past 10 years of age, indicating that the preservation and retrieval rate of non-adult human remains is good. In comparison to other cemetery sites the number of non-adult burials is high (47% under 20 years), which disagrees the findings from identified urban medieval samples. As noted in previous literature though, the life expectancy at birth is not necessarily representative of the mortality profile, but could be an indication of the fertility and sample growth present at that site (Buikstra *et al*., 1986; Johansson and Horowitz, 1986; Milner *et al*., 1989).

Other sites report much lower non-adult samples, including St Andrews Fishergate, York (14%), St Mary Spital, London (29%) and St Helens-in-the-Walls, York (27.3%). Wharram Percy, which was a rural medieval cemetery, has the highest number of non-adult burials recovered (39%; 273/690 burials) from an excavation. However, it should be noted that the excavations at Wharram Percy recovered a much higher number of neonatal and infant burials from the site than have been found at Poulton Chapel so far, resulting in a lower life expectancy at birth (20.14 years). This difference in life expectancy at birth estimations may be due to the Poulton Chapel excavations not being complete, with ongoing work on the North and South sides of the Chapel and the East still to be investigated. There are also many studies noting that concentrations of neonatal and infant remains are also a possibility at medieval sites, following on from the Anglo-Saxon practice more commonly referred to as eaves drip burials (Craig-Atkins, 2014).

The distribution of sex at the Poulton Chapel site was even, which is not in agreement with other medieval sites (Bardsley, 2014). All pelvic elements were available for sex determination in nearly 40% of the sample, with over 70% retaining the greater sciatic notch. In the cranium, the mastoid process was the most commonly preserved elements, with all traits available in over 50% of the sample. There was no difference in the retention rate of the elements by either sex.

To gain a better understanding of the past activity at the site, and how it has affected the preservation of the human remains, soil sampling was undertaken and analyses conducted to gain an understanding of the site at both a cemetery and burial level. When human remains are excavated from a site, it is a destructive process. By collecting as much information as possible about both the skeleton and the surrounding burial medium, it is possible to gain a better understanding of the taphonomic conditions present. This not only aids the initial osteological assessment, but also enables those undertaking further analytical testing to assess the potential for successful results.

Interestingly, there were few direct relationships at cemetery level between the studied soil characteristics and collagen extraction rates, with particle size having a minimal impact, but not enough to produce a relationship between the variables. Collagen yield at this site seems to be more directly affected by pH levels in the soil and taphonomic damage to the bone, with neutral pH levels associated with higher collagen values. Taphonomic damage to the bone is directly affected by the soil conditions, with particle size, and the iron levels in the soil both having an influence. This was most likely due to the abrasive sand particles causing a greater degree of erosion on the cortical bone surface, making the bone more vulnerable and likely to fragment.

The burials in the northwest corner of the cemetery were more poorly preserved when compared to those interred elsewhere, most likely due to the continual occupation of this section of the cemetery. The construction works that had produced the gulleys for the Roman building that once stood on site had introduced foreign material to the clay, which changed the burial matrix. The destruction of the Roman buildings, possibly from a fire, may have further influenced the preservation of the burials interred in this area many years later (pers. comm. Dr Kevin Cootes). Subsequent disturbance by later burial phases and by ploughing of the fields, when the area became farmland again, would have placed increased pressure on the burials in the north of the cemetery. The relationship between burial depth and location, although weak, coincides with the increased fragmentation seen on the adult burials in this area and may provide an insight to the burial differences seen in cemetery sites not previously considered by the literature.

The high frequency dependent magnetic susceptibility levels at the cemetery sites highlights areas of anthropogenic activity as the parent material becomes mixed with foreign material brought to the site. The areas demonstrating higher levels of past activity at the site coincide with the extension of a Roman ditch and its associated backfill on the western edge of the cemetery (*pers. comms*. Kevin Cootes, Poulton Site Director). Further areas to the south of the Chapel have produced redeposited medieval construction material. Reworking was noted on the North side of the chapel, particularly in the North East, which could relate to the Roman ditches that run through this section of the cemetery. The north side of the chapel gave values that compared more directly to the natural clay. This was most likely due to the samples being taken from areas around the Roman ditches, and therefore derived from the parent material instead of the foreign materials brought on to the site during periods of past human occupation.

The grain size obtained at Poulton was predominantly silt, with varying amounts of clay and sand present. In areas where the amount of sand increases and clay decreases, the skeletal remains had a greater degree of abrasion/erosion resulting in lower collagen yields. Fragmentation was not affected by the increase in sand but became more severe in areas with increased silt levels and decreased clay. The percentage of iron present in the soil had an impact on the degree of abrasion/erosion and fragmentation, with both becoming more severe as the iron levels dropped. Comparison of the iron level in control section C4 with each of the graves did not show a significant difference between the levels, indicating that the iron is present in the soil rather than as a result of human decomposition.

There was no difference identified in the degree of fragmentation observed when considering sex, however a slight significant difference was noted between the adult and non-adult burials, with a tendency for adult burials to have a higher degree of fragmentation present. The rate of abrasion/erosion on the bones did not differ between the different age groupings; however, there were difference noted between the sexes, with males likely to have more damage than females. Complete skeletons exhibited less erosion and fragmentation than those that were incomplete. The position of the arms within the grave gave an indication of the likelihood of abrasion/erosion, with those with lower end of the scale preferring arms by the sides or folded over the lumbar region or chest.

Taking into account all the factors analysed at this site, if you were to select an individual from the Poulton site for further analytical testing based on the data collected so far (such as radiocarbon dating and stable isotope analysis), there would be a greater chance of success with a skeleton from the south east corner of the cemetery. This area has a more neutral pH level, higher levels of clay and percentage iron in the soil, which will produce a higher number of complete skeletons, with lower abrasion/erosion and fragmentation rates. Skeletons with arms close proximal to the thorax are more likely to have been shrouded burials and therefore will have less abrasion/erosion and fragmentation, producing higher collagen yields.

Chapter 4 – Greyfriars, Chester

* This chapter has forms part of the Osteological Report for Chester Greyfriars and has been sent for publication

4.1. Site background

The Chester Greyfriars site is located between Stanley Street and Nicholas Street, Chester (SJ 40217 66297; Figure 4.1). It was planned that the site was to be developed, becoming a £33 million student accommodation complex as part of a venture between Stephenson Developments and the landowners, Chester Racecourse.

Figure 4.1. The location of the Chester Greyfriars site; the site of the medieval Greyfriars in Chester (red arrow). The site was located inside the western walls of the city. ©CAL Davenport and Google Maps.

Following the watching brief (Phase 1), Phase 2A of the excavation took place from November 2015 to January 2016. Phase 2A consisted of 12 pits, which would become manhole access points (measuring 2.56m^2 and up to 4m deep) and lift shafts, (measuring 3 x 3 x 1.6m deep) during the construction of the student accommodation complex (Figure 4.2). Phase 2B was due to commence following the completion of the initial pits, this would have consisted of two crane base pits measuring 6 x 6 x 1.5m deep. However, the development has been put on hold whilst assessments are taking place. It should be noted that crane base 2 would have directly overlay a portion of the cemetery, which would most likely result in the discovery of further burials.

Historical background

During the Roman period, the site was located between the western defences of the legionary fortress and the extra-mural civilian settlement with archaeological evidence suggesting that a bathhouse building once occupied the southwest corner of the site (Martin, 2015).

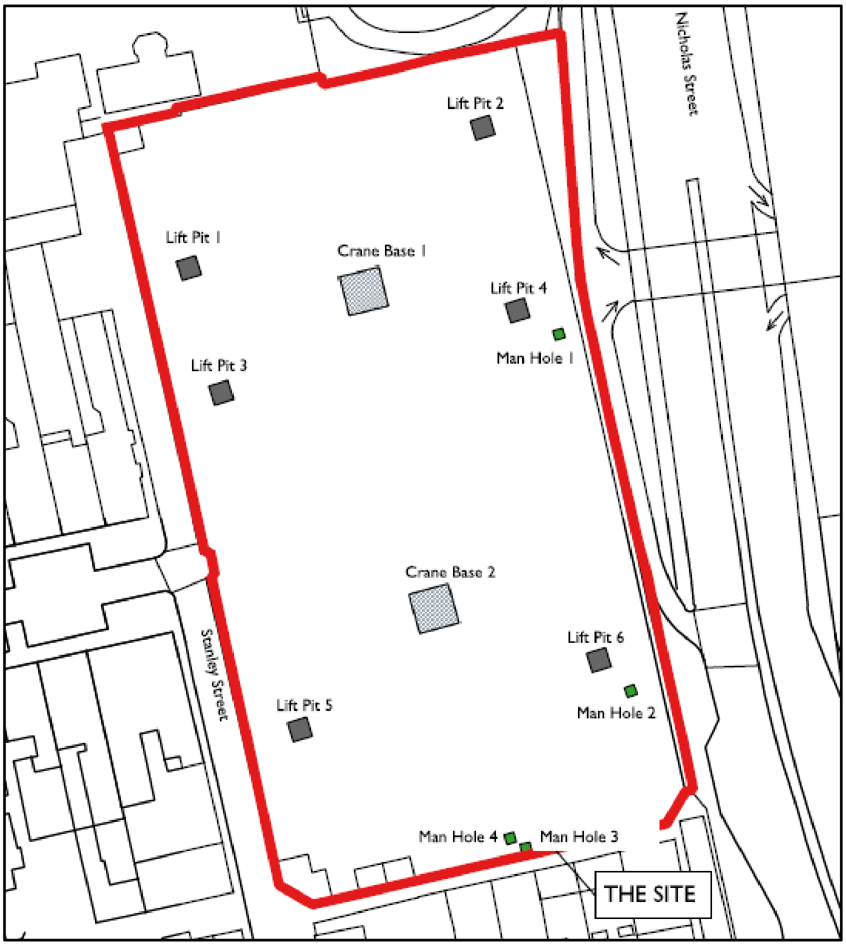

Figure 4.2. Locations of the manhole, lift and crane base pits that comprised Phases 2A and 2B of the Chester Greyfriars excavations. The red line denotes the boundary of the site. Adapted from Garner (2015).

The Franciscan Friary was founded in 1237, although not without protest from the Dominicans, who were concerned that there would not be enough alms coming in to Chester to support another friary. The initial construction began in 1240, when Henry III gave approval for a house for the Greyfriars at the site, opposite the Dominican convent.

The site of the Greyfriars was bound by the City Walls to the west, St Martins Way to the east, Bedward Row to the north and Watergate Street to the south. The site covered approximately seven acres, and was entered through a gatehouse at the south of the precinct. The church was similar in layout to Irish friaries that still survive today, with a 200-foot-long nave and large transecting chapel, a steeple with a sharp spire (‘sharpe syyar’), two bells and a ‘cross yle.’ There have been several sources that dispute the location, and number of cloisters at the site; however, the inventory drawn up in 1538, during the dissolution notes this as adjoining the north aisle of the nave (Martin, 1937).

Over the years, the king contributed to the building of the church and surrounding buildings, ordering the *custodies* of Chester to help with the building (Baggs *et al,* 1980). In 1245, the friars were also granted permission to take stone from the castle fosse (a large ditch surrounding the castle), and later breach the city walls to bring in more stone and timber to further increase the construction works. The friars increased their holdings, with a further extension to the buildings in 1360. Due to the generosity of the king, they were able to acquire permission to grind their own corn and produce malt. The popularity among the people of Chester led to many bequeathing the friary in their wills, although the values declined during the 15th century. By the early 16th century, the value and number of bequests were no longer sufficient to maintain the buildings of the friary. An agreement was made in 1528 with the merchants and sailors who helped build the church, granting them permission to use the naves and aisles for storage of their sails and tools in return for helping to repair the church (Bennet, 1921).

The friary in Chester formed one of the nine houses in the custody of Worcester, which listed 10 friars residing in the Chester house during the 14th century. It was a small house compared to others under Worcester, with the numbers decreasing further during the 15th century. The Grey Friars were less involved in local disorder than other religious houses in Chester, with only one instance noted in the literature involving a warden who was beaten in 1427, although the reason why is not clear.

On 15th August 1538, the house was surrendered to Richard Ingworth, Bishop of Dover by the warden, William Wall, in accordance with the Act for Dissolution of the Lesser Monasteries (1535). The friary housed seven friars at this time, with the sale of the furnishings within the friary not enough to cover the debts of the church. This led to Ingworth removing a chalice, mazer (a drinking vessel) and six spoons before handing the property over to the Mayor and informing him that they were not to receive any rents. The warden had prepared for the dissolution by renting portions of the precinct to the people of Chester. Unfortunately, Robert Ingworth thought that some of the leases were suspect, and it was later found that one dated to April 1538 had only been sealed three days prior the friary being handed over. The site was leased to Richard Hough initially, but changed hands several times over the year (Table 4.1). Not much is known about those that were buried at the friary, with the only known burial within the church being that of Robert Grovesnor of Hulme (Bennet, 1921).

Table 4.1. Owners of the Friary site following the Dissolution of the Monastery in 1538, until the Linen Merchants purchased the site in 1775.

Year	Owner
1538	Richard Hough
1540	Unknown
1544	John Cokkes
1588	Warburtons
1622	Stanleys, Earls of Derby
1775	Linen Merchants

By the early 17th century, the church had been converted to a house and in 1775; the land was bought by the Linen Merchants who further broke up the site. The western half of the site was sold off, and became the surrounding residential streets that still exist today. The eastern half of the site was used for the erection of the new Linen Hall. The remaining friary buildings were demolished at this point, with the antiquarian William Webb writing:

> "It was a great pitie that the steeple was put away, being a great ornament to the citie. This curious spire steeple might still have stood for grace to the citie had not private benefit, the devourer of antiquitie, pulled it down with the church, and erected a house which since hath been of little use, so that the citie lost so good an ornament, that tymes hereafter may talk of it, being the only seamark for direction over the bar of Chester".

(Hemingway, 1831 ,p.25)

The Chester Greyfriars (1778-1920), which spent time as a very popular cheese market following the economic downturn in linen trade, was succeeded by the construction of stables for Chester's racecourse. The stables were demolished in May 2009 and the site has been used as a carpark since. The construction works for the carpark involved the application of a tarmacadam surface, repairs to the existing boundary walls, the creation of two vehicular links to the St Martin's Way ramps, the replacement of the former stables access gates with bollards and the erection of signage. Figure 4.3 shows the plan of the site with the archaeological phases superimposed to show the expected location of the archaeological features.

As this site has previously not been studied, this gives the opportunity to add to the historical background of the city of Chester. This section of the thesis will concentrate on the findings from the skeletal remains and burial environment rather than the archaeology, which is being investigated in detail by L-P Archaeology.

4.2. Collection to date

Twenty articulated burials were recovered from Phase 2A of the Chester Greyfriars excavations (12 from trench 11 and 8 from trench 12). The author assisted in the excavation of the human skeletal remains and undertook the subsequent analysis. Permission was given for research into the preservation characteristics of the burials, along with standard osteological assessments. Radiocarbon dating and palaeodietary analysis was carried out on six individuals to determine the timespan of the cemetery in the areas excavated.

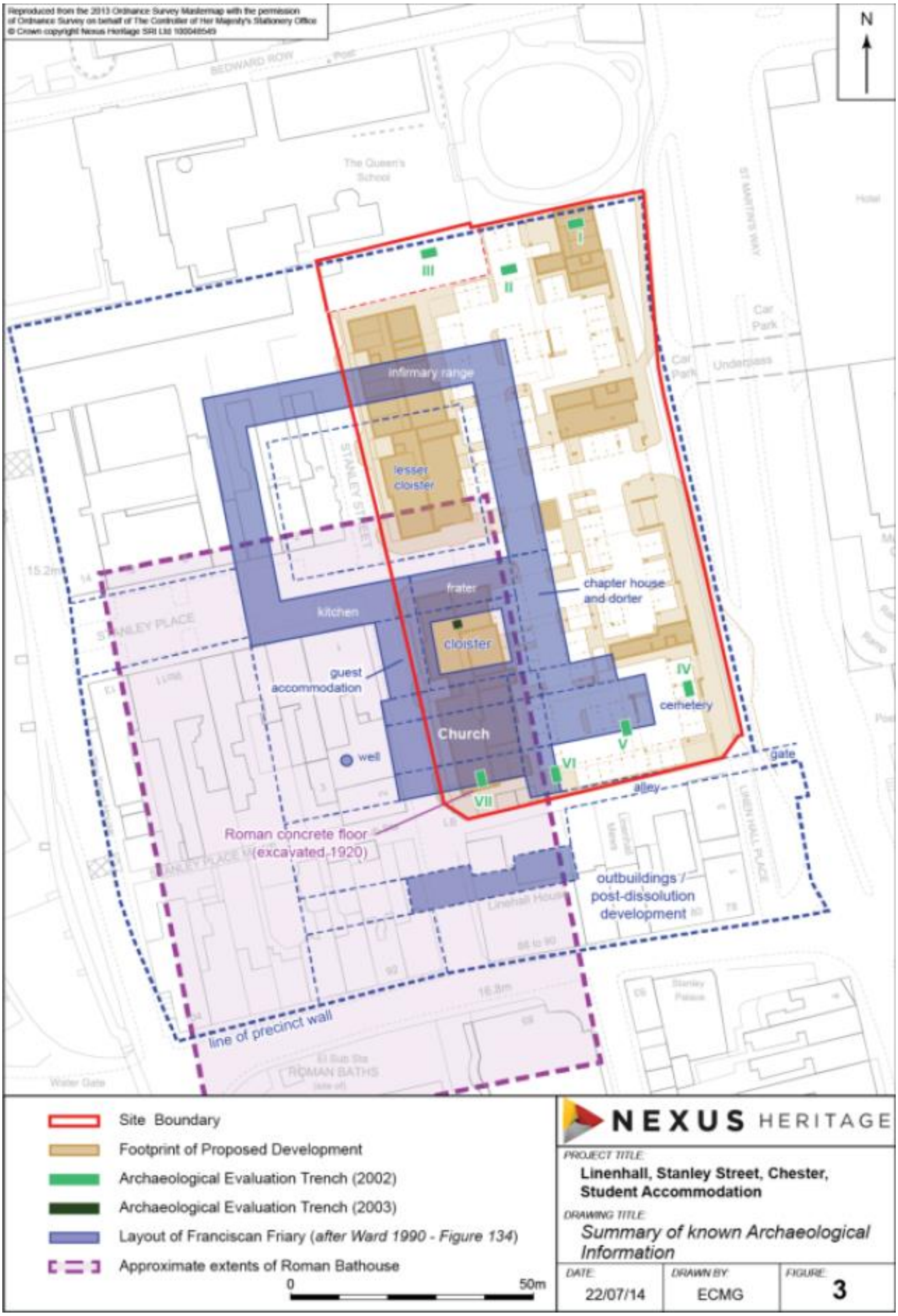

Figure 4.3. Site plan showing the archaeological history of the Chester Greyfriars site, produced by Nexus Heritage during the planning phase of the excavation. © Crown Copyright Nexus Heritage-SRI Licence No. 100048549.

The human skeletal remains were reburied in August 2017 following analysis, in accordance with the terms set out in the Ministry of Justice License (see Appendix A4) and the wishes of the Society of St Francis, who are the guardians of the remains. To enable work to continue on the remains following reburial, four of the skulls (SK 002, SK004, SK013 and SK019) from this collection have been digitally scanned by Maria Castańeyra Ruiz from Face Lab at Liverpool John Moores University, with the intention of carrying out facial reconstruction (Figure 4.4).

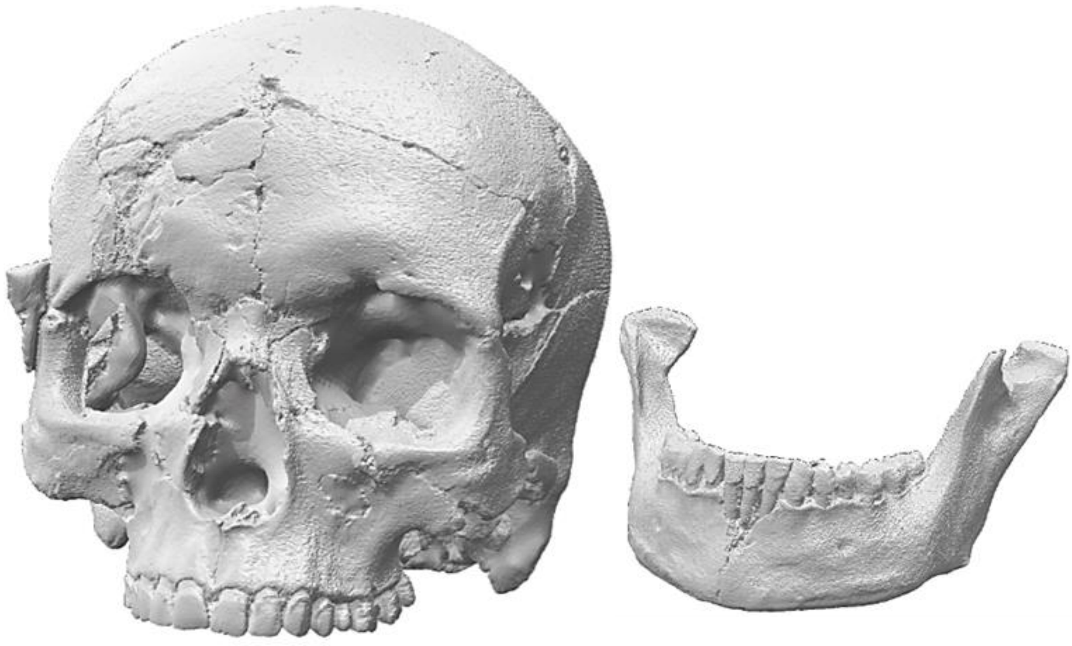

Figure 4.4. Digital scan taken of Skeleton 019 to allow further work to continue on the skeletal remains following reburial in August 2017. ©CAL Davenport and Maria Castańeyra Ruiz.

4.3. Excavation methods

Recovery was carried out following the guidelines as set out in the Guidance for Best Practice for Treatment of Human Remains Excavated from Christian Burial Grounds in England (Heritage England, 2005). Subsequent analysis and the production of the osteological report follows the guidelines as set out in Human Bones from Archaeological Sites: Guidelines for producing assessment documents and analytical reports (Heritage England, 2002).

Trenches 11 and 12 were excavated stratigraphically using small hand tools and brushes to preserve as much of the burial as possible. Sieving on site was not possible due to the wet conditions and clay component of the soil, therefore where it was possible that remains could be lost, the bone and surrounding substrate were lifted as a block and the soil removed in the laboratory. All large lumps of soil were broken up and checked for smaller bones and fragments to ensure maximum retrieval of the remains. Due to the section depths exceeding 1.2m, shoring boxes were used to prevent the section walls from collapsing. To enable the placement of the shoring boxes, all archaeological and skeletal material that lay within section walls had to be removed. The burials of skeletons 004 and 005 were two skeletons with trench 11 that lay within the walls of the trench and careful excavation of any skeletal material belonging to the skeletons that was carried out. Unfortunately, as skeleton 004 was being prepared for photography prior to lifting from trench 11, the section wall collapsed. Skeleton 004 was lifted once re-exposed and underwent full skeletal reconstruction in the laboratory to enable the maximum amount of information to be retrieved from this skeleton.

Excavation and cleaning challenges

Infant burial - Skeleton 007

Three of the burials produced challenges due to the adverse preservation environment in which they were interred. Skeleton 007 was a highly friable infant burial, which would have been lost during excavation if inexperienced staff and non-traditional methods were used (Figure 4.5). Once it was established that there was an articulated infant burial present and the boundaries of the burial identified, the decision was made to block-lift the entire infant encased within the soil. Any attempt at excavation on site would have resulted in loss of the remains due to the delicate nature of the bone. This was further complicated by the wet weather throughout the excavation. After ensuring that there were no further burials adjacent to the infant, a block was marked out, giving an extra 5-10cm boundary of soil. A tabletop excavation of the block was performed to allow spades to slide under the whole block and lift it onto a tray.

Figure 4.5. Skeleton 007 was an infant that required lifting as a block in the field, followed by controlled excavation in the laboratory. © CAL Davenport.

Following transport to the laboratory, the block was slowly air dried in a controlled environment before further investigation once the remains had stabilised. Careful excavation on the block, using small amounts of water helped to soften the soil, which had a clay component. Controlled wet sieving to limit the exposure to water followed this. It was not possible to use brushes, as this would have resulted in loss of information from the skeletal remains. Even with the control measures undertaken, less than 25% of this individual was retrieved. However, there were enough age markers to enable biological assessment.

Adult female – Skeleton 011

Skeleton 011 was the most complex burial to excavate due to the taphonomic factors affecting the preservation of this individual and the constraints of the surrounding archaeological features. The adult female individual was cut into a Roman foundation wall that provided a path for water to travel onto the burial. As the skeleton was overlying the natural clay, the water would then pool as it had nowhere to drain. This resulted in the trabecular bone turning black, and the outer cortical bone becoming very thin, soft and friable. It was noted that the bone that had not been continually exposed to water (cranium, distal humeri, proximal radii, proximal ulnae and the hand bones) was well preserved in comparison (Figure 4.6). After careful excavation and lifting, the skeleton was dried out in the laboratory to stabilise the remains prior to cleaning. Once the remains had stabilised, the majority of the skeleton could be washed using standard methods. Delicate fragments were wet-sieved to avoid any further damage and then air-dried in the laboratory.

Adult female – Skeleton 018

Skeleton 018 was particularly friable during excavation, both due to the damp soil environment and the reduced thickness of the cortical bone (Figure 4.7). Following air-drying in the laboratory, it friable nature of the bone suggested a mixed approach to cleaning would be required. Further damage to the skeletal remains was limited by using a combination of standard washing and wet sieving, which helped retain the information required for biological profiling. Following the cleaning of the articulated burials and disarticulated material, photography and recording of the condition of the skeletal remains was carried out prior to analysis and reconstruction.

Figure 4.6. Skeleton 011 is shown on the left prior to lifting. The position of skeleton 011 is shown in a working shot of trench 11 (right photograph – highlighted in white), with the Roman wall foundation highlighted in yellow. © LP Archaeology and CAL Davenport.

Figure 4.7. Skeleton 018 was a poorly preserved flexed burial, which required a combination of traditional cleaning methods (water and brushes) and controlled wet sieving in the laboratory to retain the biological profiling information. ©CAL Davenport.

4.4. Excavation plans

The plans for the trenches excavated at the Chester Greyfriars site are given here as separate entities rather than as part of the full site plans that LP Archaeology will produce for the formal report. The trenches were located on the south side of the Chester Greyfriars site approximately two metres apart.

Trench 11: Ten articulated, and two disturbed burials in varying states of preservation, were recovered from trench 11 (Figure 4.8). Any bone lying within the walls was removed to prevent any damage when the shoring boxes were placed in the section. Trench 11 shows three wall boundaries; the outer wall shows the section boundary, the middle line is the original section boundary, prior to expanding for the shoring box and the inner wall is the limit of the shoring box within the trench.

Trench 12: Eight adult articulated burials were recovered from trench 12 (Figure 4.9). Five burials were situated on the North side of the trench, in four layers. On the South side of the trench, there were three intercutting burials representing three separate burial phases.

4.5. Archaeological phasing of the site

During the excavation, burial layers were estimated based on the order in which they were placed within the grave, and any truncation that had occurred between the burials. This enables further analysis of the burial practises that occurred during the lifespan of the cemetery, the arm positions of the earliest layer of burials in trench 11 being one such example. Although trench 12 does not show this same pattern, the presence of shroud, coffin and flexed burials show different burial practices throughout the layers. Where

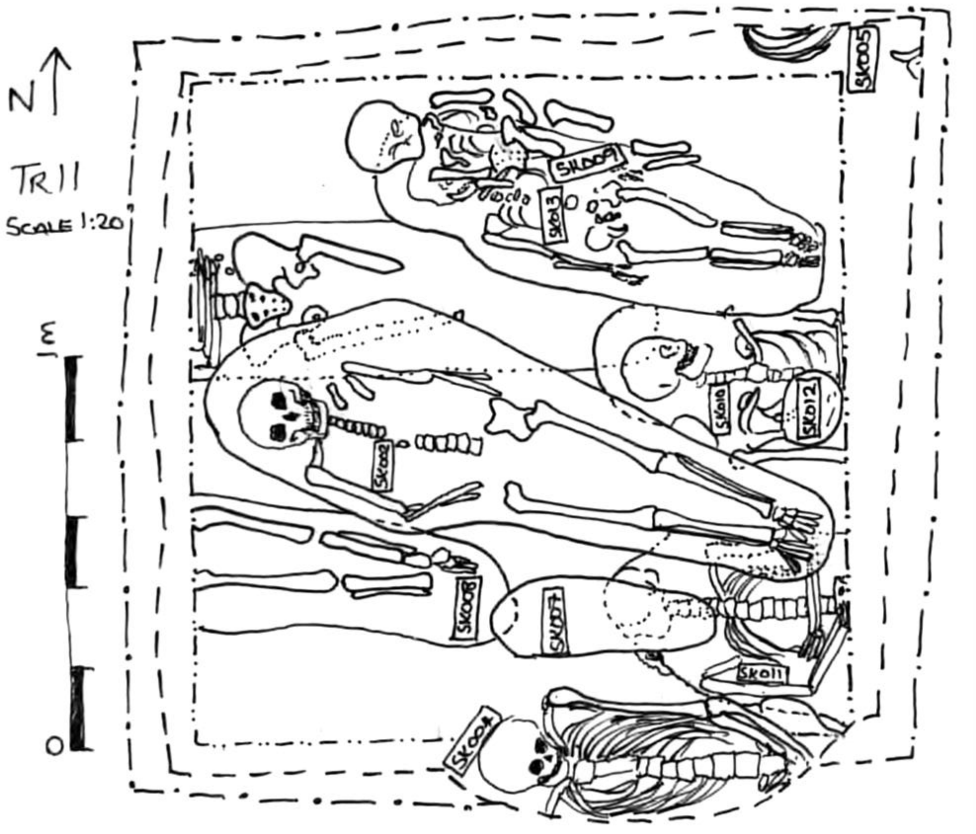

Figure 4.8. Full plan of trench 11 demonstrating the relationship between the burials recovered. The disturbed burial of SK001 is not shown on this plan. ©CAL Davenport.

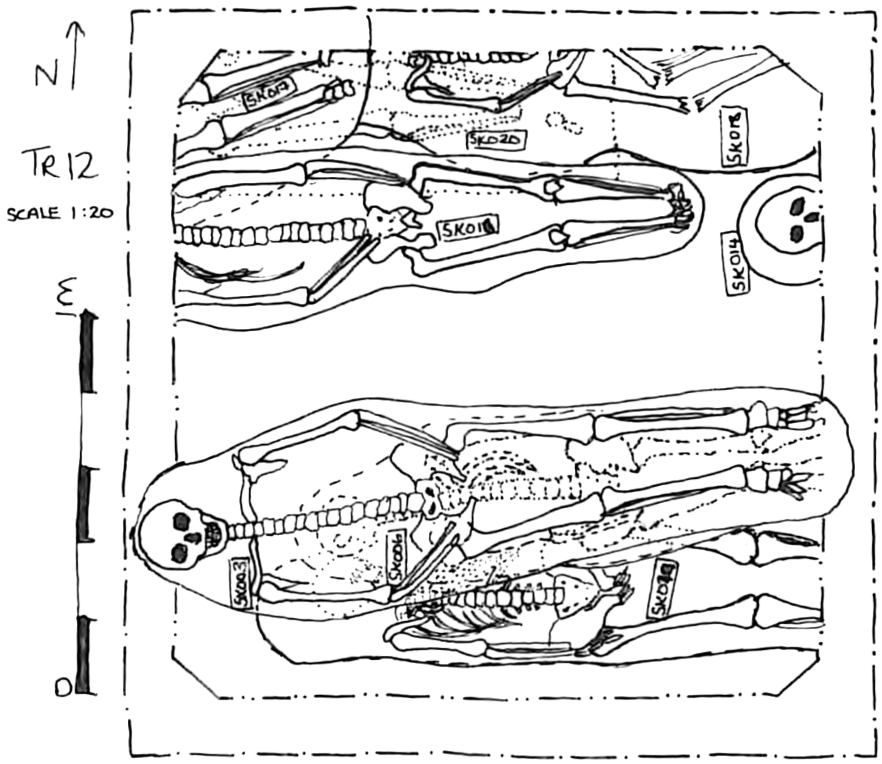

Figure 4.9. Full plan of trench 12 demonstrating the relationship between all the burials recovered. ©CAL Davenport.

possible, samples were taken for radiocarbon dating to determine the overall timespan for this section of the cemetery and to confirm the phases assigned to the skeletons. The plans shown in this section were the archaeological interpretation of the likely phases prior to radiocarbon dating. The suggested phasing of the burials following the excavation phase are shown in figures 4.10-4.12 for trench 11 and 4.13-4.16 for trench 12. The plans for trench 11 show only the inner walls of the shoring box, which was used to prevent any further section wall collapses, whereas trench 12 shows both the inner and outer walls of the shoring box. The phasing following radiocarbon dating is given in subchapter 4.13.

Trench 11

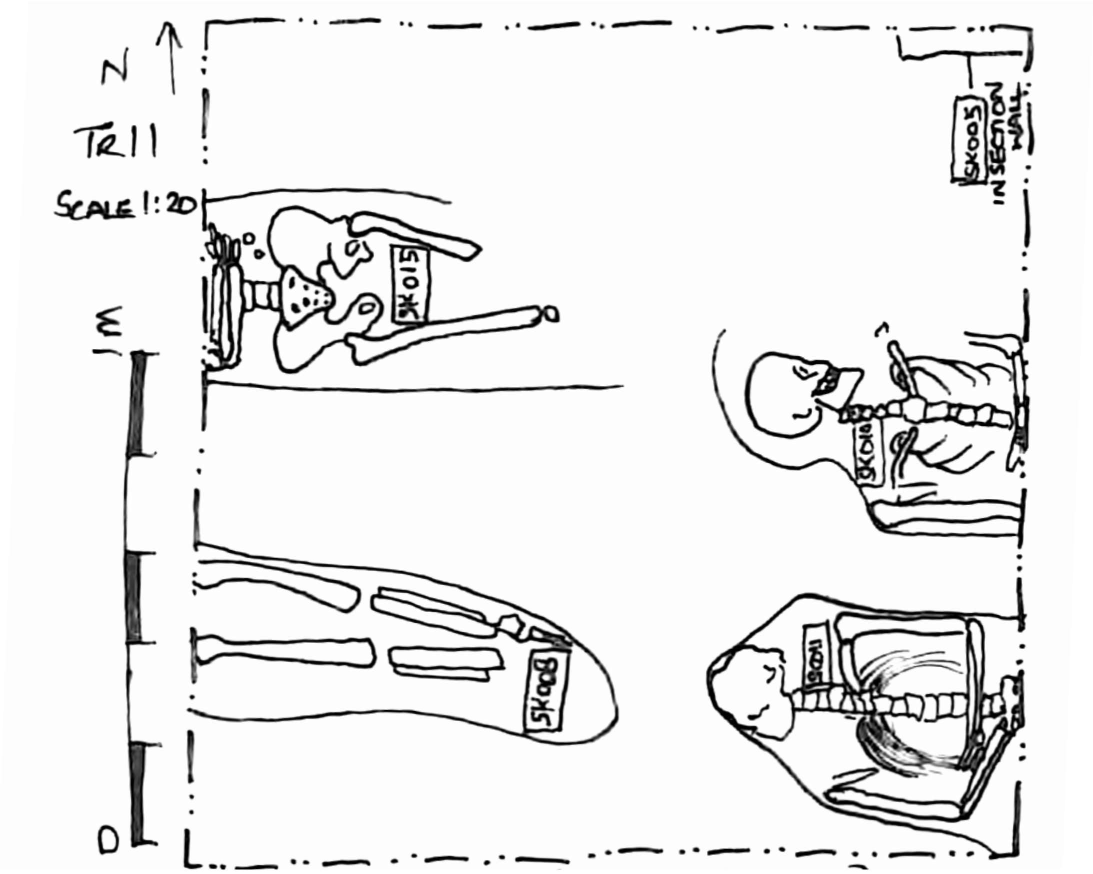

Figure 4.10. Trench 11: Phase I (early burials). SK005 is in the north section wall but highlighted due to its alignment of the ribs and pelvis with SK010 and SK011. All burials at this level share the same arm position. ©CAL Davenport.

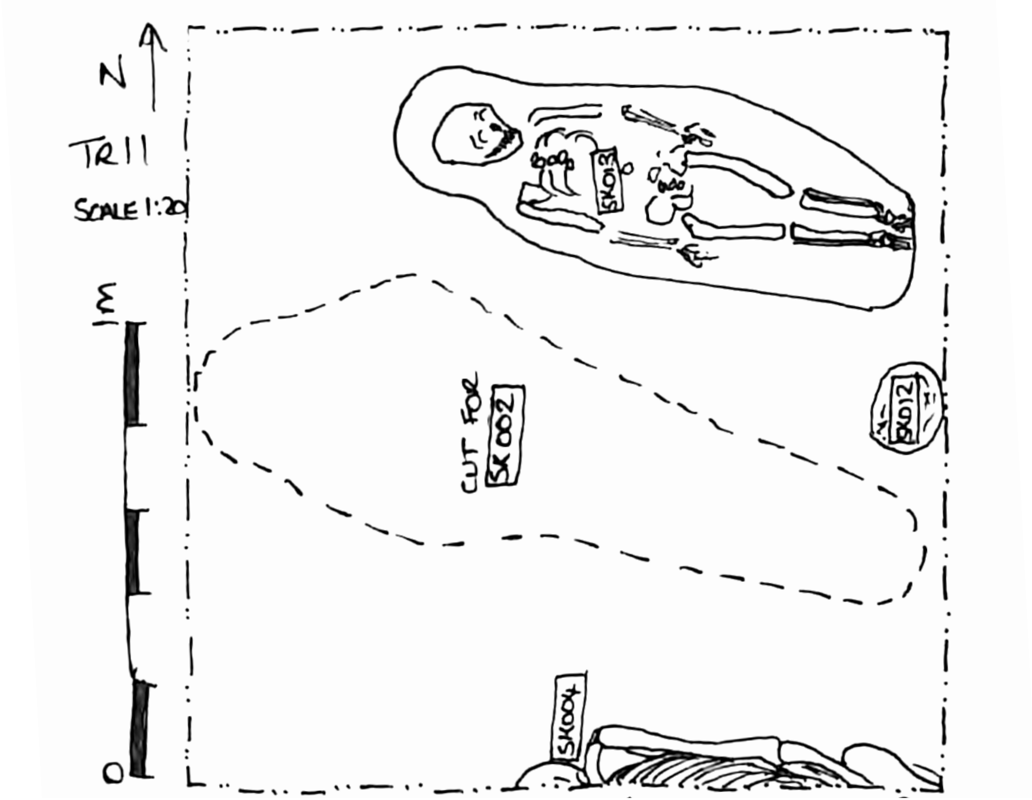

Figure 4.11. Trench 11: Phase II (middle layer of burials). As SK001 was disturbed in full by the burial of SK002, the grave cut identified for SK002 is highlighted to represent approximate likely position of SK001. ©CAL Davenport.

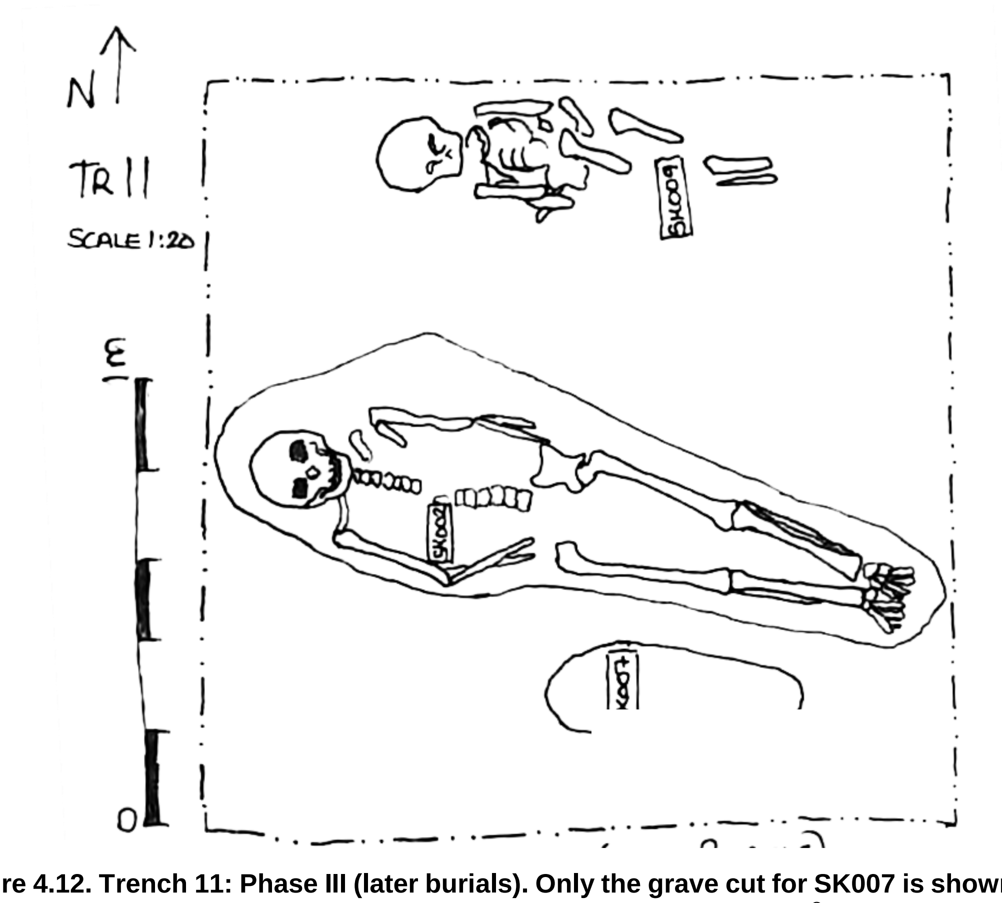

Figure 4.12. Trench 11: Phase III (later burials). Only the grave cut for SK007 is shown due the poor preservation of this individual and the need to lift it as a block. ©CAL Davenport.

Trench 12

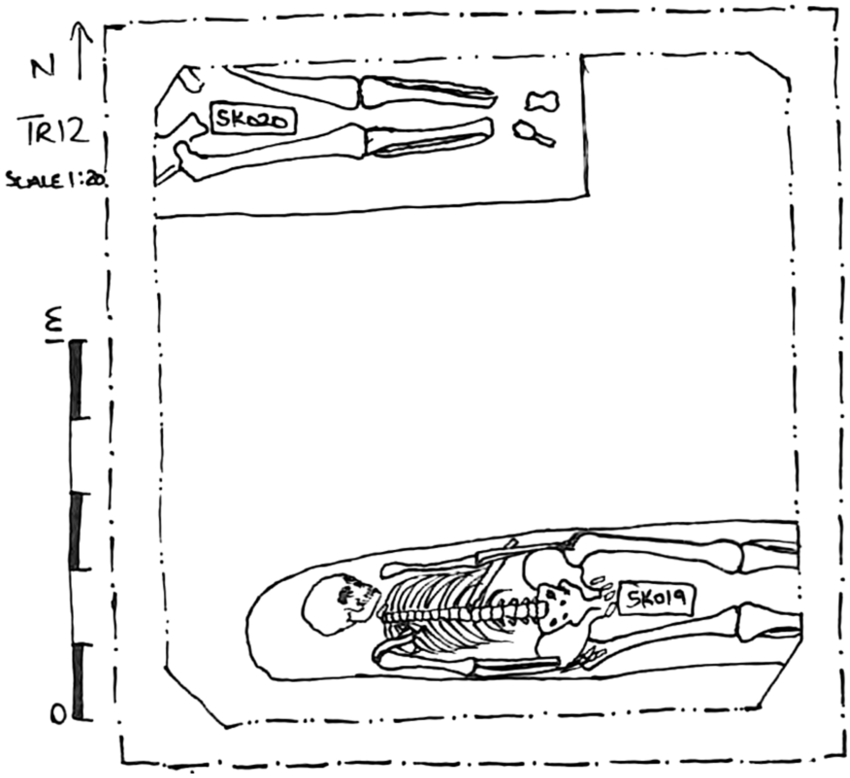

Figure 4.13. Trench 12: Phase I (early burials). SK020 is likely a coffin burial due to the presence of coffin nails recovered from within and around the burial. The burials do not share the same arm position as the early burials in trench 11, which suggests a difference in the dates of burial. ©CAL Davenport.

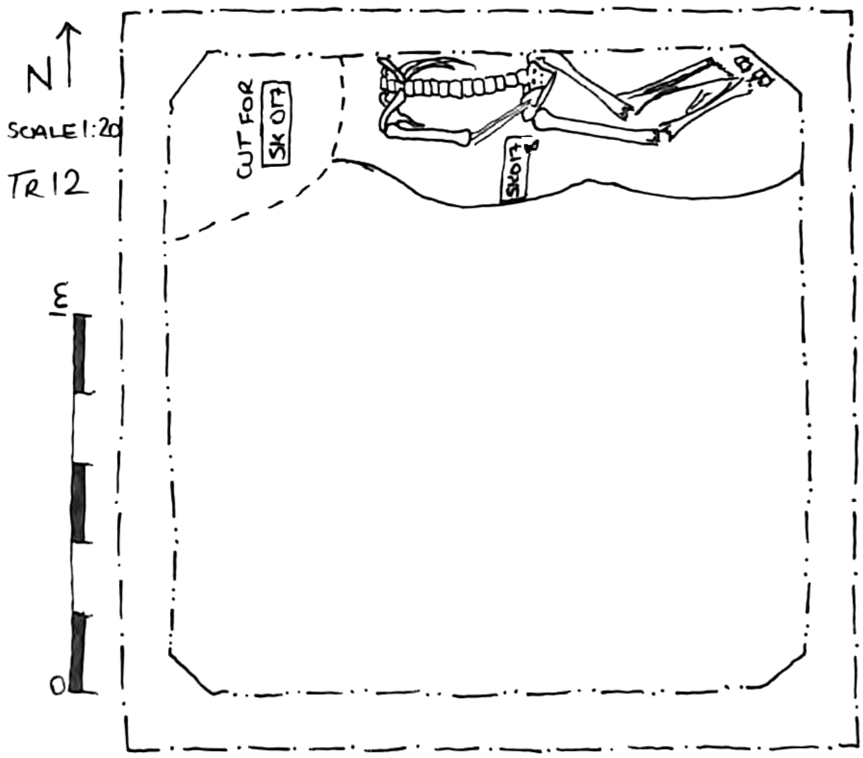

Figure 4.14. Trench 12: Phase II (mid-layer burials). SK018 was an adult flexed burial truncated by SK017. The mandible and skull were recovered during the excavation of SK017. ©CAL Davenport.

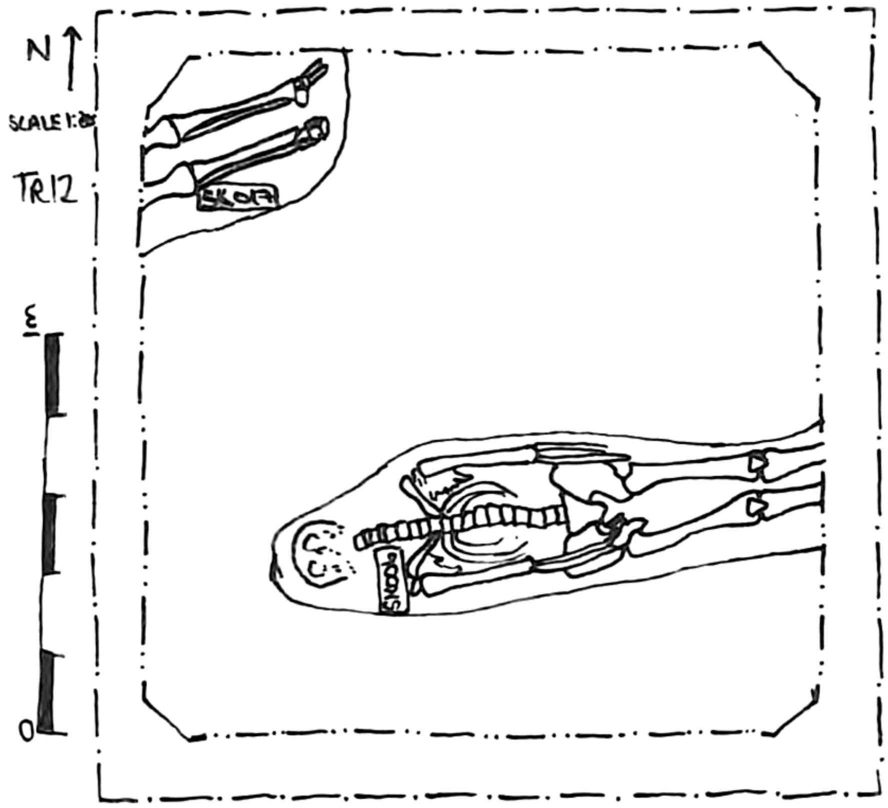

Figure 4.15. Trench 12: Phase III (mid-layer burials). SK006 was directly below SK003, with the missing mandible recovered from above SK003. ©CAL Davenport.

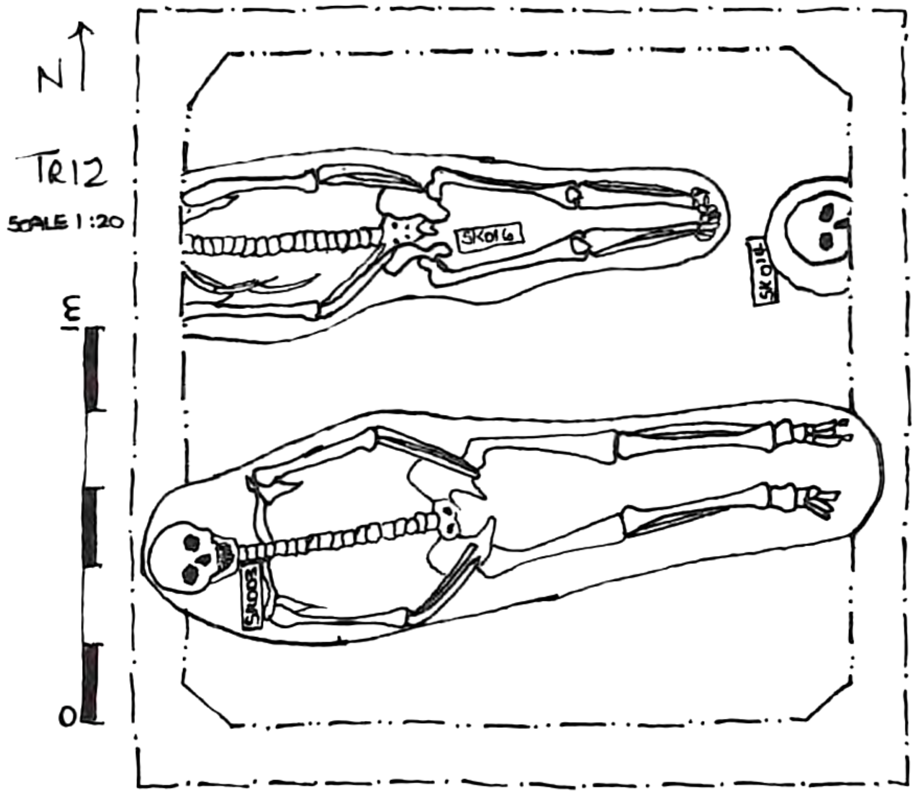

Figure 4.16. Trench 12: Phase IV (later burials). SK003 was excavated prior to the shoring box being placed in the trench, hence its extension past the box walls. ©CAL Davenport.

4.6. Curation and storage

Following excavation, the analysis of the human skeletal material took place at the specialist Forensic Anthropology Laboratories at Liverpool John Moores University, where the material was on temporary loan to the author for osteological analysis and private research. The storage was in a secure laboratory with limited access. Photography of each skeleton in anatomical layout was carried out, along with the recording of any identified pathologies and taphonomic influence. Thirteen skulls were reconstructed to enable measurements to be taken for craniometric analysis (chapter 4.11) and four were laser-scanned to digitally archive the crania for future work (including facial reconstruction). The digital archive will also enable community outreach, museum exhibitions and teaching to be carried out using digital 3D images and prints of the material. The skeletal remains excavated from Chester Greyfriars are scheduled for reburial in August 2017.

4.7. Geoarchaeology

The Chester Greyfriars site is located between Stanley Street and Nicholas Street in Chester (SJ 40217 66297) and is currently in use as a car park with a tarmacadam surface. The site covers an area of 7,737m^2, with 387m^2 at the north end of the site to be gifted to Queen's School. The rest of the site was to be used for development, with a £33 million student accommodation complex proposed at the time of writing.

The British Geological Survey lists the bedrock geology as solid strata comprising 'Chester Pebble Beds Formation' of the Sherwood Sandstone Group. The Cheshire Pebble Beds formation is a Triassic period sedimentary bedrock, which forms in environments dominated by rivers, leading to its stratified appearance and inclusion of pebbles and gravel. The superficial geological layers consist of Devensian diamicton till, a poorly sorted deposit comprising of material eroded from the land containing particles ranging in size from clay to boulders and suspended in a matrix of sand or mud. This deposit formed approximately two million years ago during a glacial period. The borehole records held by the British Geological Survey from two nearby sites are shown in Table 4.2, with the locations of the boreholes shown in figure 4.17.

The stratigraphic layers identified during excavation by LP Archaeology will be discussed in detail in the archaeological report once published. Soil samples were taken of each stratigraphic layer in accordance with the Statement of Compliance and Research Design (Garner, 2015). Working shots were taken during the excavation which show the stratigraphic layers deposited above the burials, prior to the placement of the shoring boxes (Figures 4.18 and 4.19). The photographs were taken at a 1.4 metre depth, with the burial layers emerging at this point.

Table 4.2. British Geological Survey stratigraphic descriptions and depths obtained from the boreholes at Crook Street, Chester (SJ 4037 6631) in 1973 and the well at Chester Racecourse (SJ 4001 6605) in 1977.

Site	Description of strata	Thickness (m)	Depth (m)
Crook Street, Chester	Made Ground – Soil, ashes, bricks, wood, metal and sandstone	3.00	3.00
	Red/brown fine to medium grained highly weathered sandstone	0.50	3.50
Chester Racecourse well	Alluvium – soil and hard river silt	5.78	5.78
	Marine alluvium – sea sand	11.73	17.51
	Drift – Sand and gravel, boulder clay with stones	3.50	20.01
	Lower mottled sandstone – sandstone and sandstone rock	71.31	92.32

Figure 4.17. Location of the Chester Greyfriars site (white square) in relation to the boreholes taken at Crook Street (green dot) and Chester Racecourse (yellow dot). Image courtesy of Google Maps.

Although the trenches were only 2 metres apart, trench one seemed to cut through the walls of the Chester Greyfriars, with some features still in place upon excavation. In contrast, although demolition material was present, trench 12 contained fewer brickwork features, but a cobbled pathway instead, suggesting this trench lay outside the walls of the Chester Greyfriars.

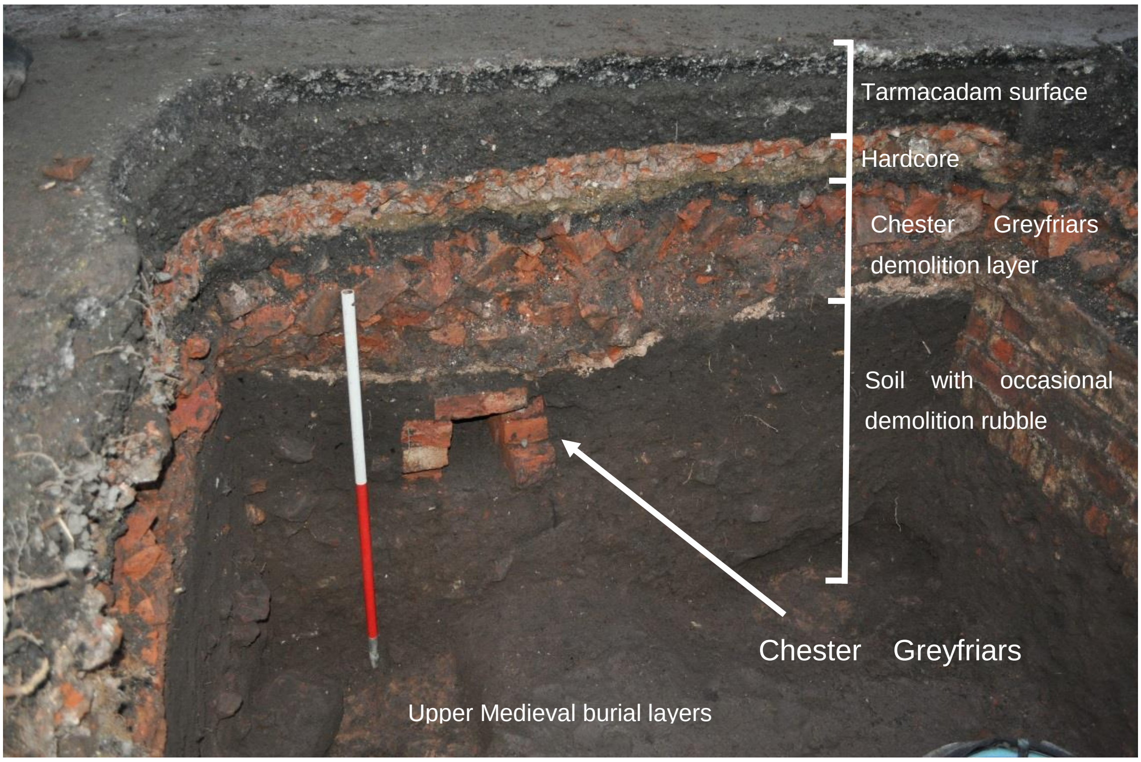

Figure 4.18. Stratigraphic layers evident during the excavation of trench 11, shown here is the north-facing wall of the trench. Scale is 1m. ©LP Archaeology and CAL Davenport.

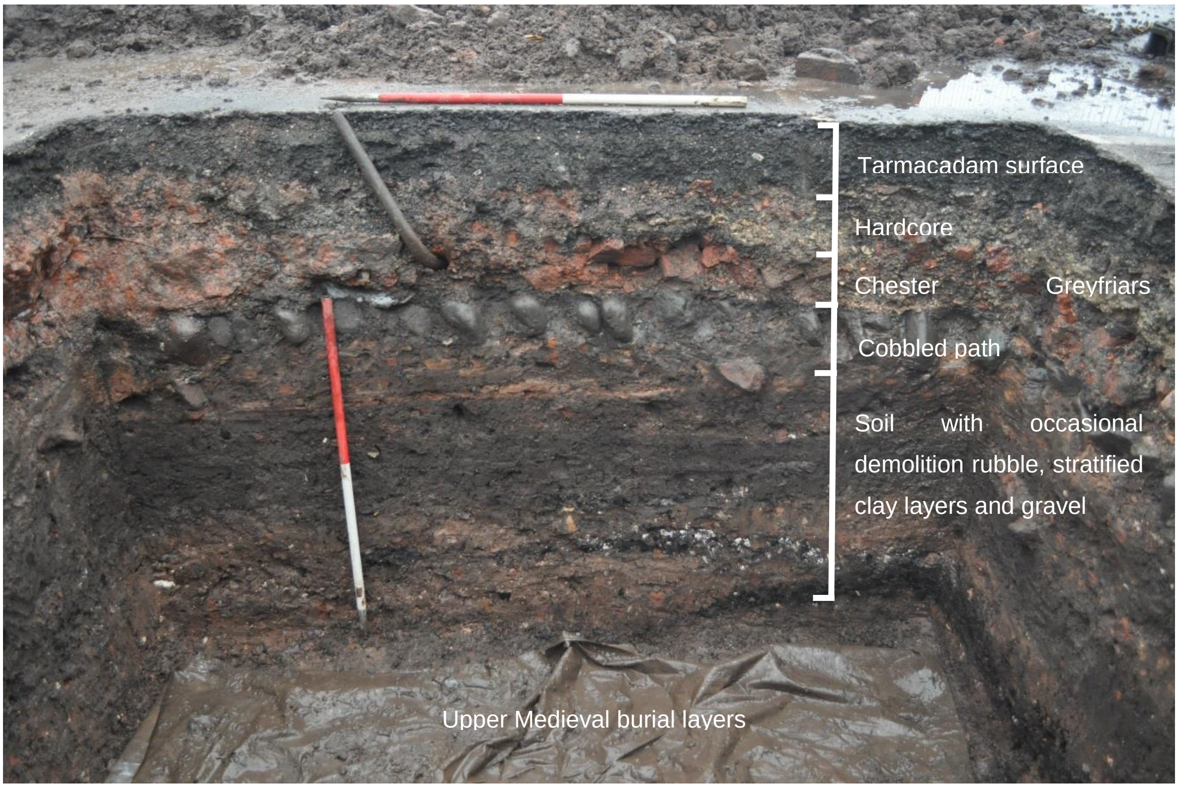

Figure 4.19. Stratigraphic layers evident during the excavation of trench 12, shown here is the north-facing wall of the trench. Scale is 1m. ©LP Archaeology and CAL Davenport.

4.8. Soil analysis

Seven of the graves provided soil samples (n=11), which were collected following the lifting of the skeletal material from locations that had been in contact with the bone, to allow a direct assessment between the soil and skeleton (Table 4.3). Soil samples were not collected from all burials due to the time constraints placed on the excavation.

Table 4.3. The number of soil samples collected from the cemetery of Chester Greyfriars and associated skeleton numbers.

Skeleton Number	Trench	Number of samples
003	12	2
010	11	1
011	11	1
013	11	3
015	11	1
016	12	2
020	12	1

Soil colour determination

The dry soil samples collected from trench 11 varied by skeleton and ranged from brown (10YR 4/3) to dark greyish brown (10YR 4/2), whereas those from trench 12 were identified as 10YR 5/3 or brown. The variability in the dry soil samples from trench 11 are most likely due to the archaeology present at the site resulting in a range of burial environments present and contamination from foreign soils brought in for construction at the site since the Roman period. The damp soil samples for both trenches all identified as dark brown (7.5YR 3/2 or 7.5YR 3/3), with the exception of the soil sample taken from under the feet of SK003 which identified as a very dark brown (7.5YR 2.5/2). This could be due to the stacked burials of SK003 and SK006 being coffin internments, with the combination of burial leachate and coffin wood resulting in a darker stain in the surrounding soil. A relationship was identified with the damp chroma and samples taken from trench 11, with the chroma becoming weaker as the skeleton number increases. The higher numbered burials in trench 11 were those that had been interred earliest, at the lowest depths and in contact with burial substrate containing higher levels of light coloured clay.

pH determination

The pH ranged from 5.0 to 5.5, with lower pH values more commonly found in trench 12 ($r_{s(11)}$ = -0.624, p=0.040). The pH was consistent in trench 11, with only one sample differing from determination of 5.3 given for all other samples. The sample taken from by the feet of skeleton 013 had a pH of 5.5, most likely due to this area of the skeleton not overlying the clay, which all other skeleton sample points lay on. There were no significant differences between the pH levels identified for trench 11 overall, or between the individual samples (p>0.05).

The burials in trench 12 had a consistent pH of 5.0, with the exception of the soil sample taken by the feet of skeleton 016 (pH – 5.5). All other soil samples were taken from individuals that had been placed in a coffin or areas close to a coffin burial. Skeleton 016 was a shrouded burial, with a non-shrouded burial (Skeleton 018) next to the legs/feet of skeleton 016. There were no significant relationships or differences between the pH levels identified for trench 12 overall, or between the individual samples (p>0.05).

Magnetic susceptibility

The frequency dependent magnetic susceptibility readings did not show any difference or relationships when assessed overall, within or between trenches (combination of Mann Whitney, Kruskal Wallis and Spearmans rank correlations; p>0.05). On closer inspection of the data, it was noted that one sample collected from the cranial region of skeleton 013, gave very high values which could indicate increased contamination to the soils in this area. The burial of skeleton 009 was situated above skeleton 013, which had in turn been disturbed by later construction. During the excavation of the upper layers of this trench, a brick feature was uncovered that ran from beyond the north wall through to the south wall, continuing beyond the section boundaries (Figure 4.20). The location of this feature places it directly above the cranium of skeleton 013, most likely contributing to the increased frequency dependent magnetic susceptibility readings due to the continual human disturbance in this area of the trench.

Figure 4.20. Working shot of trench 11 during the earlier phases of excavation, showing a brick feature from the later Chester Greyfriars construction phase. The feature was capped by an additional layer of bricks, which had been removed for this photograph. ©LP Archaeology.

Field portable x-ray fluorescence on soil

Field portable x-ray fluorescence was carried out on the soil samples to determine the distribution of the main elements associated with decomposition, calcium (Ca), iron (Fe), potassium (K), phosphorous (P) and magnesium (Mg). Calcium and phosphorous were not detected in any of the Chester Greyfriars soil samples collected, either due to them not remaining in the soil samples analysed or being present in quantities too small to be detected by the forensic setting developed on the XRF analyser. To confirm this, the readings were also carried out using the mineral setting for calcium, and light elements setting for phosphorous.

There were differences noted in the levels of iron, potassium and magnesium when assessing the samples individually confirming the variation in the burial environment for each skeleton. Fluctuations in magnesium levels indicate areas with increased archaeological activity, with the increased iron levels consistently seen with coffin burials. Potassium concentrations can indicate areas of surface burning, or the deposition of ashes from a fireplace or stove (Custer *et al*, 1986).

Particle size analysis

The particle size analysis for trench 11, showed that as the levels of clay increased, silt levels also increased ($r_{(6)}$=0.958, p=0.003), with this relationship becoming much stronger than that for the comparisons between all samples. When the levels of both clay and silt increased, the amount of sand decreased (clay vs sand $r_{(6)}$= -0.969, p=0.001; silt vs sand $r_{(6)}$= -0.999, p<0.001), which was seen in the lower burial layers as the clay levels seemed relatively undisturbed by contamination from foreign material. Differences were identified in the particle size quantities for clay ($t_{(5)}$=12.378, p<0.001), (silt $t_{(5)}$=11.248, p<0.001) and sand ($t_{(5)}$=4.075, p=0.010), which supports the correlations identified for this trench. The soil particle size analysis is shown in an overlay plot (Figure 4.21). The particle size analysis for trench 12 showed no relationships in the levels of clay, silt and sand (p>0.05), indicating that the variability in the soils present were either too similar to produce correlations, or too different for the identification of a significant relationship. As differences were identified between the levels of clay ($t_{(4)}$=7.831, p=0.001), silt ($t_{(4)}$=15.243, p<0.001) and sand (one sample Wilcoxon signed rank test: p=0.043) when assessing the individual samples, it suggests that the variability was too great to produce any meaningful relationship between the variables. The soil particle size analysis is shown in an overlay plot (Figure 4.22).

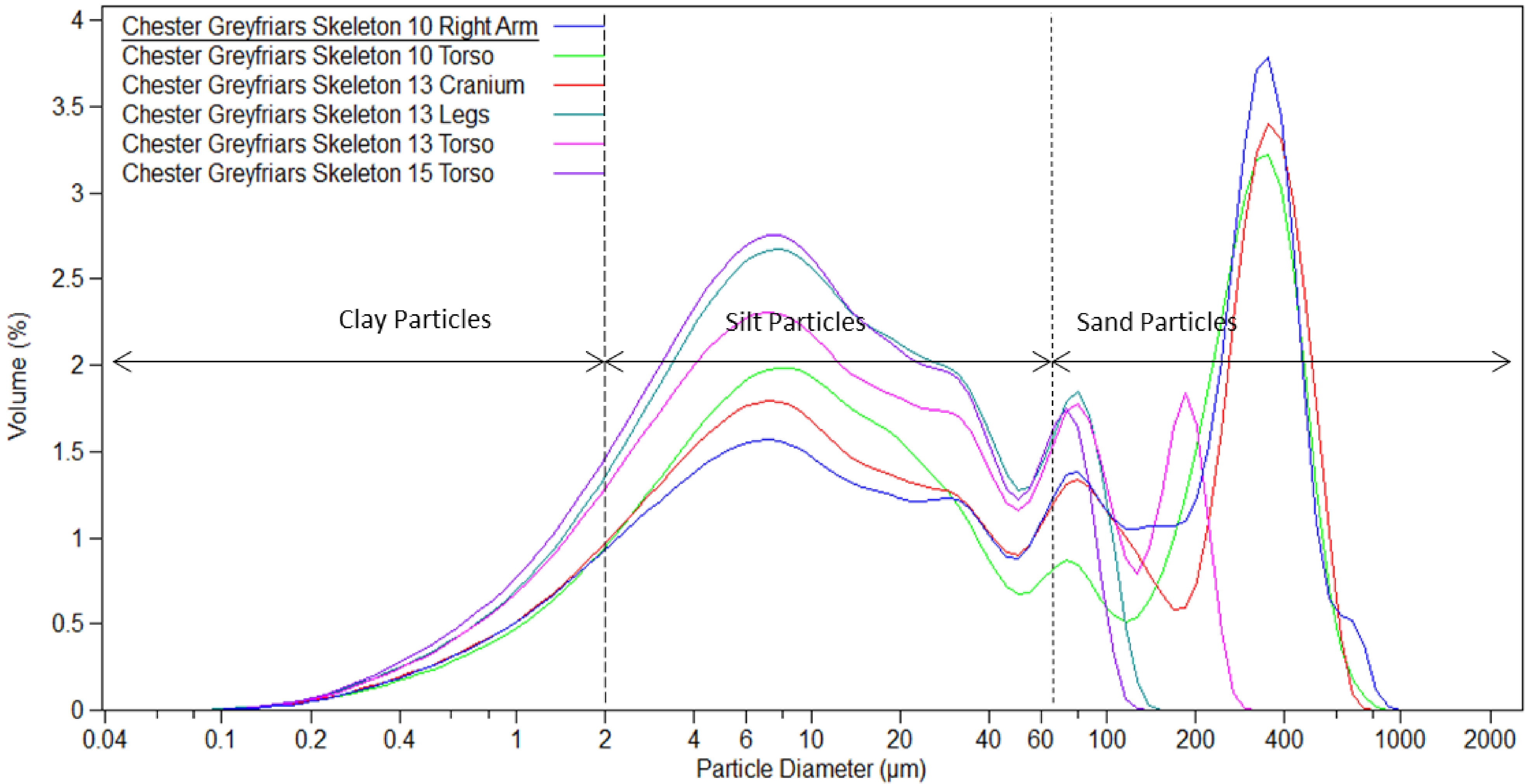

Figure 4.21. Soil particle analysis overlay plot for the six samples collected from three skeletons in trench 11. ©CAL Davenport

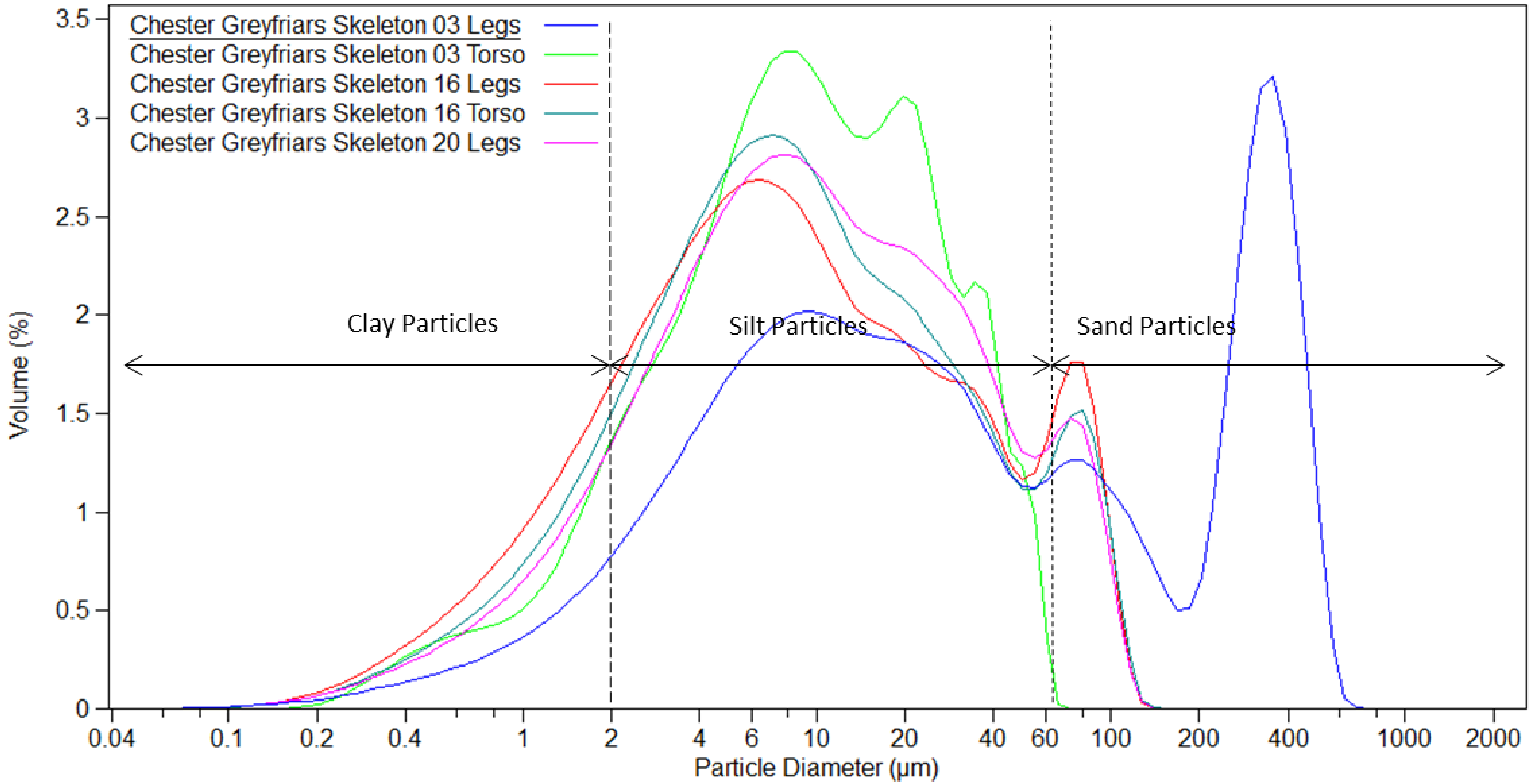

Figure 4.22. Soil particle analysis overlay plot for the five samples collected from three skeletons in trench 12. ©CAL Davenport

4.9. Archaeothanatology

The cemetery sections investigated were relatively undisturbed by later construction, which offered the potential to study the archaeothanatology of the burials. The articulated burials from Chester Greyfriars were assessed to identify arm position, burial type, practice and orientation. Of the 20 burials recovered from this phase of excavation, 15 allowed an assessment of the arm position (Table 4.4) with the remaining 25% being burials truncated by the section boundaries or disturbed burials.

Table 4.4. Arm position codes assigned to the Chester Greyfriars burials giving overall percentage, along with sample breakdowns for each individual arm position.

Arm Position Code	*n*	%	Sample breakdown by arm position (%) Male	Female	Non-adult
1	3	15.0	-	33.3	66.7
2	3	15.0	100.0	-	-
3	5	25.0	20.0	60.0	20.0
4	-	-	-	-	-
5	-	-	-	-	-
6	4	20.0	25.0	75.0	-
7	-	-	-	-	-
8	-	-	-	-	-
9	5	25.0	40.0	20.0	40.0
Total	**20**	**100.0**	-	-	-

Analysis showed that non-adults tended to have the arms by the sides, with only one exhibiting a different arm position (skeleton 008 displayed arms folded over lumbar). Whereas adults were more commonly found with arms folded across the lumbar region or in arm position six (one hand over pelvis, one at the side), with only one female having her arms placed by her sides. This relationship was not statistically significant when looking at the arm position within each trench, but was for the samples overall ($r_{s(14)}$=0.625, p=0.017). A large number of the adult skeletons were interred with one hand over pelvis, one at the side, a position most often seen in coffin burials. However, this could be due to the empty space present within the coffin allowing for movement of the body during decomposition.

All of the undisturbed burials assessed (*n* = 18) were orientation East-West, typical of Christian interments. The two remaining individuals had been disturbed by later burials, but it was clear that care had been taken to place the remains carefully back in the grave. This suggests that there could have been family plots present at the site and the gravediggers expected to discover previous burials.

Burial practice was identified for 16 of the skeletons using position of the skeletal elements, presence of coffin nails, the burial cut and the preservation of the skeletal remains. Half of the individuals were identified as shrouded (n=8), with the remaining eight indicating internment within a coffin (Figure 4.23).

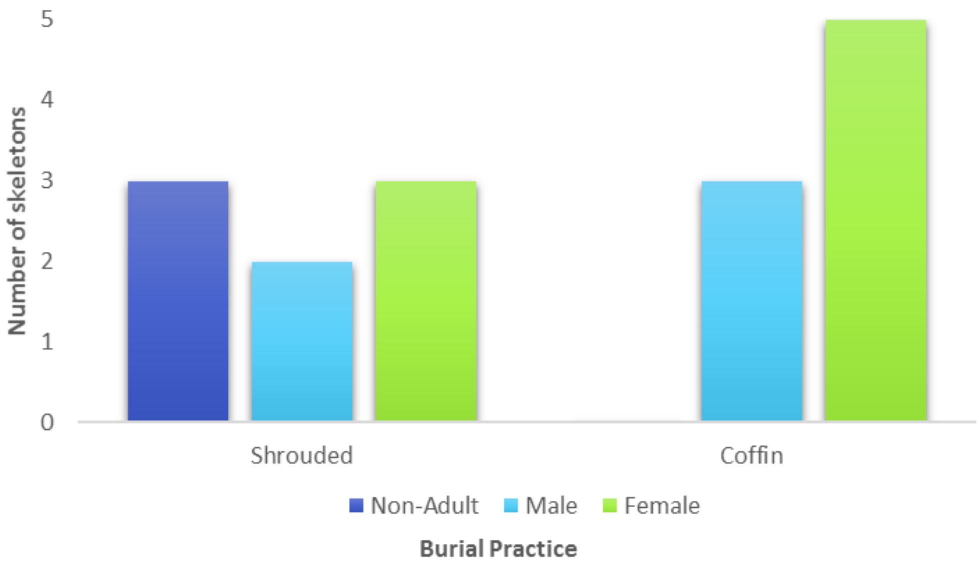

Figure 4.23. Frequency distribution of the non-adult (n=3), male (n=5) and female (n=8) skeletons exhibiting the different burial practices at Chester Greyfriars.

Aside from the archaeothanatological evidence, the skeletons from Chester Greyfriars also exhibited flaking of the cortical surface of the bones (Figure 4.24), which occurs due to periodic wet and dry periods the skeleton undergoes whilst in a coffin. The outer cortical bone surface will be subjected to wet conditions prior to the inner, deeper layers of cortical bone; conversely, the surface will dry before the inner layers too. The bone expands and contracts, causing flaking of the surface along the natural lines of cleavage provided by the lamellar bone (Berryman *et al*, 1996).

Figure 4.24. Posterior view of the right proximal tibia exhibiting the characteristic flaking of the cortical surface see in coffin burials. ©CAL Davenport.

Further skeletal evidence of coffin internment was provided by the differential preservation of the skeleton, causing excessive erosion to the areas of the body, which would be exposed to the elements first during decomposition. This excessive erosion also helps give information regarding the placement of the skeleton during interment, as those elements in the base of the coffin or casket will be subjected to any moisture (from water or decomposition fluids) that collect at the bottom. Erosion was especially evident on skeleton 016, exhibited on the spinous processes of the vertebrae, scapulae, innominates and many of the joints. A number of skeletons displayed a decomposition pattern consistent with the soft tissue decomposition process seen in natural decomposition, rather than an individual that has undergone embalming.

In natural burials, the torso decomposes at a faster rate than the appendages due to the high amount of anaerobic activity taking place in this region from microbes present in the human digestive tracts. As the soft tissue breaks down, it not only exposes the skeleton to the elements, but for those in contact with the base of the coffin, the decomposition fluids will increase the rate of decay. Skeleton 003 (Figure 4.25) presented as a natural coffin burial due to the differential preservation of the torso and appendages. The soft decomposition patterns repeats itself with the skeleton: the ribs did not survive; only half of the vertebral bodies remain; and areas of the pelvis and sacrum are heavily eroded. The right scapula and clavicle were also subjected to heavy erosion (Figure 4.26), with only the coracoid process and partial glenoid fossa surviving from the left shoulder girdle. By comparison, the long bones exhibit flaking of the cortical surface expected of coffin burial, with a small amount of erosion to joint surfaces, however, the morphology of the bone is intact.

Figure 4.25. Skeleton 003 was a burial showing differential decomposition due to interment in a coffin. ©LP Archaeology and CAL Davenport.

Figure 4.26. The right clavicle and scapula of Skeleton 003 showing excessive erosion of the bone due to a coffin interment. ©CAL Davenport.

There was a significant positive relationship for location ($r_{s(16)}$=0.630, p=0.009), with a higher number of coffin burials present in trench 12 than in trench 11 ($\chi^2_{(1)}$=6.349, p=0.012). A relationship with age was identified when looking at the overall cemetery sample, with all non-adults identified as shrouded burials ($r_{s(16)}$=0.577, p=0.031).There was no relationship identified between burial practice and sex for the adult burials. Frequency dependent magnetic susceptibility increased in coffin burials ($r_{s(7)}$= -0.866, p=0.012), which would be expected due to the disturbance to the soil matrix and breakdown of compounds from the corpse, coffin and any burial finds. When assessing the burials in each trench separately, trench 11 showed a relationship between age category and burial practice ($r_{s(9)}$=0.747, p=0.021), however this relationship was not present for in trench 12, most likely due to the lack of non-adult burials present.

The burial types identified during the excavation of the Chester Greyfriars skeletons were primarily supine, with only one flexed burial in trench 12 deviating from this (Skeleton 018). There were two disturbed burials present in trench 11, which appeared to have been moved during later burials and then placed back in carefully as many of the elements were present. It is likely that both 001 and 012 were fully skeletonised during this process, as no articulations remained, suggesting that a degree of care was used during the removal and subsequent secondary burial. Skeleton 009 had been disturbed during the later construction of the Chester Greyfriars resulting in the movement of skeletal elements, but with little damage to those moved, suggesting a respect for the dead when working on the site during the 18th century.

4.10. Cemetery sample analysis

The excavation produced 18 articulated and two disturbed human burials in total: seven adults and five non-adults from trench 11 and eight adults from trench 12 (Figure 4.27). The small amount of disarticulated material recovered indicated that the majority of this material came from the post-depositional disturbance of the burials present.

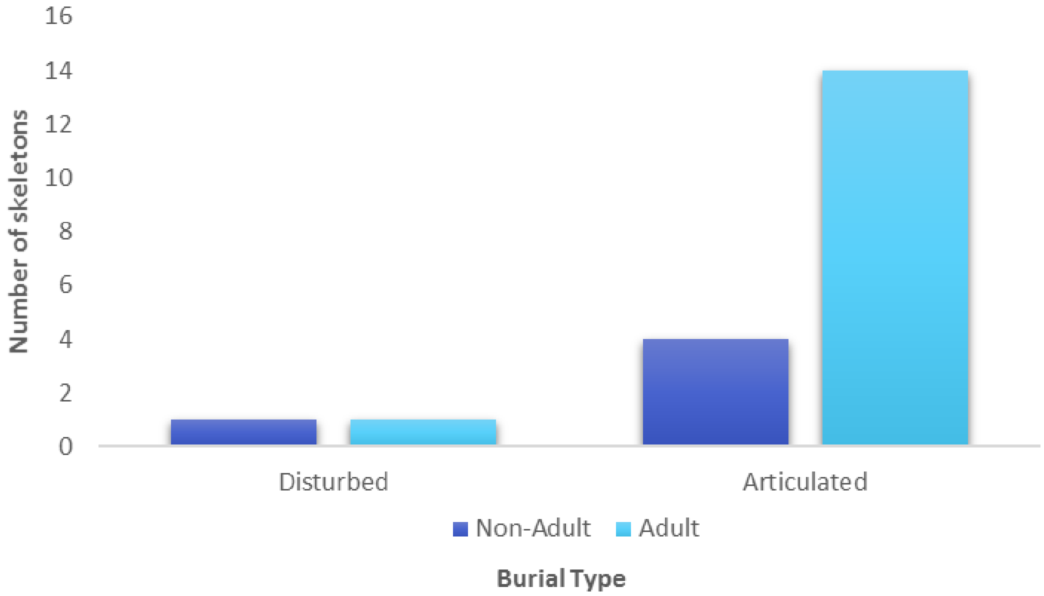

Figure 4.27. The number of disturbed and articulated adult and non-adult burials retrieved from Chester Greyfriars.

Each skeleton was assessed for completeness with the resultant data compiled into Table 4.5. There were no relationships identified for location or sex when assessing skeletal completeness of the overall sample (Spearmans rank correlations; $p>0.05$). Age had an impact on the amount of skeleton retrieved, with the bones of older individuals having a better survival rate than those of non-adults ($r_{s(18)}=0.499$, $p=0.035$).

Table 4.5. Skeletal completeness of the inhumations recovered from trenches 11 and 12 at Chester Greyfriars.

	>75%	50-75%	25-50%	<25%	Total
n	7	7	3	3	20

A number of skeletons were incomplete due to the constraints of commercial archaeology preventing the retrieval of remains that lie beyond the section wall, rather than truncation due to further use of the site (Figure 4.28). However, when assessing whether truncation had an impact on the percentage of the skeleton retrieved, no significant difference was found ($t_{(3)}=3.000$, $p=0.058$).

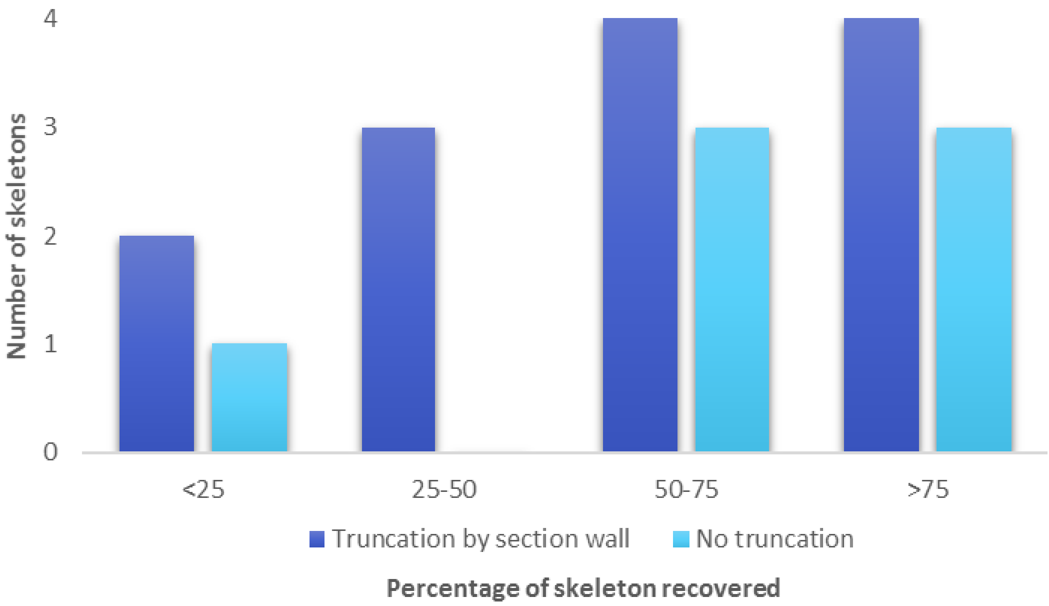

Figure 4.28. The percentage of the skeleton available for analysis from Chester Greyfriars from graves truncated by section walls and those that were not.

The preservation of the skeletal remains varied within the trenches, due to the topography and underlying archaeology. Several burials had been subjected to bioturbation from plant roots resulting in the disturbance of the skeletal remains and, in some cases, taphonomic destruction of some elements. The later burials had been subject to different soil conditions, burial practices, drainage and bioturbation, resulting in poor preservation of the areas of bone with a thin cortical layer (for example, epiphyses of long bones, ribs, vertebral bodies, hand and foot bones). However, long bone diaphyses and the crania of the later burials were relatively well preserved with the bone morphology intact, even with the coffin internments. Where fragmentation to the crania prevented craniometric measurements from being taken, basic reconstruction was carried out in line with the guidelines presented in the Standards for Recording Human Remains (Buikstra and Ubelaker, 2004). The lower and mid-layer burials varied from very well preserved to poor preservation. The articulated burials of SK007 and SK011 have areas of extremely poor preservation, which has been attributed to the fluctuating levels of water present (Figure 4.29).

All individuals had been subject to conditions that resulted in partial erosion, with some pathological information lost on skeletal elements with heavy erosion (Table 4.6). Older individuals were found to exhibit a higher degree of taphonomic interference than the non-adults ($r_{s(20)}$=0.510, p=0.022). Older individuals tended to be coffin interments (n=8), presenting a higher rate of abrasion erosion than the shrouded interments ($r_{s(16)}$=0.721, p=0.002). This suggests that the abrasion/erosion is due to the burial practice rather than the mineral content of the bone (Figure 4.30), which disagrees with the findings of previous studies (Gordon and Buikstra, 1981; Walker *et al*., 1988; Walker, 1995; Mensforth, 1990; Mays, 1998; Stojanowski *et al*., 2002; Nagaoka and Hirata, 2007).

Figure 4.29. SK011 and SK010 from trench 11 demonstrating the difference in preservation between skeletons in the same trench. ©LP Archaeology and CAL Davenport.

Table 4.6. Post mortem preservation of the Chester Greyfriars articulated skeletal material following excavation using a grading system adapted from Brinkley and McKinley (2004).

A/E Grade	Non-Adult	Male	Female
0	-	-	-
1	3	2	2
2	-	-	1
3	1	1	2
4	1	2	1
5	-	2	2
6	-	-	-

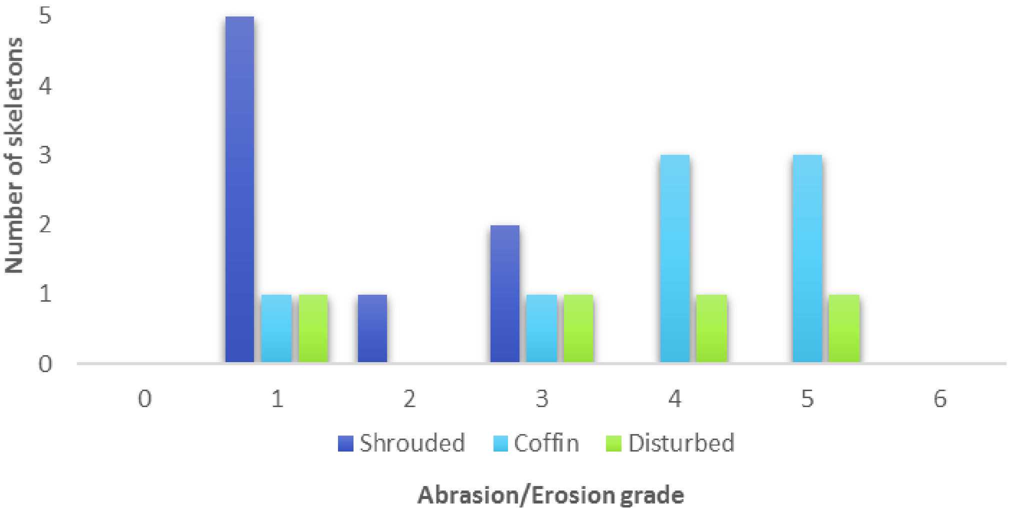

Figure 4.30. The abrasion/erosion grades separated by burial practice for the Chester Greyfriars sample (n=20).

When assessing the skeletons from each trench separately, the relationship between age and abrasion/erosion score was not significant in either trench. Burial practice continued to have a significant impact on the grading of the skeletons in trench 11 ($r_{s(9)}$=0.826, p=0.006), with a higher rate of abrasion erosion present on coffin burials. Arm position was noted as having an impact in trench 11, with the skeleton scoring grade 5 having one hand by the side, the other over the pelvis, indicating movement had occurred within the coffin burial from the original arm position. There were no relationships identified between the variable in trench 12. However, this is most likely due to the small sample size (n=7) as one individual was truncated by the section wall giving no information and the lack of significant variability in the remaining burials.

All skeletons were scored on the fragmentation scale, with all exhibiting at least minimal fragmentation rates (Figure 4.31). The completeness of the skeleton impacted the post mortem fragmentation grade assigned to each skeleton, with the level of fragmentation increasing as the completeness decreased in trench 11 ($r_{s(12)}$= -0.653, p=0.021). This relationship was not present in trench 12, nor when all samples were assessed without considering location. Of those that were graded a four in trench 11, skeleton 011 had a unique taphonomic environment resulting in the fragmentation of the remains and skeleton 001 was a disturbed burial. However, both burials were 50-75% complete, whereas the infant (skeleton 007) was <25% complete and very fragmented, but had very little abrasion/erosion.

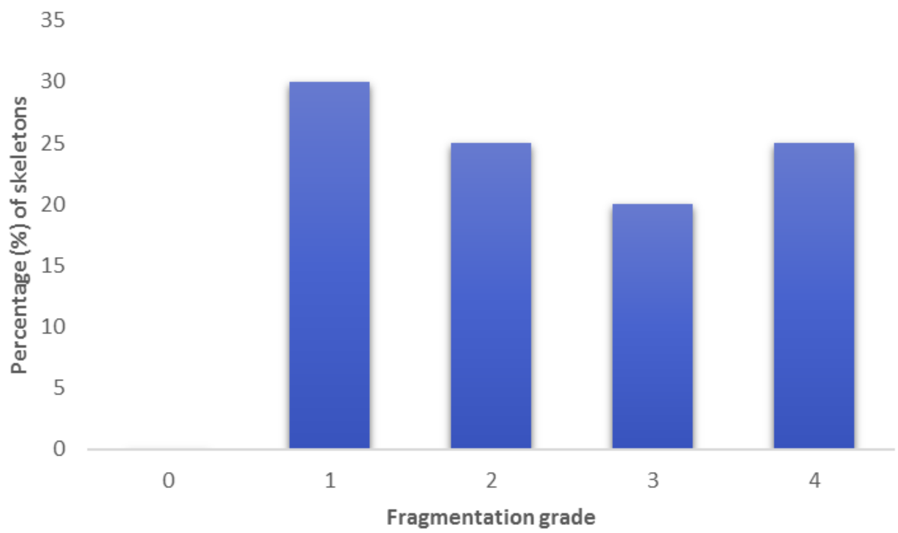

Figure 4.31. Post-mortem fragmentation of the Chester Greyfriars articulated skeletal material following excavation.

Collagen extraction carried out on 11 skeletons from Chester Greyfriars (Table 4.7). One non-adult burial was selected for testing to determine whether the collagen levels had been impacted by post-mortem physical and chemical deterioration due to the small size and reported poor mineralisation (Nagaoka and Hirata, 2007). The non-adult burial of skeleton

013, which was a shrouded interment on the north side of trench 11 (Figure 4.32), produced the highest collagen yield observed from the extractions. The lowest collagen yield was provided by skeleton 015, situated below and further to the west of the trench of skeleton 013. In trench 12 it was noted that the collagen yield increased as the completeness of the skeleton increased ($r_{s(8)}$=0. 910, p=0.011). However, due to the amount of truncation due to section boundaries in this trench, this result needs to be taken with caution.

Table 4.7. Skeleton selected for collagen extraction from Chester Greyfriars and the respective collagen yield from each sample.

Skeleton Number	Bone	Bone weight (g)	Collagen weight (g)	Collagen yield (%)
003	foot phalanx	0.77	0.09	11.68
004	rib fragment	0.61	0.04	6.56
006	rib fragment	0.55	0.05	9.09
010	rib fragment	0.63	0.08	12.69
011	rib fragment	0.70	0.03	4.29
013	rib fragment	0.53	0.08	15.09
015	rib fragment	0.54	0.01	1.85
016	rib fragment	0.56	0.06	10.71
018	rib fragment	0.66	0.06	9.09
019	rib fragment	0.56	0.07	12.50
020	metacarpal head	0.64	0.02	3.13

Figure 4.32. Skeleton 013 was a 7-8 year old shrouded burial located on the north side of trench 11 with low abrasion/erosion and fragmentation grades, and a high collagen yield. ©LP Archaeology and CAL Davenport.

Field portable x-ray fluorescence on bone

The skeletal material from Chester Greyfriars was analysed using Field Portable X-Ray Fluorescence to determine if there were any differences in the bone mineral components. The calcium levels within the bone were more abundant in burials that had not been disturbed, with skeletons 001 and 012 both exhibiting lower levels (burial type $r_{s(20)}$=0.552, p=0.012). It was noted that the female individuals retained a significantly higher calcium level than male ($r_{s(15)}$0.670, p=0.006). Those with identified pathology had higher calcium levels ($r_{s(20)}$=-0.462, p=0.040), which could be due to a number of the pathological conditions affecting the composition of the bone (e.g. osteoporosis, osteomyelitis and DISH). As the levels of calcium increased in the bone, there was an increase in phosphorous ($r_{s(20)}$=0.518, p=0.019), which indicates that the protein-mineral bond has survived well in those with higher levels.

Iron and potassium levels increased at a similar rate ($r_{s(20)}$=0.527, p=0.017), but decreased as the calcium levels rose (iron - $r_{s(20)}$=-0.628, p=0.003 and potassium - $r_{s(20)}$=-0.561, p=0.010). Iron levels were influenced by burial type, with the disturbed/secondary skeletons exhibiting higher levels than the supine and flexed burials ($r_{s(20)}$=-0.532, p=0.016). Potassium levels increased with the disturbed burials ($r_{s(20)}$=-0.597, p=0.005), whereas the increase caused a drop in the phosphorous levels present ($r_{s(20)}$=-0.732, p<0.001). Interestingly, decreased potassium levels were observed in the most complete skeletons ($r_{s(20)}$=-0.535, p=0.015). The burials were subject to taphonomic interference from the coffin environment, causing the breakdown of the protein-mineral bonds. This would cause the potassium held within the bone mineral to be displaced by calcium as the protein mineral matrix breaks down, leading to decreased levels present in the non-truncated, but less complete burials (Gill-King, 1999; Forbes, 2003; Dent *et al*, 2004).

There was no relationship identified between calcium and sex in trench 11, although there was a significant relationship identified in trench 12 ($r_{s(8)}$=0.916, p=0.001). The levels of iron in the bone were higher in the coffin burials ($r_{s(9)}$=0.741, p=0.022), whereas the magnesium levels were higher in the shrouded internments ($r_{s(9)}$=-0.689, p=0.040) from trench 11. Disturbed burials had lower levels of potassium ($r_{s(12)}$=-0.744, p=0.005) and higher levels of phosphorous ($r_{s(12)}$=0.599, p=0.040), however, this relationship was only identified in the trench 11. Higher levels of iron in the bone corresponded with lower levels of fragmentation ($r_{s(12)}$=-0.653, p=0.026), and increased phosphorous levels corresponded with poor collagen yields ($r_{s(4)}$=-0.959, p=0.041).

The results from the bone XRF were compared to the geological conditions to see if this would lend any further insight into the conditions affecting the levels of elements in the bones. When looking at the results overall, pH was found to have an impact, with more neutral pH corresponding with higher calcium levels in the bone ($r_{s(11)}$=0.671, p=0.024). Within trench 11, there was a significant positive correlation between the levels of iron in the soil and bone ($r_{s(6)}$=0.820, p=0.046). It was noted that as the levels of clay and silt increase, the iron levels in the bone decrease (Spearmans rank correlations; all p>0.05). However, an increase in clay also correlated with an increase in phosphorous in the bone ($r_{s(6)}$=0.941, p=0.005) in trench 11, but a decrease in both bone potassium and magnesium in trench 12 (Spearmans rank correlations; all p<0.05). Trench 12 saw the levels of calcium and phosphorous increase as the clay levels rose (Spearmans rank correlations; all p<0.05).

4.11. Skeletal analysis – biological profiling

Sex determination

Of the 15 articulated adult burials assessed, there were seven males and eight females (Figure 4.33). The ratio of males to females at this site was even ($\chi^2_{(1)}$ = 0.067, p=0.796), showing no skewing of the sexes as seen with other medieval sites (Bardsley, 2014). The most commonly available pelvic element for sex determination was the greater sciatic notch, which led to high survivability of the pre-auricular sulcus.

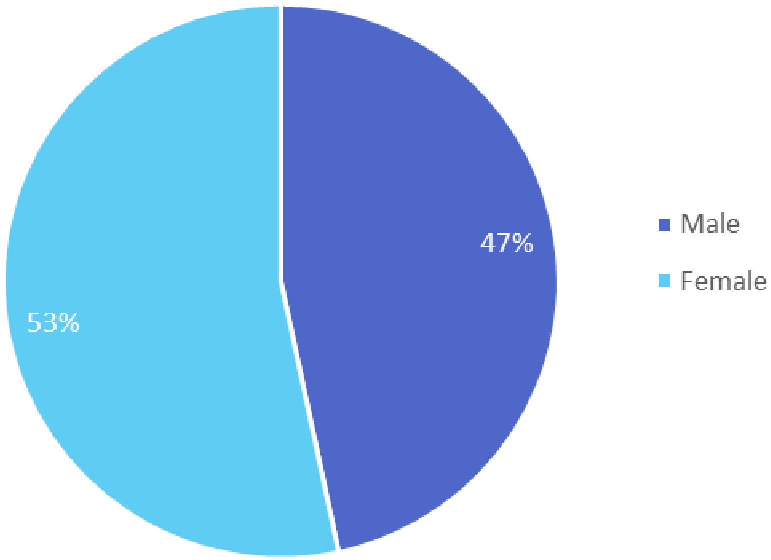

Figure 4.33. Sex determination distribution for the adult skeletons analysed from Chester Greyfriars (n=15).

Of the individuals that were recovered with a pelvis, over 50% of males and 30% of females retained at least half of the pubic traits required for sex determination. However, this was often detached from the rest of the innominate, leading to the complete obturator foramen not being observable in many cases (Figure 4.34).

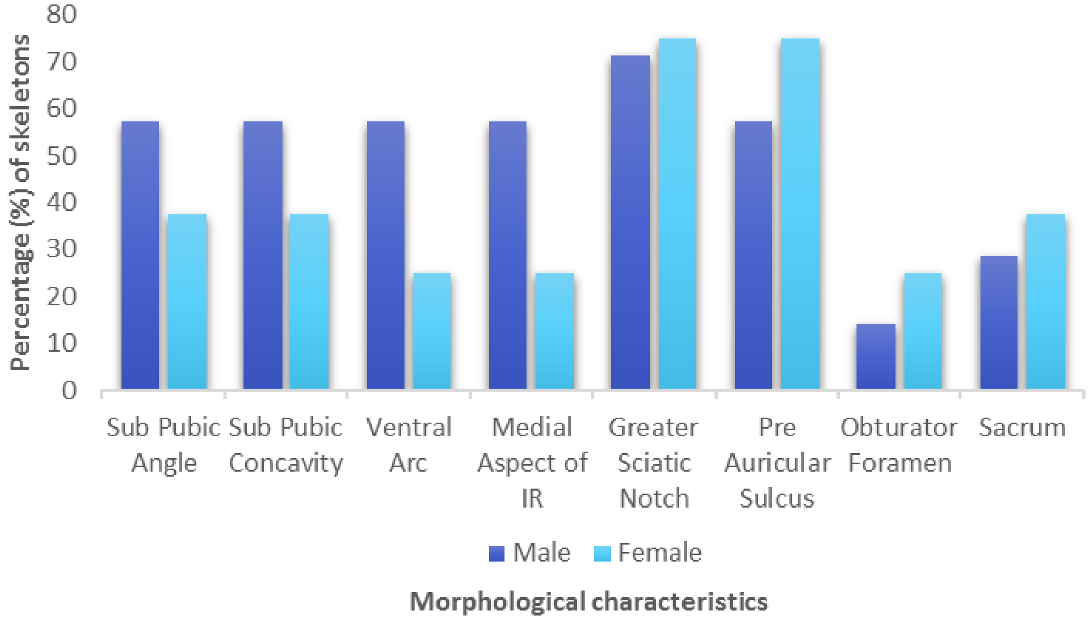

Figure 4.34. Preservation rates of the pelvic morphological characteristics from the males (n=7) and female (n=8) Chester Greyfriars burials.

The survivability of the elements did not differ significantly between males and females, leading to a similar number of techniques being available for each sex ($U=37.000$, $p=0.796$). Where pelvic traits were not available, sex determination was made solely from cranial morphology and metric measurements. The most commonly available cranial traits for sex determination were the mastoid process and nuchal crests. The mandible was available for analysis in over 60% of the individuals, with all three traits available for analysis (Figure 4.35). This may be due to the position of the mandible in the grave protecting these elements, helping to preserve the traits and contributing the high survivability of these elements.

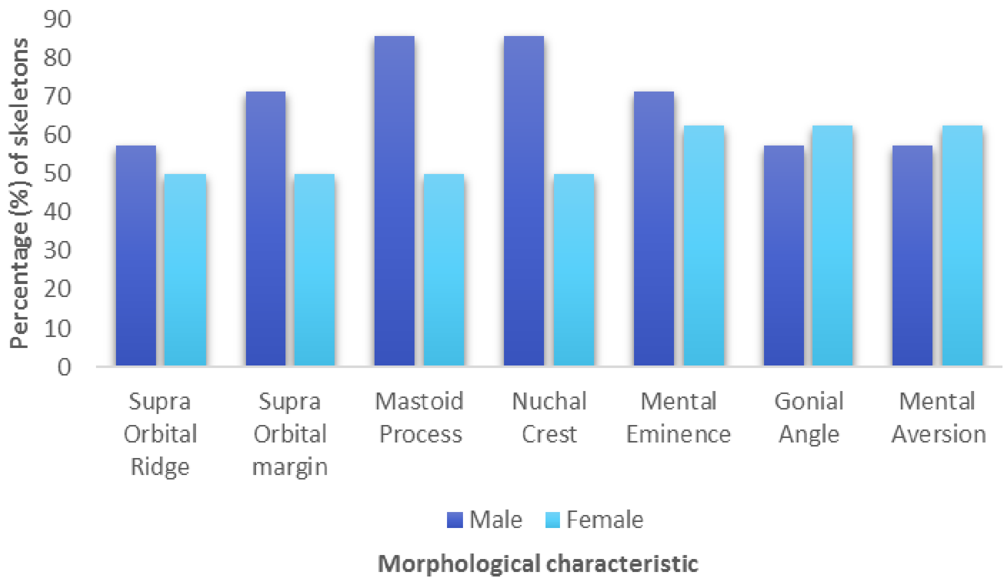

Figure 4.35. Preservation rates of the cranial and mandibular morphological characteristics from the male (n=7) and female (n=8) Chester Greyfriars burials.

The survivability of the elements did not differ significantly between males and females leading to a similar number of techniques being used to for determination of each sex (U=25.500, p=0.505). Cranial and mandibular assessments showed that over 40% of males and 50% of females provided elements for all seven sex determination techniques. The most commonly available metric measurement for sex determination was the femoral head (67% of the adult sample), with the humeral head being present in 60% of the total adult sample. The proximal ends of both the femur and humerus form ball and sockets joints, which provide some protection to the cortical surface of the bone. In turn, this aids the preservation of this element and the potential for metric measurements to be taken. The analysis of burial position demonstrated that elements that are proximal to the torso are more likely to be preserved. Of those assessed for sex, the percentage of burials preserving elements providing metric measurements for analysis are shown in Figure 4.36.

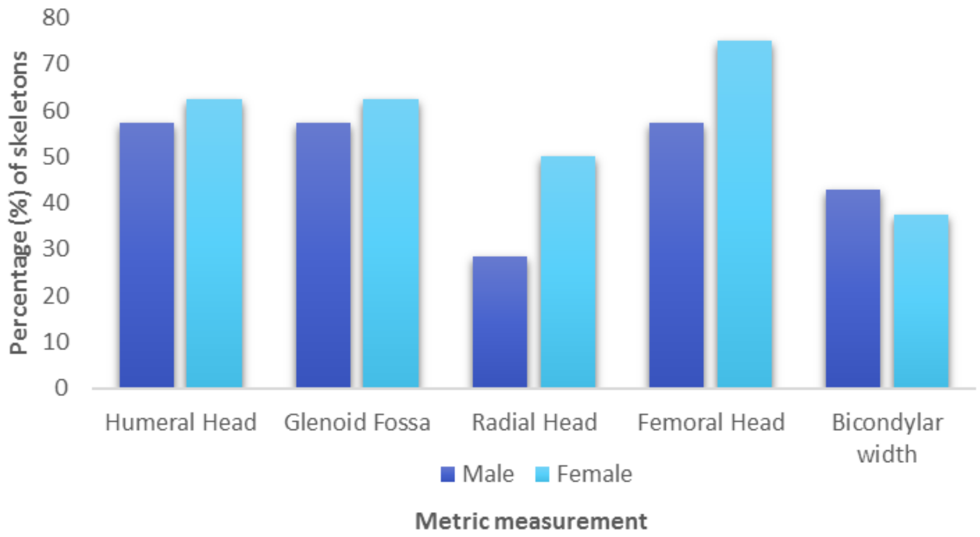

Figure 4.36. Preservation rates of the anatomical structures providing metric measurements from the male (n=7) and female (n=8) Chester Greyfriars burials.

The survivability of the elements did not differ significantly between males and females leading to a similar number of techniques being used to for determination of each sex (U=14.500, p=0.589). Of the skeletons assessed using metric measurements, only 14% of males and 13% of females provided elements for all sex determination techniques. The pre-auricular sulcus was examined for all adult skeletons where the landmark was preserved (n=10) to determine whether it was a groove of pregnancy (GP) or groove of ligament (GL). None of the males assessed from this sample presented a pre-auricular sulcus, with only one female identified with a groove of pregnancy. Of the remaining five females, three had a groove of ligament and two had no groove present.

Age estimation

There were 20 articulated burials (15 adults, 5 non-adults) available for assessment of age, with 18 providing characteristics required for the estimation. The two skeleton which could not be placed into an age category (10%), were classified as adult. The age-at-death distribution (Figure 4.37) shows that not all ranges were accounted for in this small sample size, which would influence any palaeodemographic assessment. The lack of non-adult burials recovered from trench 12 meant there was a significant relationship identified between the two trenches ($r_{s(14)}$=0.480, p=0.032). However, this is more likely to be linked to sampling bias than to a low non-adult sample at this cemetery given the constraints of commercial excavation practices.

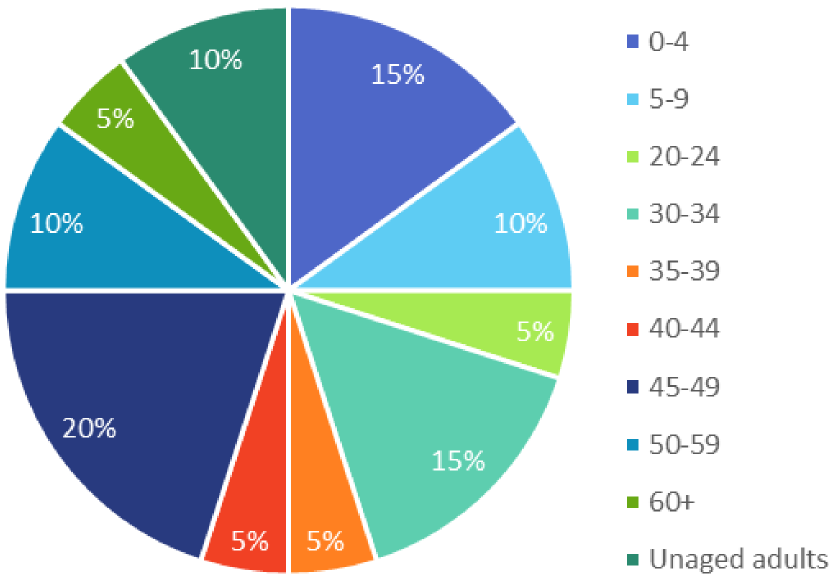

Figure 4.37. Age at death distributions for the Chester Greyfriars burials (n=20). Note that there were no individuals in the 10-14, 15-19 or 25-29 year age categories.

Figure 4.38 shows the percentage of adult articulated burials that could be aged using each macroscopic aging technique. The preservation of the elements for age assessment did not vary significantly between males and females ($t_{(5)}$=0.378, p=0.721), with both sexes similarly having poor preservation of the ribs. Although the cranium survived in many cases, heavy fragmentation of this region would have affected the assessment of age using the cranium. Of the techniques available, none of the individuals assessed were able to use all seven aging techniques, with the majority of individuals (66%) of individuals using three or five. The auricular surface was the most commonly available method for females, with dental attrition the most commonly available methods for the males.

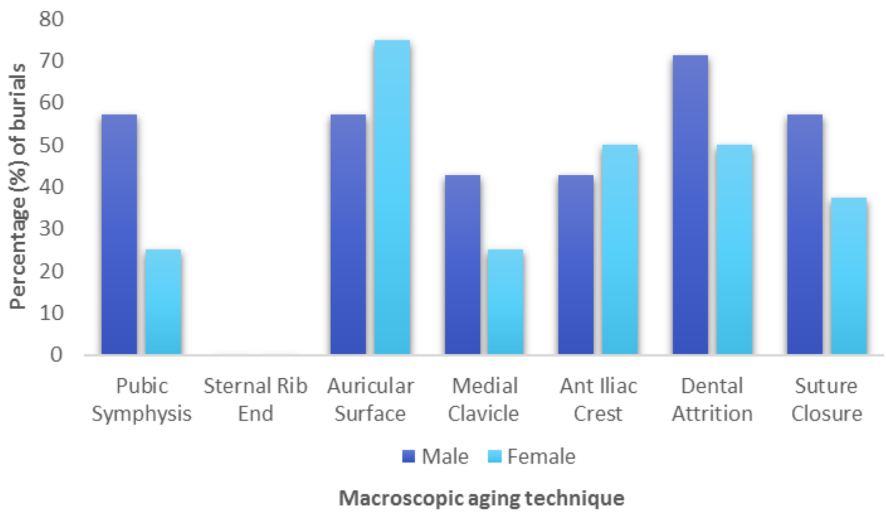

Figure 4.38. Preservation rates of the anatomical regions enabling assessment of the macroscopic aging techniques from the adult male (n=7) and female (n=8) Chester Greyfriars burials.

The increased number of available elements in the non-adult burials allowed a high percentage of individuals to use all three techniques for age-at-death (Figure 4.39). The non-adult skeletal elements showed preservation comparable to the adult sample ($\chi^2_{(3)}$=1.548, p=0.671), which conflicts with previous literary evidence stating that non-adults are under-represented in the archaeological record due to poor preservation (Molleson 1991; Crawford 1991;1993). All non-adult articulated burials were able to use at least two aging techniques, with 60% using all three.

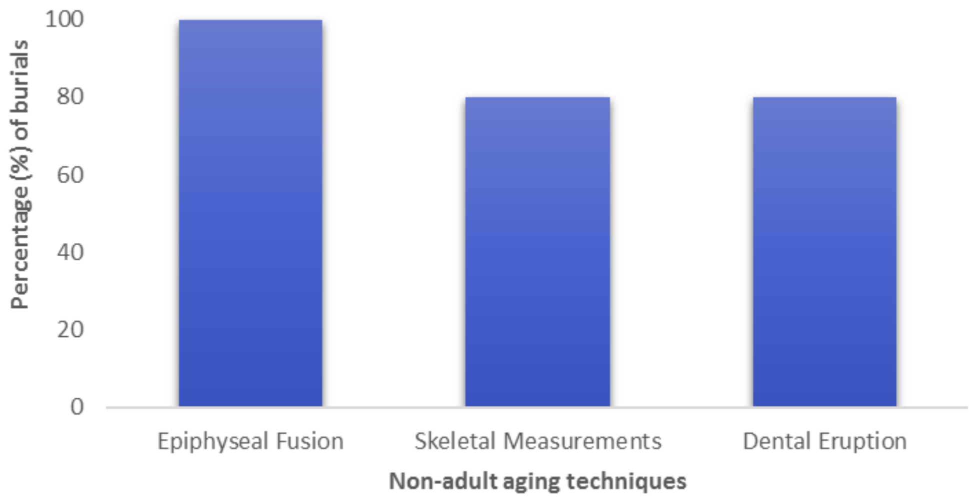

Figure 4.39. Preservation rates of the anatomical structures enabling assessment of age from the non-adult Chester Greyfriars burials (n=5).

Stature estimation

All articulated adult burials (n=15) were assessed for long bone length, with all available measurements recorded. Of those assessed for sex, 73% (*n* =11;6M/5F) produced measurements from at least one long bone for the estimation of stature, with the recovery rates of long bones similar for both sexes (U=24.000, p=0.946; Figure 4.40).

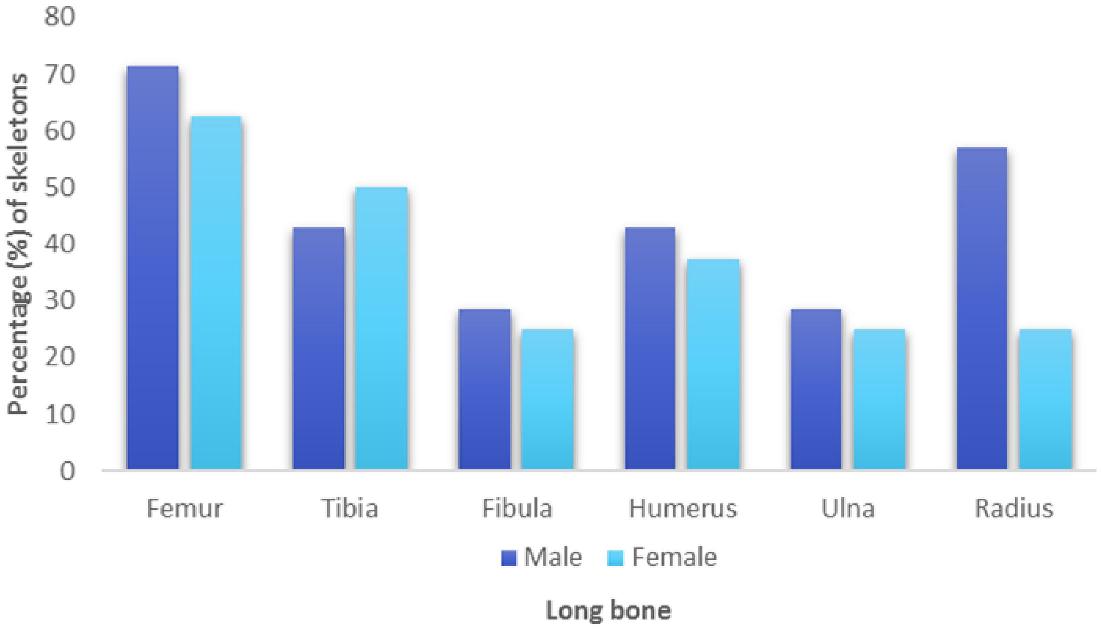

Figure 4.40. Preservation rates of the complete long bones available for stature estimation from the adult male (n=6) and female (n=5) Chester Greyfriars burials.

To ensure consistency, maximum femur length was used to estimate stature for the Chester Greyfriars burials, where this was not possible the tibia was used (n=1). Average femur length for males was 45.10 ± 1.73cm (n=5) and for females was 40.42 ± 2.95cm (n=5), demonstrating the strong sexual dimorphism present within the sample ($t_{(8)}$=2.737, p=0.026). Female stature ranged from 143.12cm to 165.35cm, with female mean height (152.82 ±5.29cm) which was significantly less the mean for the medieval period (158.60cm; Cafell and Holst, 2005). Male stature ranged from 163.04cm to 173.13cm, with a mean male stature of 169.43 ± 4.37cm. The mean male stature sits within those given for British samples in the 12th century (168.4m; Munter 1928) and 13th-14th centuries (171.8m; Huber 1968; Steckel, 2005); although it sits slightly lower than the overall male mean for Northern Europe (172.1m; Steckel, 2005).

It was not possible to assess stature using long bone measurements for four individuals from Chester Greyfriars. Of these, skeleton 014 had been truncated at the fourth cervical vertebra and skeleton 11 had been truncated at the lumbar vertebrae. The remaining two skeletons (005 and 018) preserved at least one trait, which would allow for the estimation of stature using fragmentary femora measurements. Given the small sample size it was not possible to determine the accuracy of the fragmentary femora regression formulae by Simmons *et al* (1990) for this sample. Therefore, the reported formulae are used in this case, with caution in any reported stature estimation given that the female sample falls significantly below the mean for the medieval period. Skeleton 005 provided measurements for vertical head diameter (VHD) and proximal femoral breadth (VHA), which produced estimates of 158.82 ±7.16cm and 154.75 ± 6.67cm respectively. Skeleton 018 provided a measurement for vertical head diameter (VHD), giving an estimate of 150.10 ±7.16cm.

Craniometrics

Following the cranial reconstructions undertaken by Satu Valoriani, 36 measurements were collected from 10 adult crania (see Appendix A4). The data were used to determine if there were any relationships between the measurements and sex, which would indicate sexual dimorphism within the sample. Cranial indices were also calculated to investigate the variation of skull types in the sample. A Kolmogorov-Smirnov tests identified four of the craniometric variables as not normally distributed (44, 16, 26, 23a), which will be subjected to non-parametric correlation analyses when testing for relationships with sex. Of the craniometric variables, only two were impacted by sexual dimorphism; bi-auricular breadth ($t_{(6)}$=4.595, p=0.004) and foramen magnum length ($t_{(3)}$=5.400, p=0.012). Cranial and basion-height indices were calculated to determine the variability in cranial shape present in the Chester Greyfriars sample (Table 4.8). There were no significant differences between the sexes when assessing the indices for the cranium (U=3.500, p=0.637), or for basion-height (U=1.500, p=0.667).

Table 4.8. Cranial and Basion-height Index interpretations for the Chester Greyfriars adult skeletons)

	Description	Measurement	*n*
Cranial Index			
Dolichocrany	Narrow or long headed	X - 74.99	1
Mesocrany	Average or medium headed	75.0 - 79.9	2
Brachycrany	Broad or round headed	80.0 - 84.9	4
Hyperbrachycrany	Very broad headed	85.0 - X	-
Basion-height index			
	Low skull	X - 78.99	1
	Medium or average skull	79.0 - 85.99	4
	High skull	86.0 - X	-

Post-cranial indices

Measurements were taken from the femur and humerus where possible to calculate robusticity indices, such as the *platymeric* index for femoral robusticity (Table 4.9). Robusticity indices are calculated by multiplying the mean of the anterior-posterior and medio-lateral diameters by 100 (Pearson *et al*, 2000). The position of the diameter measurements on the shaft are dependent on the robusticity index being assessed, in this case below the trochanter for the femur, and the mid-shaft of the humerus.

When using the *platymeric* index to calculate the shape and robusticity of the femoral shaft, all individuals fell into the *platymeric* range, which is identified by flattening of the shafts from back to front (Wescott, 2006). However, caution should be taken with this assessment, as there is evidence to suggest that femur subtrochanteric shape can be influenced by mechanical stress, as well as genetic factors (Frost, 1983; Ruff, 1987; 2000). The highest index was recorded for skeleton 004, which fell within the *eurymeric* category (Table 4.10). This skeleton displays the skeletal markers of a longbowman, who would have undergone training from a very young age, possibly causing mechanical stress to the bones to account for the increased robuscity index level (Wescott, 2006). Most of the femora for this sample had a degree of anterior-posterior flattening of the femoral shaft, with only two individuals falling within the *eurymeric* (average, no flattening on either plane) category.

The humeral index measurements showed a range of values, with the highest being for skeleton 015, a female individual who bears the skeletal markers of a person who spent time horse riding, or carrying out an activity involving similar movements. The lowest index came from Skeleton 018, an older female who had suffered with a very severe case of osteoporosis, which could have led to her being bedridden during the final months of her life. Mechanical stress is important for maintaining mass, therefore the lack of mobility would further increase bone atrophy and osteoporosis, which would influence any robusticity indices (Eimori *et al* 2016). There were no significant differences between the sexes when assessing the robusticity indices for the humerus ($t_{(6)}$= -0.228, p=0.827) or femur ($t_{(10)}$=0.802, p=0.441).

Table 4.9. Robusticity indices for the humerus and femur from the male and female articulated burials from Chester Greyfriars.

		Robusticity Index	
Skeleton	Sex	Humeral	Femoral
001	Male	-	80.7
002	Female	81.8	79.3
003	Male	88.3	75.0
004	Male	93.8	92.9
005	Female	-	80.6
006	Male	88.4	74.9
010	Male	97.8	-
015	Female	113.3	78.5
016	Female	93.01	73.1
017	Female	-	73.3
018	Female	-	69.0
019	Female	86.7	91.9
020	Male	-	83.8

Table 4.10. The distribution of the Chester Greyfriars skeletons providing the required measurements for assessment of the *platymeric* index of the femur.

	Hyperplatymeric (<74.9)	Platymeric (75.0-84.9)	Eurymeric (85.0-100)
Male	1 (20%)	3 (60%)	1 (20%)
Female	3 (42.9%)	3 (42.9%)	1 (14.3%)

Non-metric traits

Non-metric traits occur frequently in skeletons and it is thought that their appearance could be hereditary (Saunders, 1989) or due to environmental or mechanical stress (Trinkhaus, 1978; Kennedy, 1989). Additional sutures, processes, foramina and caudal shifts are all examples of non-metric variation within the human skeleton and can give an insight into possible genetic links within samples or the activities undertaken in life. It is thought that cranial non-metrics are likely to be hereditary due to the lack of mechanical stress to this area (Saunders, 1989). Using the methodology of Brickley and McKinley (2004), 29 recommended non-metric traits and, a further three noted non-metric traits were observed during assessment (sacralisation, lumbarisation and presence of a third trochanter; see Appendix A1 for data collection sheets). Of the traits described by Brickley and McKinley, fourteen were observed on the Chester Greyfriars adult skeletons (Table 4.11). Non-adult skeletons were not assessed due to the level of non-fusion in many of the skeletons.

The most commonly observed cranial traits were parietal foramen and the mastoid foramen exsutural, both observed in 33% of the sample and a tendency to be more frequent in the males. Accessory transverse foramina were the most common post-cranial trait, present in 27% of the adult cemetery sample. Femoral plaques were observed in male skeletons only, though overall, there was no significant difference in the distribution of the non-metric traits between the sexes.

Table 4.11. Non-metric traits and frequencies observed on the Chester Greyfriars cemetery sample.

Non-metric Trait Observed	Number of Skeletons	
Cranial	**Male**	**Female**
Metopism	-	1
Coronal wormian bone	-	1
Lambdoid wormian bone	1	1
Parietal foramen	3	2
Infraorbital foramen	1	2
Mastoid foramen exsutural	3	2
Frontotemporal articulation	1	-
Hypoglossal canals - double	1	-
Post-cranial		
Femoral plaque	3	-
Tibial squatting facets	-	1
Suprascapular foramen	1	-
Superior atlas facets - double	2	-
Posterior atlas bridge	-	1
Accessory transverse foramina in cervical vertebrae	2	2
Lumbarisation of S1*	1	1
Sacralisation of L5*	1	-
3rd trochanter*	1	1

* Additional traits noted

When assessing the distribution of the non-metric traits in the cemetery, individuals sharing traits tend to be located together. The mastoid foramen exsutural is seen in three skeletons in trench 11, which are all located in the southeast corner of this trench. Skeletons 10 and 11 were buried earlier than skeleton 004, but the link between this and other shared non-metric traits in the cranium (infraorbital and parietal foramina) and the accessory transverse foramina in the cervical vertebrae (all located at C6/C7) suggests that genetic links may be the cause. Skeleton 004 also had an unfused sternum, with the first segment of the sternal being separate from the second and third segments. Skeleton 003 was interred directly above skeleton 006 in trench 12, with the close proximity of the skeletons suggesting this could be a family plot. Both individuals have large parietal foramina, double superior atlas facets and femoral plaques, indicating that even if the postcranial traits are subject to environmental or mechanical stress, they could have been affected by the same factors.

Pathology and trauma

The skeletons excavated from trenches 11 and 12 at Chester Greyfriars were assessed for pathology and trauma that had left an imprint on the bone and therefore could provide further information into the lives and deaths of these individuals. Half of the skeletons (n=10) provided insight into some of the conditions that could affect the human skeleton during this period (Figure 4.41), with fifteen providing information on dental health. Pathological conditions were more frequently observed on the adult sample ($r_{s(18)}$= -0.510, p=0.031), with all adults over 50 years (Skeletons 011, 016 and 018) having a number of conditions. When assessing the elemental levels in the bone, it was noted that those that had a pathological condition tended to have higher levels of calcium ($r_{s(20)}$=-0.462, p=0.040).

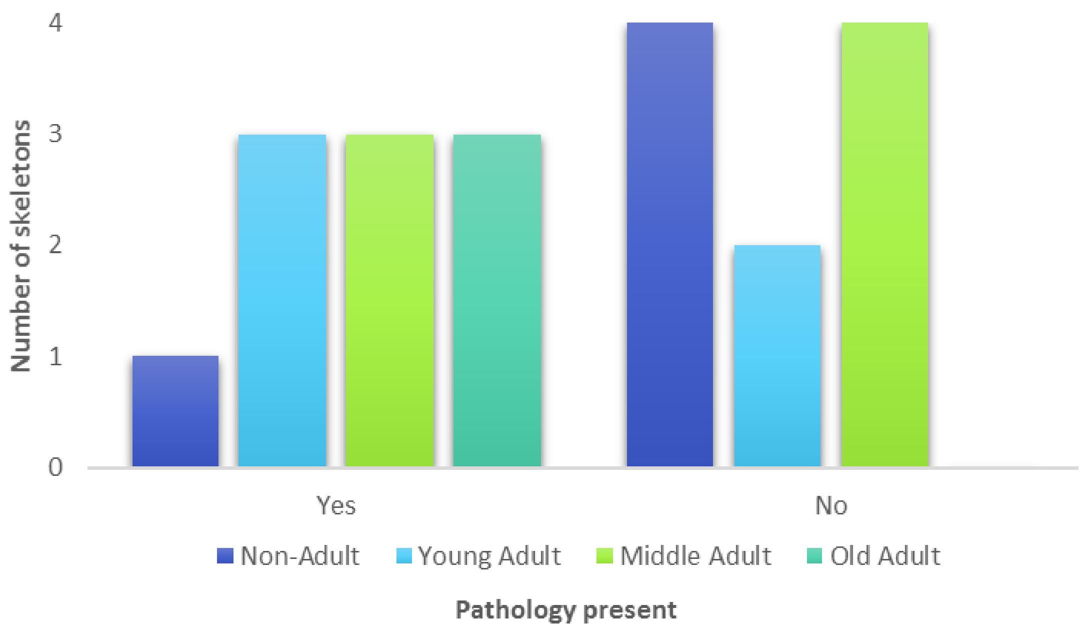

Figure 4.41. The frequency of pathological conditions present in each of the age groupings at Chester Greyfriars.

Joint diseases

Joints disease can be described as proliferative (such as osteoarthritis) or erosive (such as gout or rheumatoid arthritis). The major feature of the disease is the growth or destruction of bone within a joint, which can lead to limited movement and pain in the affected areas (Waldron, 2009). The use of terms when describing degenerative joint disease are often used interchangeably, which can lead to confusion when discussing various conditions, therefore the terminology used in this chapter will follow the guidelines set out in Roberts and Manchester (2010, 3rd edition, p134, table 6.1).

Primary osteoarthritis is the most commonly occurring joint disease seen in both clinical and archaeological settings and is associated with increasing age (Jurmain and Kilgore, 1995; Roberts and Manchester 2010). Primary osteoarthritis is characterised by the deterioration of the joint cartilage, leading to exposure of the underlying bony joint surface. The resulting bone-on-bone contact can result in eburnation, a polishing of the bone surfaces and the most distinctive characteristic of osteoarthritis. Osteoarthritis can be the result of mechanical stress or other factors, including lifestyle, food acquisition and preparation, social status, sex and general health (Larsen 1997). People with osteoarthritis may experience pain and limited movement of the affected joint (Roberts and Manchester 1995).

Osteophytic growth was observed on the 20% of the Chester Greyfriars skeletons, of which three were adult females and one was an adult male. Each of the Chester Greyfriars individuals exhibiting primary osteoarthritis had changes to the spinal column, which further changes noted on other joints dependent on the severity of the condition and any associated pathologies present. Primary osteoarthritis and eburnation was observed on the left radial head and distal humerus, the right distal ulna and trapezoid and the left articular facets of the 2nd (inferior surface), 3rd (both superior and inferior surfaces) and 4th (superior surface) cervical vertebrae of skeleton 011. As only the upper body of this skeleton was available for analysis and the taphonomic damage due the intrusion of water into the grave, it was not possible to determine how extensive the osteoarthritis was and whether it affected the lower body. The presence of lipping on the cervical facets was observed on skeleton 018, with osteoarthritis confirmed by the presence of further osteophytic growth and eburnation on the right patella (Figure 4.42).

Extra bone growth observed on the vertebral column, both clavicles, radii, ulnae and carpals of skeleton 010, though eburnation was not present in the elements available for analysis. Slight osteophytic growth was observed on two cervical (C5 and C6) and six thoracic vertebrae (T1, T8, T9, T10, T11 and T12) of skeleton 019; however none was noted in the lumbar regions. Osteophytic lipping (costovertebral osteoarthritis) was present on ribs 5-10 of skeleton 019, which is caused by the elevation of the rib cage. The lifting of the rib cage can be caused by pregnancy, or by the carrying of heavy objects whilst also carrying further objects on the back (Capasso and Di Tota, 1991; Merbs, 1983). The presence of pre-auricular sulci on both the left and right innominates indicate potential stress on the pelvic ligaments, which may indicate pregnancy or heavy lifting for a sustained period.

Figure 4.42. Eburnation and osteophytic lipping present on the articular surface of the right patella of skeleton 018. ©CAL Davenport.

Secondary osteoarthritis occurs following damage to a joint, and is not associated with increasing age. Only one skeleton from the Chester Greyfriars sample was observed as potentially having secondary arthritis. Skeleton 016 suffered fractures to the right tibia and both fibulae, which would have put increased stress on the left ankle, as weight bearing on the right leg would have been difficult, given the resultant osteomyelitis. The left tibia and talus had developed osteophytic growths, with the articular surfaces showing increased porosity, although polishing was not evident.

Rheumatoid arthritis is a classed as an immune joint disease, characterised by the presence of the rheumatoid factor (RF – an antibody in the serum), but has an unknown cause, with genetic, environmental and immune factors all considered to contribute to this pathology (Waldron, 2009). Extensive erosive lesions were identified on the left foot of skeleton 002, which had resulted in the fusion of metatarsals 2-5 (Figure 4.43). The distal ends of both tibiae and fibulae have thin and porous cortical bone, and the calcaneus, talus and first metatarsal from the right foot show erosive changes. There are additional erosive lesions present on the distal end of left fibula, and the facets of thoracic vertebrae 2-5. There is additional wear of the joint surfaces on the acromial and sternal ends of the clavicles. Unfortunately, taphonomic destruction of portions of the sacrum and ilia of the pelvis mean that it is not possible to determine whether there was sacral involvement. However, new bone formation is present on the observable areas of the bone and the presence of osteoporosis around the affected areas was confirmed by radiographs. The first documented rheumatoid arthritis case in the UK was reported by Waldron *et al* (1994), on a post medieval adult female skeleton, with further cases documented from medieval England, France, and Japan Packing *et al*, 1994; Blondiaux *et al*, 1997; Inoue *et al* 1999).

Figure 4.43. The left foot of skeleton 002 from Chester Greyfriars showing the erosion of the bone joints from rheumatoid arthritis (photograph top left and radiograph bottom left) and cortical thinning of the bone in the distal ends of the tibia and fibula (right radiograph). ©CAL Davenport.

Schmorl's nodes form when herniation of the intervertebral disc occurs through the vertebral endplate decompressing the adjacent nucleus and transferring the load onto the annulus (Waldron, 2009). The position of Schmorl's nodes can vary dependent on the mechanism leading to formation, with stress to the spine due to activity or sport a common cause for this pathology (Capasso *et al*, 1999). Schmorl's nodes were observed on the inferior surfaces of T6 and T7 in skeleton 10 (Figure 4.44).

The herniations present were classified as Type B, which is a herniation of the nucleus pulposus with posterior crossing of the annulus fibrosus, or an 'intra canalar herniation' (Capasso *et al*, 1999). The Schmorl's nodes present on skeleton 004 were found on two thoracic and three lumbar vertebrae (inferior surfaces of T11, L1 and L2, and the superior surfaces of T12, L2 and L3). The herniations present on the vertebrae of skeleton 004 were classified as Type A, an intraspongious herniation without crossing the annulus fibrosus

(Capasso *et al*, 1999). All Schmorl's nodes were located posteriorly on vertebral plates, indicating that significant stress was placed on the vertebral column whilst flexed, most likely while lifting heavy objects.

Figure 4.44. Inferior view of the sixth and seventh thoracic vertebrae showing the Type B herniations present in the spine of skeleton 010. ©CAL Davenport.

Bone forming conditions

Diffuse idiopathic skeletal hyperostosis (DISH) is an extreme bone forming condition, which is characterised by the production of new bone into the anterior longitudinal ligament and ossification of surrounding enthuse, ligaments and soft tissues (Waldron, 2009). The ossification forms down the right hand side of the vertebral column and can resemble candlewax, with the fusion of four or more adjacent vertebrae being the diagnostic feature required for the identification of this pathology. In the medieval period, the pathology was commonly seen in those who enjoyed a rich diet, typically those of high status or following the monastic way of life (Harvey, 1993; Rogers and Waldron, 2001). This was observed in skeleton 010 from Chester Greyfriars, who displayed a candlewax formation, involving vertebrae T7-T11, although T11 had not yet fully fused (Figure 4.45). There was an additional costovertebral fusion involving the seventh thoracic vertebra and seventh rib on the left side. Skeleton 010 had undergone dietary analysis as part of this analysis (see geochemical studies on human material), which suggested that this adult male was a higher status individual.

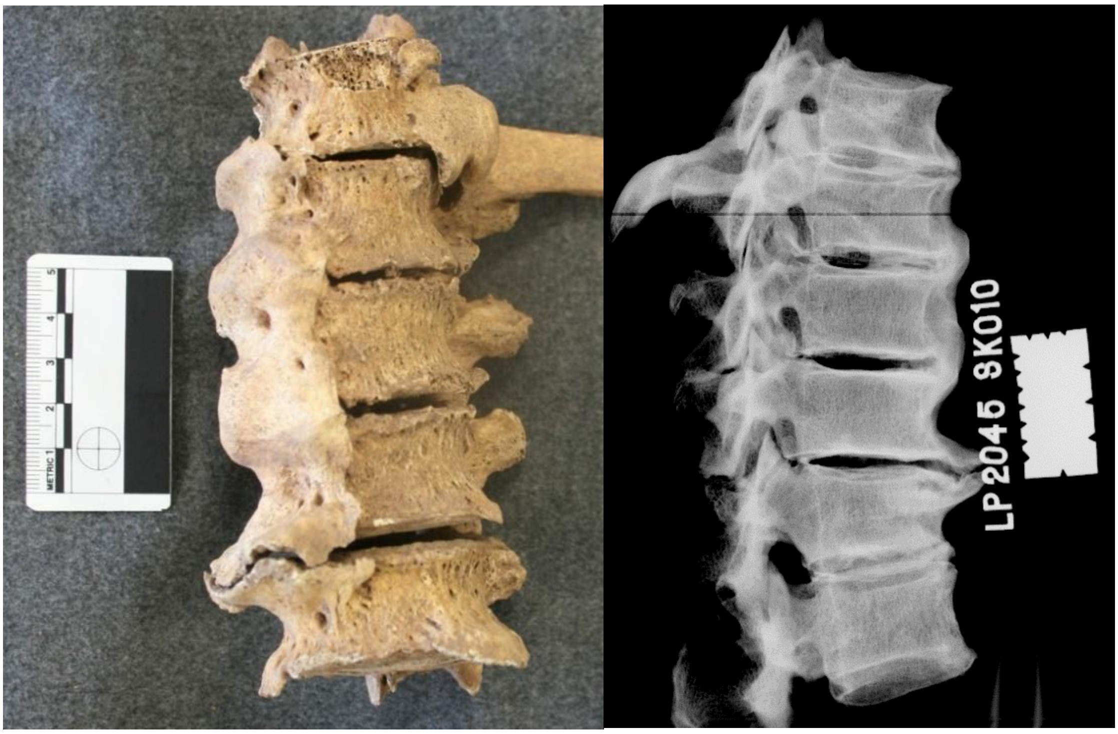

Figure 4.45. Seventh to 11th thoracic vertebrae of skeleton 010 from Chester Greyfriars showing a candlewax formation typical of DISH and additional costovertebral fusion of the seventh rib (left), along with a radiograph of seventh to twelfth thoracic vertebrae. ©CAL Davenport.

Metabolic conditions

Osteoporosis is one of the most commonly observed skeletal metabolic diseases, which is identified by a reduction in total bone volume caused by the thinning of cortical bone, thinning and loss of trabecular bone and increased porosity of cancellous bone (Burr and Martin, 1989). This can lead to an increased risk of fracture in weight bearing bones, or a loss of more than 30% of the bone mass (osteopenia is the diagnosis with bone loss at less than 30%, Roberts and Manchester, 1995; Ortner, 2003).

Extensive cortical thinning was noted in skeleton 018 (Figure 4.46), which was identified as osteoporosis following radiographic analysis and the calculation of the cortical thickness index and calcal to canal ratio (Dorr, 1986). Studies have been carried out on a number of samples, with the CTI and CCR thresholds set at 0.57 or lower (Yeung *et al*, 2006; Sah *et al*, 2007; Yun *et al*, 2011; Köse *et al*, 2015). The osteoporosis seen in skeleton 018 is extensive, resulting in lightweight, fragile bone, though no fractures were evident from the analysis. The CTI score was for skeleton 018 was 0.21, which fell well within the expected range for osteoporosis. The CCR score was 0.87, which is higher than the score given in the study by Köse *et al* (2015) However, Köse *et al* (2015) states that there are differences in the scores between samples. Furthermore, the assessments made in the study were based on living patients, which does not account for the changes to bone during decomposition.

Figure 4.46. Left femoral shaft from skeleton 018 showing the decreased cortical thickness (left) and radiograph of the left proximal femur and shaft. ©CAL Davenport

Cribra orbitalia was observed in 20% of the Chester Greyfriars sample, a metabolic condition that has been linked to iron deficiency anaemia (Wapler *et al*, 2004) and periods of stress such as poor sanitation, infectious disease, cultural practices and times of famine (Walker *et al*, 2009). Although the debate in the literature continues, the presence of this metabolic condition in three different stages (SK014 - active, SK 002 and SK013 - healing and SK019 - healed), demonstrates that there could have been a periods of stress that affected these individuals. A large caries and abscess on the left M_3, which would have made eating difficult and painful for skeleton 014, possibly leading to deficiencies in the diet. Skeleton 019 had a pathological condition, which may have hindered her access to food during periods of illness. All skeletons with *cribra orbitalia* (see also skeleton 013 with rickets) also had other pathological conditions, which may have also caused the individuals stress, further complicating the interpretation of the presence of the illness in this case.

Paget's disease of bone (PDB) is characterised by increased osteoblast activity, leading to increased numbers of enlarged cells, fragility and bone deformity (Cortis *et al*, 2011; Burrell *et al*, 2016). Although the exact cause of PDB is not known, genetic and environmental factors are considered to contribute to the illness (Cooper *et al*, 2006). The increased activity disrupts the bone remodelling process resulting in disorganised woven and lamellar bone. Paget's is a non-inflammatory, metabolic disease that commonly affects the bone of the crania, vertebral column and lower limb bones (Cortis *et al*, 2011), with a high prevalence in males. Paget's disease was suspected in the crania of skeleton 004, with further changes noted in both clavicles. The cranial bone showed thickening, with measurements in excess of 8mm noted where the bone had been damaged post-mortem (Figure 4.47). To confirm the presence of PDB in this skeleton, the cranium was subjected to radiographic assessment in both anterior and lateral views. The marked thickening of the cranial bone was clearly visible in the radiographs (Figure 4.48), along with the disruption to the bone remodelling process resulting in poorly defined bone in many areas. The clavicles were also radiographed to determine the extent of the changes occurring in this area, with the images showing that the changes indicated the early onset of PDB.

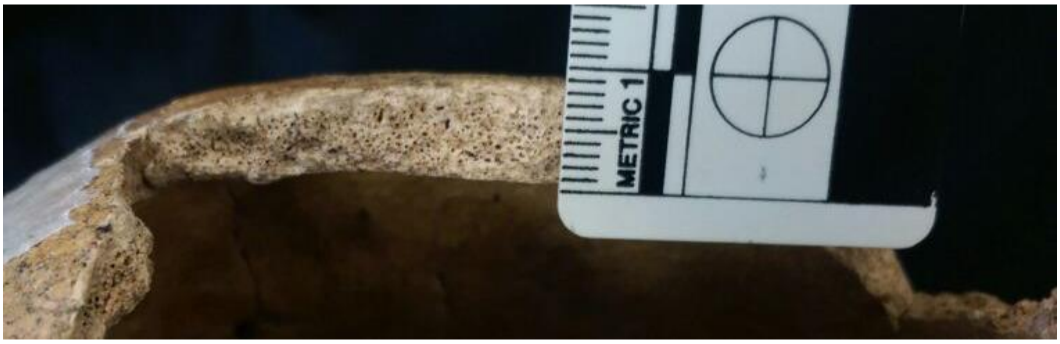

Figure 4.47. Cross section of the left parietal of skeleton 004, showing cranial thickening, remodelling of the cortical layers, and increase in woven and lamellar bone. ©CAL Davenport.

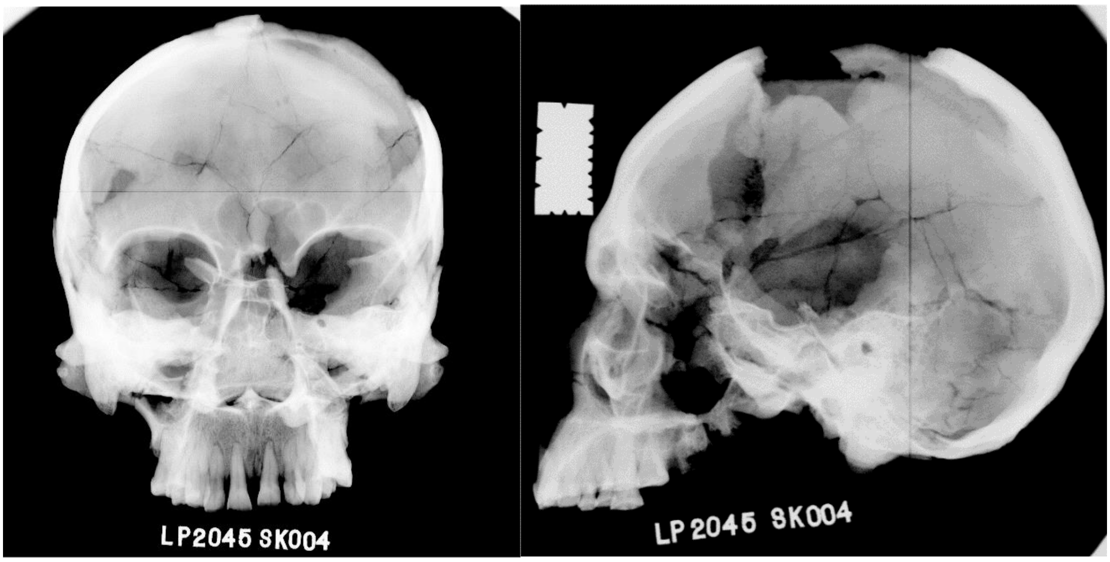

Figure 4.48. Cranial radiographs of skeleton 004 showing the increase in depth of the cranial vault bone and the 'cloudy' appearance of the bone often seen as a result of the remodelling process. ©CAL Davenport.

Rickets is a metabolic condition that occurs due to vitamin D deficiency, which can result in a number of skeletal changes. The most commonly noted skeletal change in rickets is the deformity of the long bones, which occurs due to the softer bones not being able to bear the weight of the individual while standing or walking (Waldron, 2009). A distinct bending of skeleton 013's left femur caused a difference in length of 0.8cm by the time of death (Figure 4.49).

Figure 4.49. Comparison of the right (top) and left (bottom) femurs from skeleton 013, showing marked bowing of the left femoral shaft. ©CAL Davenport.

Although this shortening would have not been sufficient to cause significant clinical dysfunction, it is likely that this non-adult individual had a slight limp. Although this illness is described with symmetrical bowing of the long bones, there have been cases where the deformity is only present in one bone (Brickley *et al*, 2010).

Systemic disease

Systemic lupus erythematosus (SLE)

Skeleton 019 presented with slight osteo-arthritic lipping on thoracic vertebrae and rib tubercles, along with periosteal reactions to the bone surface on the left and right lower orbital margins and the midline of the zygomatic (Figure 4.50). Lytic lesions were observed on the left leg, which was mirrored between the lateral tibial plateau and lateral femoral condyle, and the thoracic vertebrae. All joint surfaces throughout the skeleton had a rough texture indicating a reaction occurring at these locations. Research into the archaeological literature did not explain the presentation of the unusual bone modelling, in particular the reactions present on the lower orbital margins. A search in the medical literature for information on illnesses that would cause infection or inflammation in this area of the face resulted in a possible diagnosis of systemic lupus erythematosus (SLE).

Figure 4.50. Lower orbital margins of skeleton 019 showing the symmetrical areas of reactive bone on the left and right lower orbital margins (yellow) and the periostitic area on the midline of the zygomatic (white). ©CAL Davenport.

This condition has been documented in medical literature since the 10th century; however, it was likely known as herpes esthiomenos or gnawing dermatosis prior to this (Mallavarapu and Grimsley, 2007). The term *lupus* translates to 'wolf', and it is thought that the term was given to this illness due to the appearance of those suffering with this condition bringing to mind animals and the fear that people could transform into them (Michelson, 1946; Bertsias *et al*, 2012). SLE is a chronic, relapsing illness, which can cause inflammatory reactions of the skin, joints, kidneys and serosal membranes. The condition occurs when the body does not recognise its own tissues and releases antibodies to attack it. It has been reported as a rare condition that is more likely to appear in young females who are otherwise healthy, presenting itself externally as a photosensitive malar rash (Bertsias *et al*, 2012; Figure 4.51).

Figure 4.51. The typical presentation of the malar rash in systemic lupus erythematosus (SLE). ©Colorado Arthritis Center, 2017.

SLE has a range of symptoms that occur during a flare which include fever, weight loss, lymphadenopathy, joint pain, anaemia, and arthritis. Of these, both osteoarthritis and cribra orbitalia are present on the skeleton, providing further evidence for the diagnosis. Skeleton 019 also had roughening of the articular joint surfaces, and an erosive lesion present in the left tibiofemoral articulation. The erosive lesions are typical of meniscal tearing, which has resulted from part, or the entire meniscus being displaced towards the joint centre, which then disrupts the movement of the knee joint (Fahmy *et al, 1983*). The erosive lesion described here is likely to have developed from excessive squatting or stooping, rather than the pathological condition observed on skeleton 019 (Capasso *et al*, 1999).

Infectious disease

Periostitis is the non-specific formation of bone due to an inflammatory response in the surrounding soft tissues (Roberts and Manchester, 2005). Periostitis is often observed in skeletons who have suffered trauma, with the presence of osteomyelitis increasing the potential for periostitic reactions. A complete compound spiral fracture to the right distal tibia of skeleton 016, most likely due to the fracture causing perforation of the skin during the injury, resulted in active periostitis present on the tibia. Further areas of periostitic reactions were also found on both fibulae (which also had fracture sites) and the left tibia.

Diffuse periostitis was present on the pleural surface of the ribs of skeleton 015, along with small periosteal changes to long bone metaphyses and pubic symphyseal changes. The presence of diffuse periostitis on the inside surface of the ribs (particularly the vertebral end) can indicate an infection in the pleural cavity, and has been documented in confirmed tuberculosis (TB) cases (Kelley and Micozzi, 1984; Matos and Santos, 2006; Roberts *et al,* 1998). Skeleton 015 was truncated by the west section wall in trench wall, limiting the potential for diagnosis, as the operational definition for tuberculosis requires the assessment of the thoracic vertebrae. However, only the lower five were available for assessment, with minimal changes present on the vertebral bodies.

Trauma

Fractures were noted on 10% of the cemetery sample, with two female adults affected. Skeleton 016 had one complete compound spiral fracture to the right distal tibia, and two complete compound oblique fractures to left distal and right proximal fibulae (Figure 4.52). The spiral fracture to the right tibia had resulted in an infection in the bone, most likely due to the fracture causing perforation of the skin during the injury. Breaking of the skin would have resulted in bacteria infecting the site and making its way into the bloodstream, however, the level of bone production and healing suggests that the individual had access to some medical care or treatment that enabled her to fight the infection. A fracture identified on the second right rib of skeleton 019 had healed fully, indicating the injury had occurred several years prior to death.

Figure 4.52. The right distal tibia of skeleton 016 showing the site of the spiral fracture (left). The cloaca (yellow arrow), which would have provided drainage of pus from the medullary cavity. The radiograph (right) shows the size of the cavity caused by the infection inside the bone. ©CAL Davenport.

Dental Pathology

The analysis of the dentition from archaeological samples can provide information on the health, diet and hygiene of a population. Fourteen skeletons (11 adults and 4 non-adults) had surviving dentition. There were very few pathologies on the non-adult dentition (36 deciduous and 31 permanent teeth); therefore, all calculations carried out to assess sample health will include the adult dentition only. Of 352 tooth positions, 66 (20.6%) were post-mortem loss (51M/44F) and are not included in the percentage frequencies to prevent bias in the sample. Congenital absence was noted in two individuals, with a third molar being absent in each case (skeleton 002 - RM_3 and skeleton 018 - LM^3). Frequencies are calculated by overall sample and within each sex grouping (Table 4.12).

Table 4.12. Per tooth frequencies for each pathological condition present on the adult dentition from Chester Greyfriars. Percentages are based on the number of tooth positions available (109M/116F) following exclusion of post-mortem loss.

Pathology	All Teeth	Sex		Age	
		Male	Female	< 35 yrs	> 35 yrs
Caries	13 (5.8%)	7 (6.4%)	6 (5.2%)	1 (1.7%)	12 (10%)
Abscess	8 (3.5%)	3 (3.7%)	4 (3.4%)	2 (3.4%)	6 (7.1%)
AMTL	44 (19.6%)	12 (11%)	34 (29.3%)	4 (6.8%)	40 (33.3%)

When the bacteria present in the plaque metabolises the sugars present within the diet, it forms acid, which weakens the dental enamel through the loss of minerals, leading to cavity formation (Zero 1999). The sugars in the diet would have been found in fruits, vegetables, dried fruits and honey, all of which were available in Chester through the markets and the import trade from Ireland. Complex sugars are usually less cariogenic and are found in carbohydrates, but they can become more cariogenic when cooked or ground into powders. Caries were identified in five individuals from Chester Greyfriars caries, with similar numbers reported in both sexes, but with a higher frequency in the older age group. When bacteria enters the pulp chamber of a tooth due caries, attrition, tooth damage or periodontal disease, it can cause inflammation and a build-up of pus at the apex of the root. This build-up can lead to the formation of a hole around the root that serves to drain the pus and relieve pressure on the surrounding nerves (Roberts and Manchester 1995; Figure 4.53). The number of abscesses were similar between the sex and age groups of the three individuals with this pathology. Antemortem tooth loss (AMTL) was reported in five individuals with a higher percentage of loss in females than males, and age also being a factor.

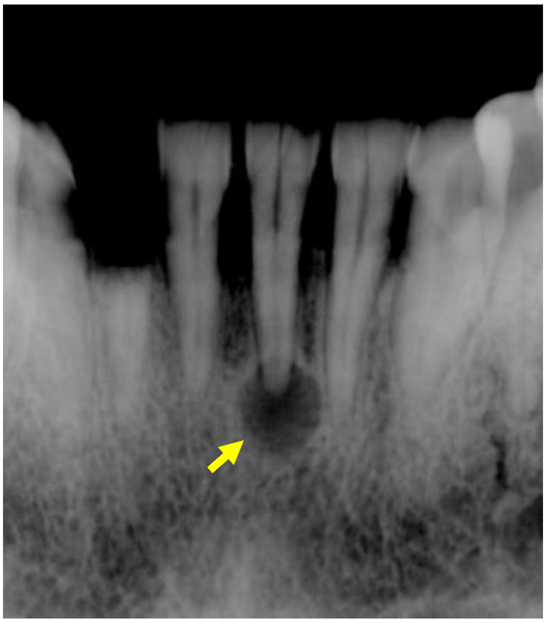

Figure 4.53. Radiograph of the abscess present at the root apex of the left I_1 from skeleton 004 at Chester Greyfriars. ©CAL Davenport.

Calculus can provide information into the dental hygiene habits of past populations. Plaque build-ups occur when the teeth are not cleaned properly or on a regular basis, leading to the mineralisation of the deposit along the gum line (Figure 4.54). High rates of calculus have also been documented in populations that have a high protein intake (Roberts and Manchester 2005; Hillson 1996). Calculus was observed in four individuals, and at a higher frequency in females than males. Dietary analysis using stable isotopes was carried out on skeletons 010, 014 and 018, with the results and impact on calculus formation discussed in the summary. Attrition was noted on nine of the adult skeletons from Chester Greyfriars. Skeleton 019 displays lingual surface attrition of the maxillary anterior teeth (LSAMAT), but no corresponding wear on the lower dentition (Irish and Turner, 1987; Figure 4.55). Gradual wear over a long period indicates that an abrasive material was placed in the mouth and pulled against the upper dentition by the tongue, possibly for preparation of plant material for food or medicines, or due to an occupation such as leather working. Another hypothesis given would be due to consuming shellfish, which was abundant in Chester during the medieval period. As the shellfish would often contain abrasive sand particles, this could account for the wear on the teeth and the notches present in the left I^1 (refer back to Figure 4.54).

Figure 4.54. Skeleton 019 presented with a build-up of calculus along the upper gum line (blue arrows indicate a portion of the total calculus sample) and dental notches present on the left I^2 (yellow arrows). ©CAL Davenport.

The presence of attrition can also be an indication of other conditions. Five of the skeletons from Chester Greyfriars had degeneration of the temporomandibular joint, which could be an indication of cultural activities leading to masticatory stress or a diet heavy in abrasive foods. Skeleton 019 had well developed pterygoideus lateralis insertions on the mandibular condyles, particularly on the right side and palatine tori, which further support the cultural or occupational reason behind the osteological changes to this particular skeleton. The remaining skeletons did not display any other pathological traits, suggesting that the changes present were due to diet.

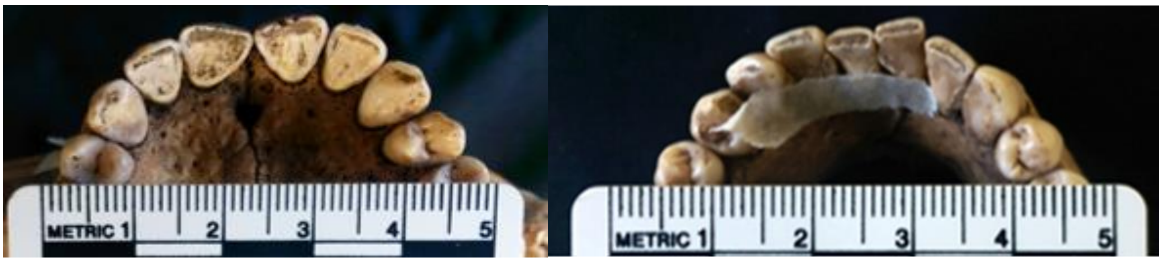

Figure 4.55. Skeleton 019 showing lingual surface attrition of the maxillary anterior teeth (LSAMAT; top), with no corresponding wear on the lower dentition (bottom). ©CAL Davenport.

Enamel hypoplasia is the manifestation of lines, grooves or pits on the surface of the tooth crown, which represent a period when crown formation is halted due to periods of severe stress, such as episodes of malnutrition or disease. Three individuals (15%) showed evidence of linear enamel hypoplasia (lines on the tooth surface). Two of the individuals were radiocarbon dated and underwent stable isotope analysis, meaning that a comparison to both the diet and timeline may provide an insight into the possible causes of stress during their childhoods.

Occupation/activity markers

Bone micro-trauma caused by continuous or repetitive strain at muscular insertion points can indicate past activity, due to the formation of bone defects at these sites. The adult skeletons (n=15) from the Chester Greyfriars sample were assessed for evidence of micro-trauma, to determine some of the activities or occupations undertaken by the medieval Chester population. In some cases, there are indications that activities carried out on a regular basis, but as it is a singular motion or action causing the marker, it is difficult to interpret what activity that individual was carrying out at the time. An example of this would be the osteophyte formation at the quadriceps tendon insertion of both knees from skeleton 003, which is most likely caused by heavy lifting. Skeleton 019 had developed tibiofemoral erosive lesions in the right knee, which indicates regular squatting or stooping actions.

The assessment of skeleton 010 gave more information due to a range of markers present on the skeleton. Humeral hypertrophy develops from a high level of arm movement and the presence of OA on the clavicles suggests that there was significant elevation of the arms. Osteoarthritis on the clavicles can be caused by heavy lifting and the throwing of items over the shoulder, with the increased robusticity at the lateral end of the clavicle indicating that there was also force applied in a downwards direction, most likely due to carrying heavy loads with the arms extended down the sides (Capasso *et al*, 1999). Skeleton 004 exhibited a range of indicators that not only suggested the activities undertaken in life, but also a potential occupation. The presence of a bipartite acromion process on the right scapula is a result of non-fusion of the acromion process caused by a continual heavy loading of the right arm (Capasso, *et al*, 1999; Figure 4.56). This trait has been seen in medieval individuals who were trained to use the English Longbow, including those the archers that were recovered from the *Mary Rose*, King Henry VIII's flagship, which sank in 1545 off the Isle of Wight (Stirling 1984; 1985). A further study by Miles (1994) also described the trait, which was seen in males and females from a Scottish, post medieval sample. Wienker and Wood (1987) investigated the trait in the skeleton of a migrant citrus picker from Dade City in Florida discovered in 1981. Although the activities described which led to the non-union, all cases note the same increased activity having occurred from a young age leading to the non-union of the acromion process. The formation of the costal syndemosis (attachment point for the costoclavicular joint) also indicates heavy labour, which has produced stress on the pectoral girdle when the shoulders were bent forward while bending and moving heavy loads (Stirland, 1985; 1991).

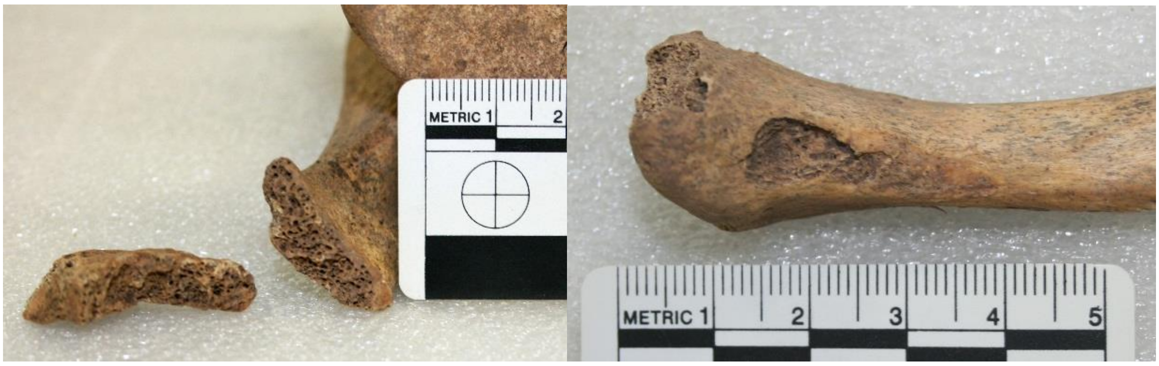

Figure 4.56. Bipartite acromion process on the right scapula of skeleton 004 (left) and the pronounced costal syndemosis on the right clavicle. ©CAL Davenport.

The insertions of the teres major and pectoralis major develop from the abduction and adduction of the arm and movement of the hand across the chest (Capasso *et al*, 1999). This trait is seen in both humeri of skeleton 004 (Figure 4.57), with stronger development evident on the right arm. Assessment of the humeral robusticity indices on this skeleton were notably different on the left (63.96) and right (68.13) sides, suggesting that the right arm was the dominant arm. Further evidence of physical activity and the lifting of heavy weights was also noted in the presence of Schmorl's nodes in the vertebral column (Kelley 1982; Kelley and Angel, 1987; Campillo 1998).

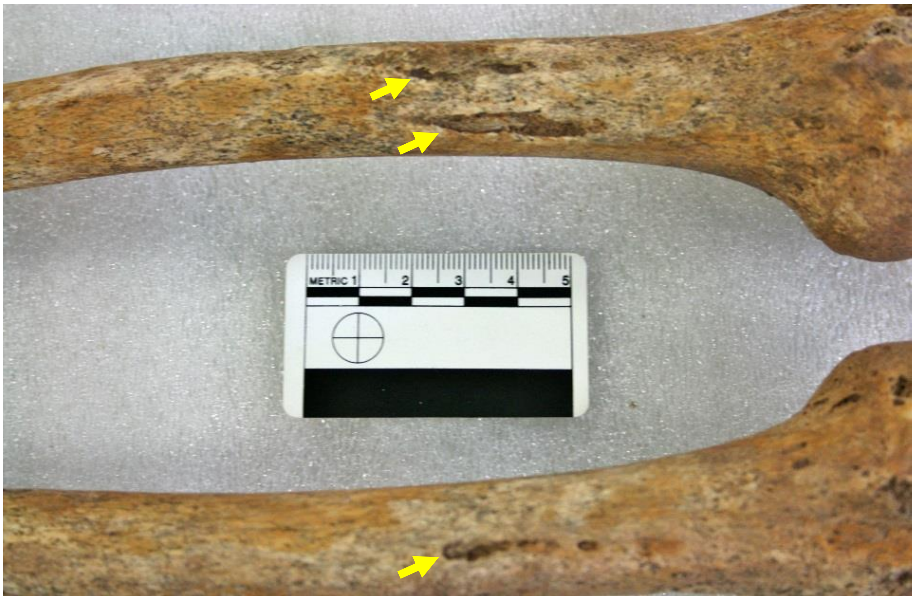

Figure 4.57. Right (top) and left (bottom) humeri show the difference in development of muscle markers present on skeleton 004. ©CAL Davenport.

During the medieval period, all males were required to learn the English longbow from a young age, with the size of the long bow growing with the individual training until reaching the adult length of 1.8 metres. The draw weight of the weapon was up to 125 pounds and during battle, the bowman would be expected to release between 12 and 20 arrows per minute (Stirland 1984; 1986). Longbow use would require extensive training and would place significant amounts of strain on the shoulder, especially in the adolescent skeleton, where fusion has not yet occurred (Stirland, 1986). The assessment on skeleton 004 indicated that this 35-39 year old male individual, 35 years old had the markers consistent with those of a long bowman. Radiocarbon dating of skeleton 004 revealed that this individual had died 1425-1470 AD, which was a time when the infamous Cheshire Bowmen were used as part of the Kings Guard, many of which originated from, or were trained in Chester. The first major battle of the War of the Roses took place on 23rd September 1459, suggesting that this individual may have trained with, or even been present at the Battle of Bloreheath.

Further evidence of activity was found on skeleton 015, a 30-34 year old female who displays traits typical of a horseman/woman. The phalanx flexor hypertrophy seen on skeleton 015, is seen when holding an object or tool in a tight grasp, with the strain of flexing the fingers causes stress on the ligament attachment points. Developed insertions for the iliacus, pectineus and gluteus maximus are caused by the extension of the hip, which serves to keep the individual upright in unstable conditions. The presence of tibial squatting facets suggests the continual dorsiflexion of the tibiotalar joint, which leads to the tibia and talus regularly meeting each other, producing additional facets on the talus. The combination of the traits mentioned above, produce the actions associated with horse-riding (Molleson and Hodgson 1993).

4.12. Geochemical studies on human skeletal material

Radiocarbon dating

Documentary evidence indicates that the site was in use from 1237 until the dissolution of the friaries in 1538. However, it is unclear whether burials continued to take place on the site for a period after the dissolution or whether this was stopped immediately. The plans of the friary show the location of the church and the East cemetery but do not show the South cemetery therefore, there is no indication as to when this part of the cemetery was in use (Bennet, 1921). Therefore, radiocarbon dating was carried out on seven of the skeletons to date the phases identified during excavation. The radiocarbon dates provided by the analysis done by Beta Analytical (Miami, USA) are shown in Table 4.13.

Table 4.13. Radiocarbon dates obtained for six skeletons from Chester Greyfriars, carried out by Beta Analytical (Miami, USA).

Skeleton number	Tooth sampled	Dates obtained
002	Right upper second molar	AD 1290-1410
004	Left upper second molar	AD 1425-1470
010	Left upper canine	AD 1155-1255
014	Right lower second molar	AD 1270-1305/AD 1365-1385
018	Right upper second molar	AD 1285-1330/AD 1340-1395
019	Left upper second molar	AD 1285-1400

The date range for skeleton 010 was given as AD 1155-1255; however, the site was not used for burials until the founding of the friary in 1237, making it possible that this individual and the others in this phase could have been among the earliest interred at this cemetery. The date range for skeleton 004, a possible medieval longbowman, covers one of the most significant battles in British medieval history, ‘The Battle of Blore Heath,’ which was the first major battle in the War of the Roses. The Cheshire archers, formed as part of the king’s guard, were notorious for their archery skills and being able to ‘get away with murder’, receiving pardons for crimes that would result in most others would being hung, drawn and quartered. The Battle of Blore Heath saw the first significant defeat of the Cheshire Archers on 23rd September 1459.

Dietary stable isotopes

Studies on diets in the medieval period have been carried out to investigate the difference between rural and urban populations, status difference and dietary trends throughout the medieval period, with particular reference to the changes in food availability either side of the Black Death (Woolgar *et al*., 2006). Both literary and environmental sources have agreed that cereals were the main components of the English medieval diet (Connell *et al*., 2012; Woolgar *et al*., 2006; Thomas *et al*., 1997). Wheat was used for bread making and oats in pottage, a basic broth consumed by most status groups within a population. Cereals were malted to produce ale and vineyards would have enabled the production of wine (Connell *et al*., 2012). As cereals can inhibit the absorption of iron, it is also likely that pulses were included in the diet, though evidence of this particular food group has been scarce due to its infrequent preservation and recovery from environmental remains (Wadsworth, 1992).

Dairy products provided much needed fat and protein for lower status groups, though there is evidence to suggest that sheep’s milk became a less popular choice for consumption following the increase in the wool trade in the 13th century (Woolgar *et al*., 2006). The most common meats used for food consumption include, pork, beef and lamb, although documentary sources have identified beef as the most commonly consumed (Albarella, 2006). The consumption of fish served as a substitute to meat consumption on fasting days and during lent, with marine fish most commonly consumed due to the restrictions on freshwater fishing (Schofield and Vince, 2003). Many higher status groups, including abbeys and priories had private fishponds, which provided freshwater varieties to the select few. As both fish and meat were more expensive, the lower status groups would have consumed these less regularly than their higher status counterparts (Schofield and Vince, 2003). During the medieval period, fish was seen to have health benefits, leading to high rates of consumption among those recovering from illness. Studies carried out on heavily marine-dependent populations have found that the rate of dental caries is significantly reduced when compared with hunter-gatherer populations (Sealy et al, 1992), possibly due to the lack of fluoride in the water, which would be negated by the consumption of marine fish.

Carbon and nitrogen isotopes analysis was carried out on six skeletons from Chester Greyfriars (Table 4.14) to assess differences in diet between the individuals interred in this section of the cemetery. The mean $\delta^{13}C$ values (-19.32 ±0.94‰) for the Chester Greyfriars samples were consistent with a diet focused on C_3 plants, which was supported by the documented evidence on trade and agriculture in Chester during the medieval period (Lewis and Thacker, 2003). Mean $\delta^{15}N$ values (11.48 ± 1.53‰) were consistent with a shift of 1-2 level trophic shift (5.67‰) above the herbivore baseline (5.81 ± 0.19‰, n=51); indicating that the diet contained animal and marine sources, along with a regular intake of omnivore or freshwater fish protein. The results are supported by the literature on the city of Chester, which reports that the city held a fish market serving both freshwater fish from the earl's fishery by the Dee Bridge, and marine fish that was caught locally or imported (Lewis and Thacker, 2003). The twice-weekly markets held by St Peters Church and the abbey gate provided agricultural commodities, with dairy produce and meat sold by the cross.

Table 4.14. Stable isotope analysis results for six skeletons from Chester Greyfriars, carried out by Beta Analytical (Miami, USA).

Skeleton number	Tooth sampled	δ13C	δ15N
002	Right upper second molar	-19.6	9.6
004	Left upper second molar	-19.7	11.1
010	Left upper canine	-18.8	12.4
014	Right lower second molar	-17.8	14.2
018	Right upper second molar	-20.9	10.0
019	Left upper second molar	-19.1	11.6

Of particular interest during the interpretation of the results was skeleton 014, whose nitrogen and carbon values where indicative of an individual with an extremely rich diet. Unfortunately, due the section boundaries, only the skull and six cervical vertebrae were retrieved from this trench, limiting the knowledge about the lifestyle of this adult male. However, the dentition gives some insight, with extensive attrition, antemortem tooth loss, caries and abscesses; it is evident that this individual likely had a varied diet, including access to sugar or honey. The dietary analysis indicates that this individual ate meat-fed omnivore protein, due to the further increase in trophic level over the other skeletons tested (Figure 4.58). The shift in carbon values indicate that skeleton 014 also had access to C_4 plants on a regular basis. Although corn was likely grown around the city, it was not in high enough quantities to be regularly available to the townsfolk. However, during Edward I's campaigns (especially in 1282-3) the supply of foodstuffs to the city from the crown increased considerably due to the cessation of trade with the Welsh. Extremely high quantities of peas wine, salmon, beans, cheese, salted meat and corn were sent to the city, with most of the foodstuffs sent from Ireland. Although the radiocarbon dates for skeleton 014 coincide with the campaigns of Edward I, the dietary requirements would need to be consistent and during childhood to account for the levels taken from the tooth enamel. The carbon and nitrogen values for skeleton 014 indicate a high status diet during childhood, with the dental pathology suggesting that this individual continued to have a high status adult life.

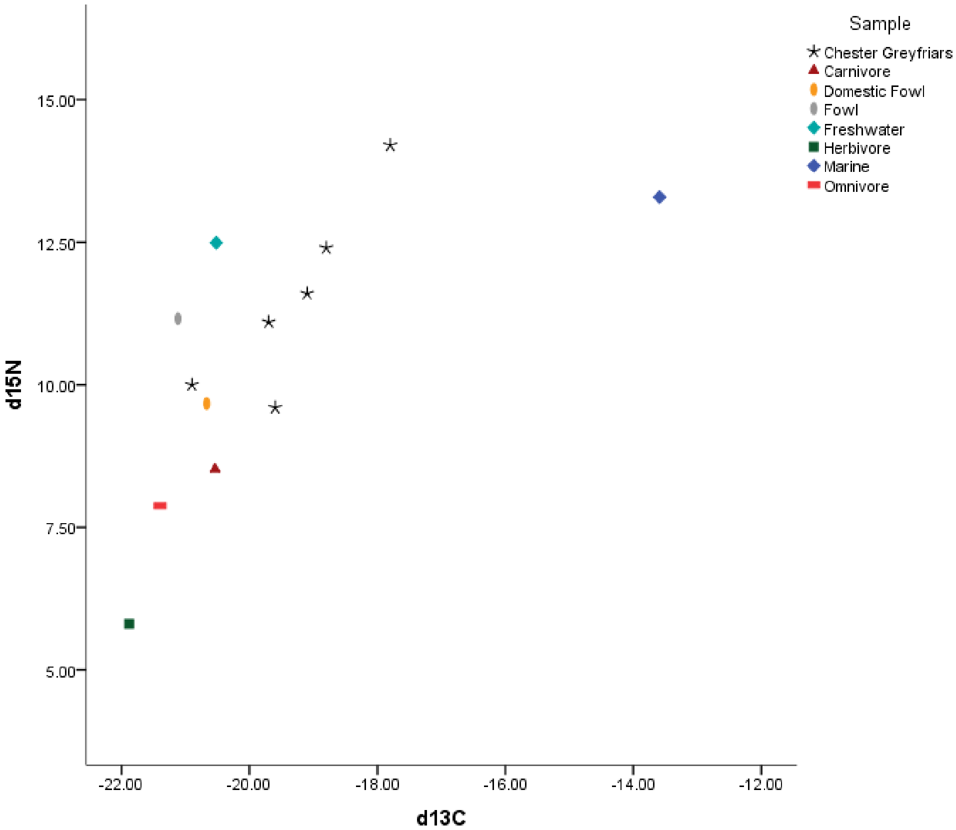

Figure 4.58. Stable isotope values ($\delta^{13}C$ and $\delta^{15}N$) for the six Chester Greyfriars skeletons in comparison with the faunal, freshwater and marine values available for the medieval period (Müldner and Richards, 2007a; 2007b; Müldner *et al,* 2009).

Skeleton 018 had very low nitrogen values when compared to the other skeletons from the Chester Greyfriars site, however, it is reported that nitrogen values can be higher in osteoporosis patients during the third and fifth decades of life (White and Armelagos, 1997). Skeleton 018 was estimated to be in her sixth decade of life at the time of death, which could account for the lower levels, although it is more likely representative of the dietary protein available to this individual (White and Armelagos, 1997). Skeleton 002 had rheumatoid arthritis, although there is no literature to support the theory that nitrogen levels could also be affected in this case, given the destruction and remodelling of the bone it may be a factor in the low values observed, or due to dietary protein availability.

4.13. Phasing following radiocarbon dating

The radiocarbon dating results show that the archaeologist's interpretation of the phasing needed to be adjusted to reflect the phases present in this section of the cemetery. The dates suggest that there were at least four phases represented in trench 11, with a readjustment of the phases assigned in trench 12 (Table 4.15). The radiocarbon date for skeleton 004 (AD 1425-1470) is the latest for any burial dated so far at this cemetery, with the uppermost burials in trench 12 possibly being interred around the same time.

Table 4.15. Revised phases and dates following the radiocarbon dating, with the skeleton numbers for each phase. Although the dates for phases II and III are similar, it should be noted that there were two distinct layers of burial during this time.

	Phase			
	I	**II**	**III**	**IV**
	1155-1255 AD	**1270-1400 AD**	**1290-1410 AD**	**1425-1470 AD**
Trench 11	005, 008, 010, 011, 015	001, 012, 013	002, 007, 009	004
Trench 12	020	014, 018, 019	006, 017	003, 016

4.14. Summary of site results

The cemetery of Chester Greyfriars was in use for approximately 300 years; however, there has been very little investigation into the site, due to the continual use of the site following the dissolution in 1538. The archaeological work carried out as part of the commercial development of the site has enabled a small insight into the lives of some of the people who lived in Medieval Chester, and were interred in the South section of the cemetery. Phase 2A of the planned works produced a mixed sample of adults and non-adult burials. However, although there was representation of both infants and juveniles (0-12 years) in the non-adult sample, adolescents (12-18 years) were not recovered. The adult sample was evenly distributed within the groups of young, middle and old, with similar numbers of males and females represented in both. The small size of this sample limits the potential for demographic analysis, as it would not be representative of the overall population. The skeletons excavated support the theory that this area of the cemetery was used by the lay population, with the friars possibly interred elsewhere on the site. This practice has been seen at Norton Priory, which identified the preferred resting places of the canons and priors found to be the east end of the Chancel and a separate cemetery immediately south of the Chancel (Brown and Howard-Davis, 2008). Given the high number of individuals with pathological traits and the level of care given in treating the sick, there may have been an infirmary present on the site, as has been observed with other Franciscan sites (Stocker, 1984; Greene, 2005; East, 2017). The level of truncation at Chester Greyfriars was much lower than had been observed at other medieval sites. In some instances, there was evidence of the gravedigger having stopped digging once a burial was reached and the new burial placed on top. The practices demonstrated at this site exhibit a higher level of care and respect for the dead, which may be due to differences between the practices in the various religious houses or the number of burials permitted at this cemetery.

When assessing the biological profiles of the individuals from this excavation, there were a number of females with very short stature, with the heights falling significantly below the mean value for the medieval period (Cafell and Holst, 2005). Despite the differential preservation of the skeletal remains, evidence of disease and trauma could be observed on half of the sample. The most common pathological conditions included osteoarthritis (n=5) and *cribra orbitalia* (n=3), with trauma noted on two individuals. Evidence for physical stress during childhood was observed in the form of pitted eye orbits and linear enamel hypoplasia. The presence of an individual who may have suffered from systemic lupus erythematosus (SLE), which is previously unrecorded in the osteological literature, highlights the potential for further research at this site. The dentition of the Chester Greyfriars skeletons had not suffered as severely from erosion as the bones, which meant that the quantity and quality of dental disease observed in this sample was much better than that of bone pathology. Tooth decay, abscesses, ante-mortem tooth loss and mineralised plaque were noted in many individuals and increased in frequency with age. While the number of cavities was typical of the period and generally low, heavy wear of the teeth was common, leading to abscesses and ante-mortem tooth loss. Oral hygiene was poor, resulting in plaque concretions.

The radiocarbon date for skeleton 004 (AD 1425-1470), who also bore the occupational skeletal markers of a bowman (Miles, 1994; Stirland 1984; 1986), coincides with the timeframe for the infamous ‘Bowmen of Cheshire’ (Gillespie, 1987). The bowmen were renowned for being the best in medieval England, most likely due to the close proximity to Wales requiring the constant training with the bows to help with the frequent skirmishes that occurred. Part of the royal bodyguard from 1334, the bowmen were involved in many battles over the years and formed part of the Lancastrian forces present at the Battle of Blore Heath in 1459. Dietary evidence suggests that the bowman had a varied diet, which is indicative of a higher status individual, lending further support to this theory as the bowmen were sourced from noble families. However, the richest diet was that of skeleton 014, which unfortunately had been truncated by the section wall and therefore limiting the amount of information retrieved about this individual.

To gain a better understanding of the activity at the site, and how it has affected the preservation of the human remains, soil sampling was undertaken and analyses conducted to gain an understanding of the differences between the trenches and as an overall sample.

When human remains are excavated from a site, it is a destructive process. By collecting as much information as possible about both the skeleton and the surrounding burial environment, it is possible to gain a better understanding of the taphonomic conditions present. A multi-disciplinary approach not only aids the initial osteological assessment, but also enables those undertaking further analytical testing to assess the potential for successful results. The calcium levels within the bone were more abundant in burials that had not been disturbed, with female individuals retaining higher levels than males. Pathological conditions also produced higher calcium levels in the bone, possibly due to high porosity enabling the calcium in the soil to replace the potassium at a faster rate. The protein-mineral bond seemed to survive well, although there was no relationship between this and collagen level. Higher levels of iron in the bone indicated the presence of a coffin, whereas increased potassium levels were present in disturbed or secondary burials. Calcium levels at this site seems directly affected by pH levels in the soil and taphonomic damage to the bone, however no relationship was identified with collagen extraction. Taphonomic damage to the bone is directly affected by the soil conditions, with particle size, and the iron levels in the soil both having an influence on the levels pf abrasion/erosion and fragmentation observed. A greater degree of abrasion/erosion on the cortical bone surface makes the bone more vulnerable to the surrounding substrate and increasing the likelihood of fragmentation. Adult burials had higher rates of abrasion and erosion the non-adult burials, although this appears to be due to the presence of coffins rather than the mineral component of the bone.

Taking into account all the factors analysed at this site, if further analytical testing was to be carried out on the skeletons based on the data collected so far (such as radiocarbon dating, stable isotope analysis or ancient DNA), there will be a greater chance of success with a skeleton with low levels of bone remodelling. A more neutral pH level and low levels of archaeological disturbance, and therefore less foreign material introduced to the burial matrix, would ensure lower abrasion/erosion and fragmentation rates. Skeletons with arms close proximal to the thorax are more likely to have been shrouded burials and therefore will have less abrasion/erosion and fragmentation, producing higher collagen yields than the coffin internments. The Chester Greyfriars sample has provided an insight into the individuals served by the Franciscan Friary and their lifestyles, which was previously unexplored in the City of Chester. Although the sample is small, the amount of data recovered was significant, and therefore adds to its importance, making it an interesting addition to the archaeological record.

Chapter 5 – Southgate Street, Gloucester

5.1. Site background

The city of Gloucester was founded by the Romans due to its strategic location on the River Severn. As the first point where the River Severn narrows enough to allow crossed, it was viewed as an ideal location for a town, with forts built to help defend the area. When the Roman civilisation went into decline in the 4th century, the town was left to local farmers, who worked the surrounding land until the Saxons captured the town in 577AD. During the Saxon period, the town flourished becoming one of the wealthiest cities in England by medieval times. Industries in Gloucester included wool, leather (tanners, shoemakers, glovers and cappers), ironworks (weapons, nails and tools), fishing and the export of grain and cloth. By the 15th century, economic downturn due to competition from other towns in the wool trade led to a time of decreased growth. The First English Civil War (1642-1646) between the army of King Charles I and Parliament led to the people of Gloucester demolishing all buildings outside the city, to prevent the invading army of the king from finding cover. The army lay siege to the town between 10th August and 5th September 1643, retreating only when hearing of the approaching parliamentary army. In 1662, the town erected a statue of King Charles I in an attempt to gain favour, however it resulted in an order from the King to destroy the walls surrounding the town. The 18th century saw the end of the wool industry in Gloucester, with pin making becoming the main industry in what was now a small, but growing city. This century saw a period of development, resulting in an infirmary, prison and two new market places being built, while the East, North and South Gates demolished to aid traffic flow. Conditions in the city continued to improve in the 19th century, with the installation of gas lighting, piped water supplies and sewer networks. The port began expanding, with warehouses, a dry dock and another wet dock added. Transport in the city increased, with the building of a ship canal, the railway and a horse drawn tram system, which provided further trading opportunities. The city of Gloucester has continued to grow, with a population of 47,000 at the end of the 19th century to over 121,000 recorded in 2011 (Census, 2011)

Southgate Street excavations

The Southgate Street, Gloucester excavations were located on the west side of Southgate Street, between Kimbrose Way and the entrance into the docks (see figure 5.1). The site was first excavated in 1983 (site 13/83) by C.J. Guy for Western Archaeological Trust (Rawes 1984, 226-7), with a further excavation which lasted 9 months on the site in 1989 (site 3/89). The literature is currently limited to site reports, but approximately 500 burials were recovered from this urban site (Atkin and Garrod, 1990).

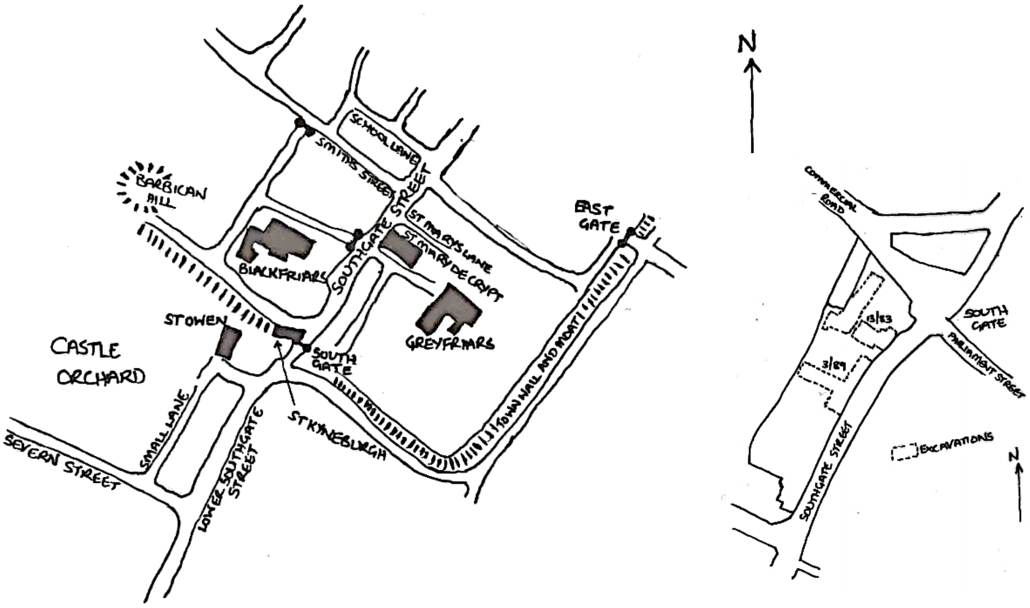

Figure 5.1. Map showing the location of St. Owens Chapel in 1500, this site later became the location of Southgate Congregational Church and Gloucester Infirmary burial ground. Map not to scale. ©CAL Davenport

The excavations were subject to time constraints due to large-scale development taking place in Gloucester at that time. This led to records being rushed and incomplete towards the end of each excavation phase, ending with large scale human bone removal in trenches, which has led to important information being lost from this site. From the archaeological record, it was clear that there were three separate burials grounds present on the site and that the archaeologists attempted to separate out the burials from each cemetery. However, both excavations covered all three burial grounds (Figure 5.2), with the crypt and confirmed infirmary burials coded differently during the 1989 excavation, but not the 1983 excavation. There was no boundary between the Medieval St. Owens burial ground and that of Gloucester Infirmary, leaving the burials in this area open to interpretation when investigating approximate time since death. Although it is possible to separate out those excavated in 1983 due to the trench layout and detailed explanations of the excavations provided (pers. comm. Neil Hampson, Mayor of Gloucester), this has not yet been possible for all of the burials excavated in 1989. To assess the demographics of the medieval St Owens Church, it was necessary to determine through archiving, curation and research, the extent of each burial ground and the human remains recovered at each excavation phase. Identification of the burial location for each inhumation was required to provide a more accurate assessment of the material given the time differences between each of the burial grounds. The following chapters provide more information on the process undertaken to separate out the individuals from each ground and the supporting historical and excavational evidence gathered during this research.

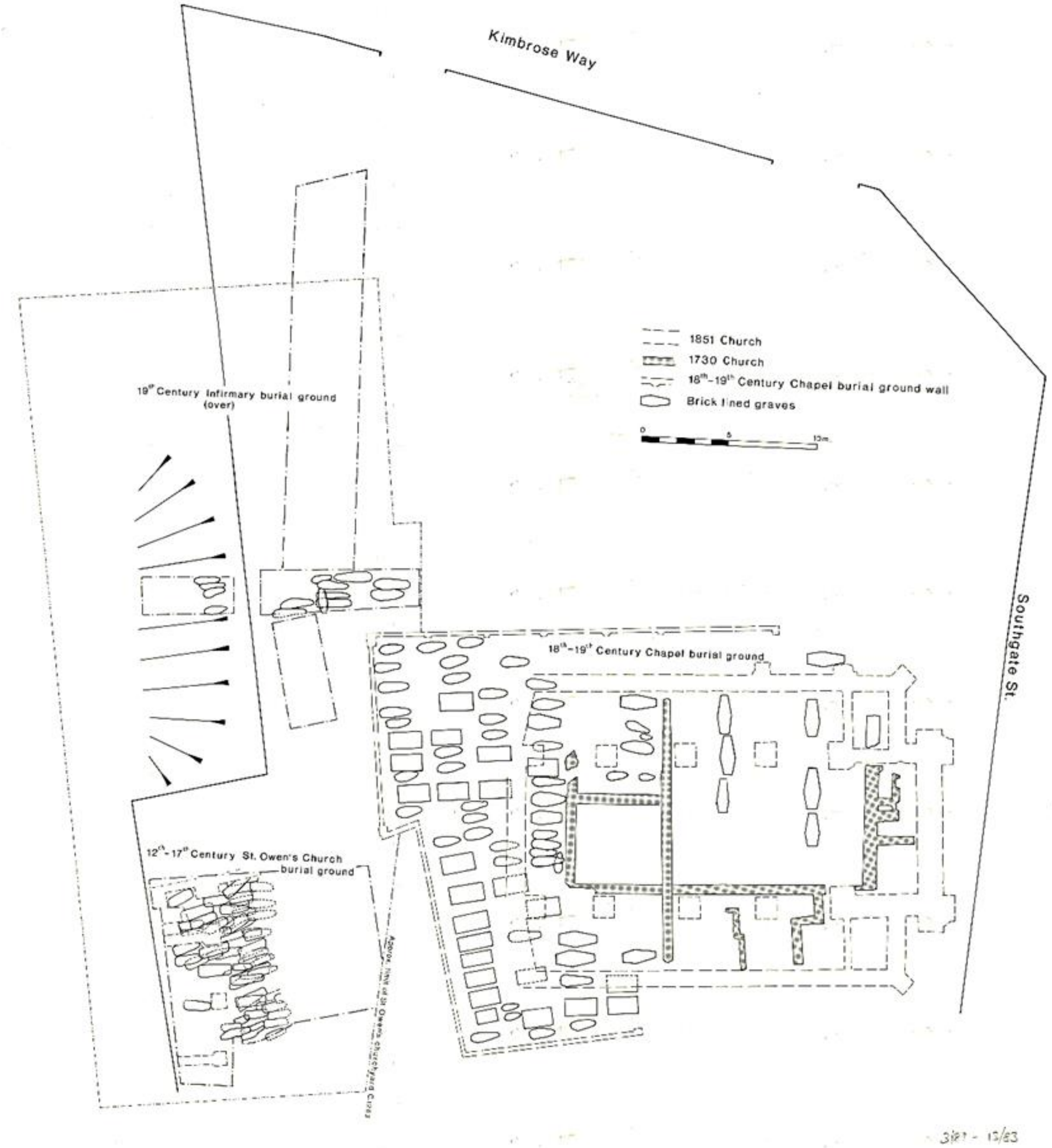

Figure 5.2. Plan drawing of the Southgate Street cemeteries produced following the 1989 excavation season. This plan highlights the boundaries of each cemetery. Note that the 19th century infirmary burial ground lies over St Owens Church. Not all burials are plotted to enable a distinction between the sites. ©Gloucester City Museum.

5.2. Geoarchaeology

The British Geological Survey (BGS, 2016) provides information on the bedrock and superficial geology of the region. The bedrock is an undifferentiated Blue Lias and Charmouth Mudstone Formation, a sedimentary rock formed between the Jurassic and Triassic periods (approximately 183-204 million years ago). This has been interpreted by the British Geological Survey as being typical of an area that was previously dominated by shallow lime-mud seas. Due to fluctuating sea levels, it is likely that carbonate deposits have been washed onto the shoreline and mixed with the mudstone. There are tidal flat deposits consisting of clay, silt and sand, overlying the mudstone. These superficial deposits most likely formed during the Quaternary period, up to two million years ago, and are found along the shoreline. The British Geological Survey data is consistent with a borehole taken approximately 140m away from the Southgate Street site (SJ 3829 2180). This borehole was taken by the City Architect, JV Wall in 1959, for the proposed development of the College of Art on Spa Road. The information given for this borehole is detailed in Table 5.1. It was not possible to obtain borehole information from the area around the docks due to the records being restricted. Water was not encountered during this borehole; however further exploration of borehole data from Gloucester have noted the presence of water at between 2.44 and 3.05m.

Table 5.1. British Geological Stratigraphic descriptions and depths taken from the Borehole at Spa Road, Gloucester (SJ 3829 2180) in 1959.

Description of strata	Thickness (m)	Depth (m)
Fill	1.52	1.52
Soft brown plastic clay	0.61	2.13
Soft mottled plastic clay	0.30	2.43
Soft to firm laminated grey shaley clay, with consistent traces of shells	1.83	4.26
Firm to hard grey shaley clay soft patches	2.44	6.70
Hard laminated grey shaley clay	3.66	10.36

As the grey clay was encountered at approximately 2.5m below the surface, it is likely that there would be mixing of this layer with the overlying deposits during construction and the burials at the cemetery. As the ground surface is likely to have risen due to development around the city, the ground level when St Owens was built would have been much lower and therefore, the true burial depth for the individuals interred at the cemetery is not known. It may be possible to investigate this issue further should the site be reopened in future development phases. At present, the site is a carpark with a level tarmacadam surface, which slopes very gently to the South (Figure 5.3).

As the excavations at the Southgate Street sites took place during the redevelopment of Gloucester city in the 1980s, it is not possible to examine the microstratigraphy of the site through sections. There are stratigraphic section plan drawings present in the excavation records; however, without extensive research it is not possible to determine the location of the sections in relation to the burials discussed in this thesis. Only two soil samples were available for analysis from the 1989 excavation, which are discussed in the following sections of this chapter.

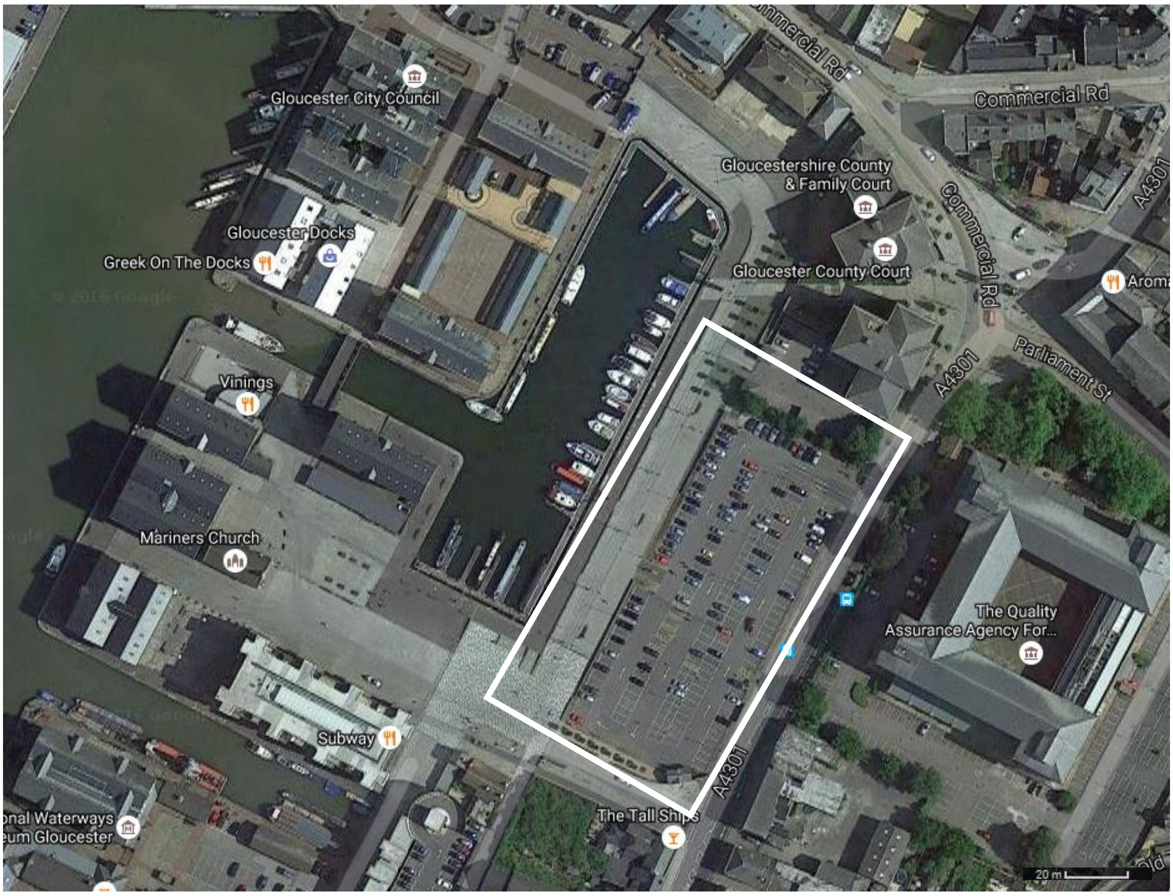

Figure 5.3. Aerial photograph showing the location of the carpark on Southgate Streets (white square), which sits on the sites of St Owens, Southgate Congregational Church and Gloucester Infirmary Burial Ground. Map courtesy of Google Maps.

5.3. Soil analysis

Two soil samples were recovered from the material made available to Liverpool John Moores University. The first was from context 1511, which was located at the south end of trench V and north of the boiler room. It was cut by the foundations for the 19th century chapel extension and crypt walls and identified as being a demolition layer from the 19th century building work. The second sample came from the burial of LC1a, which is a lead-lined coffin burial originating from the crypts/vaults of Southgate Congregational Church. As there were only two soil samples present it was not possible to present a statistical analysis of the soil data, therefore, descriptions of the findings for each sample are given.

In dry conditions the soils were noted as being dark grayish brown (2.5Y 4/2 – sample 1511) and grayish brown (2.5Y 5/2- sample LC1a), whereas both soils were noted as very dark grayish brown (2.5Y 3/2 – sample 1511, and 1YR 3/2 – sample LC1a) when wet. The British Geological Survey borehole data states that the upper stratigraphic layer comprises of fill, most likely from the extensive development carried out in Gloucester City Centre and the Docks since the Roman period. The pH values of the soil samples available were very close to neutral, rather than the expected alkaline values from deposits with high levels of calcium carbonate. The pH level identified (6.5 for both samples) is most likely influenced by the presence of coffin burials. The magnetic susceptibility values indicated the presence of iron oxides, such as hematite or goethite. The formation of goethite and hematite can occur as a result of weathering of iron rich minerals in soils, forming a red rust colour. The frequency dependent magnetic susceptibility values from the soil samples collected indicated an admixture of superparamagnetic and coarser non-superparamagnetic grains (sample LC1a - 1.764%; sample 1511- 2.252%). The mix of materials present in the soil gives further support to the inclusion of foreign material to the burial matrix through the development of the site.

Field portable x-ray fluorescence analysis was carried out on the samples from the 1989 excavation at Southgate Street to determine the distribution of the main elements associated with decomposition; calcium (Ca), iron (Fe). potassium (K), phosphorous (P) and magnesium (Mg). Phosphorous was not detected in either of the samples tested, either due to it no longer being present in the soil, or being present in quantities too small to be detected using the forensic setting on the analyser. To confirm this, the test was repeated using the light elements setting, which also resulted in no potassium detected in either soil sample. The presence of phosphates in the soil can indicate the deposition of organic wastes, or areas that contained livestock (Custer *et al*, 1986). Although human remains are organic, the lack of phosphorous in the soil demonstrates the permeable nature of the site, leading to increased leaching of this element. Calcium levels tend to increase in soil as the clay content increases, however, in the samples collected from Southgate Street this was not the case. The higher calcium level (6.37%) in the sample from LC1a, had a lower clay content (7.73%), indicating that the calcium levels may have been influenced in part by the presence of the burial. Sample 1511 was taken from a layer of stratigraphic fill rather than a burial, and had increased clay (8.04%) and reduced calcium levels (4.08%). The increased levels in the coffin may be due to leaching of the inorganic component of the bone mineral matrix. This leachate would pool in the bottom of the coffin and, in the absence of damage creating an outlet for this material, potentially lead to higher levels of calcium and other decomposition elements in burial substrate that enters. Concentrations of calcium can also be an indication of building materials such as mortar or cement present in the soil (Custer *et al* 1986). There were a number of burials that were discovered in burial crypts and vaults during the 1989 excavation of Southgate Congregational Church. As there are no surviving records indicating the location of the lead lined coffin of LC1a, it is not possible to determine whether the high calcium levels may derive from the inclusion of mortar or cement from being placed inside a crypt. Iron levels were higher in sample 1511 (4.80%), although both samples were within the expected levels for soil (between 1% and 5%). This may be due to the various construction phases at the Southgate Street site and the high number of coffin burials that were present, a number of which had iron coffin handles and nails (Figure 5.4).

Figure 5.4. Iron coffin handles recovered from the excavations at Southgate Street, Gloucester. ©CAL Davenport

Potassium and magnesium are soluble, which can lead to deficiency in sandy soils and areas of high rainfall or flooding. The soil samples collected from the 1989 excavation had good levels of potassium (sample 1511 - 1.17%; sample LC1a – 1.32%), which support the historical accounts of the clearing and firing of the site prior to the siege of Gloucester in 1643. Similarly, magnesium was also well represented even with sand components of the soil exceeding 30%, suggesting that the conditions in the areas the samples were taken from were not subject to conditions that would lead to the leaching of this element in the soil. Although, given the extremely high values present (sample 1511 – 17.45%; sample LC1a – 50.06%), it is likely that there was a source nearby leaching this element into the burial matrix. The accumulations may have increased due to the continual construction phases providing protection to the soils and further leaching.

The particle size analysis carried out on the samples revealed that both were predominantly silt, with sand making up approximately 32% of each sample and the remaining 8% being clay (Figure 5.5). The high percentages of both silt and sand particles support the results obtained from the borehole, where the upper 1.5m consisted of fill. This anthropogenic fill is most likely composed of material from the many phases of construction in the area around the docks. With construction and demolition phases present at all three cemeteries, the expansion of the docks, the addition and removal of lanes and access routes, and houses that have previously stood on the site, it would be reasonable to expect a high amount of contamination and mixing on the site.

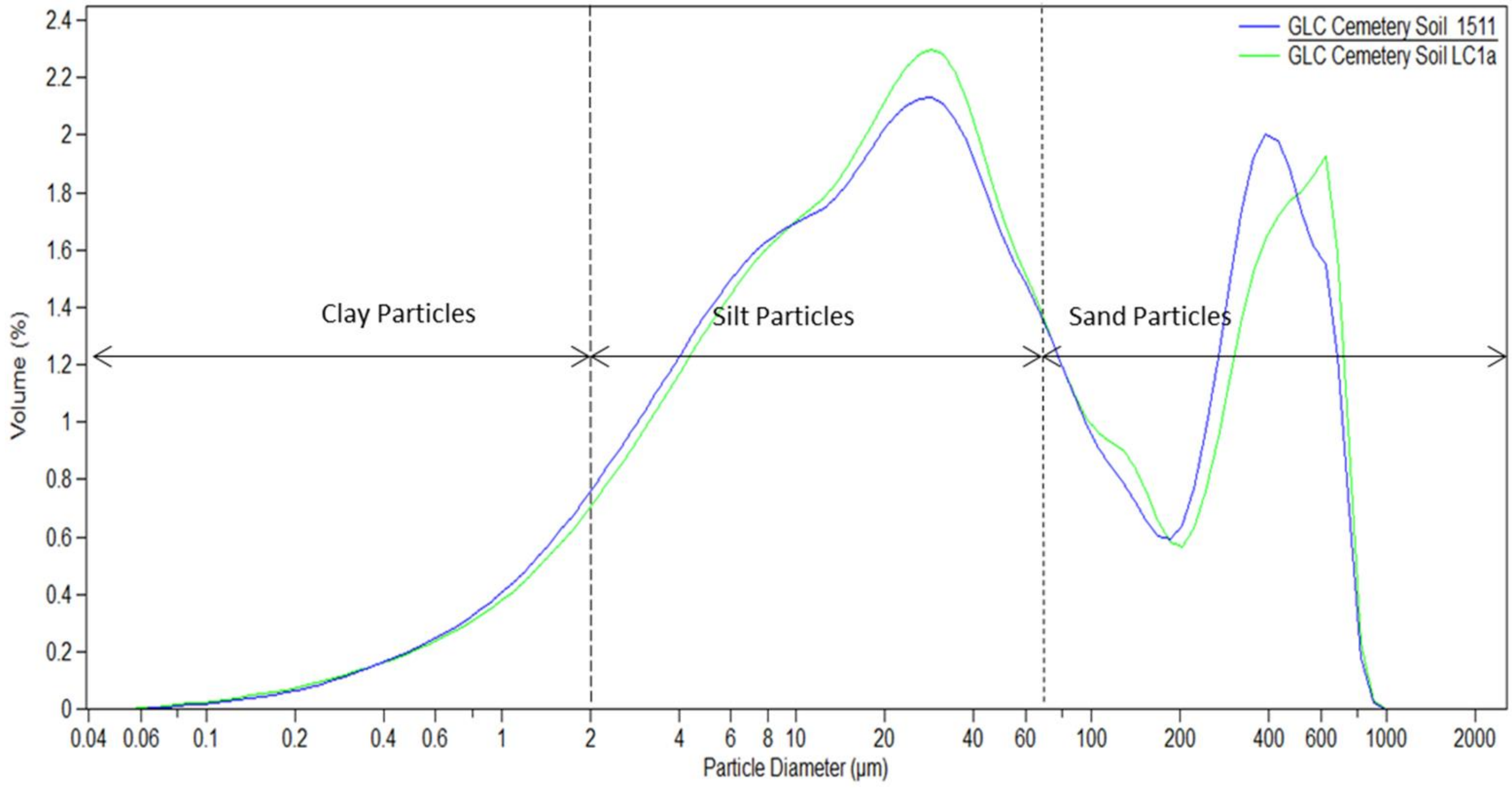

Figure 5.5. Soil particle analysis overview plot for the two soils samples available from the 3/89 excavations at Southgate Street Gloucester. ©CAL Davenport

5.4. 1983 excavation

The first excavation took place in 1983 and consisted of five trenches covering three burial grounds (Figure 5.6). The first two trenches (I and II) were the most extensive, uncovering the foundations of the congregational church and associated burials. The majority of the burials recovered from these trenches were interred in coffins, which were preserved in part and retained by the Museum of Gloucester. Trench III was located outside the church and contained burials from both the congregational church and the infirmary. Trench IV contained disarticulated remains from St Owens Church, with trench V containing disarticulated material from the crypts and vaults at the congregational church. The context records from trench III detail the limited time constraints on the excavation, so it is probable that the last two trenches were excavated using machinery, rather than by hand, resulting in the loss of contextual information. The high amount of disarticulated material recovered from trench III could be due to the disposal of human remains following teaching and research at the hospital, as several of the disarticulated crania were found with cuts consistent with autopsies. In some of the individuals, the cuts presented numerous hesitation marks, indicative of inexperience when removing the skullcap for inspection and removal of the brain.

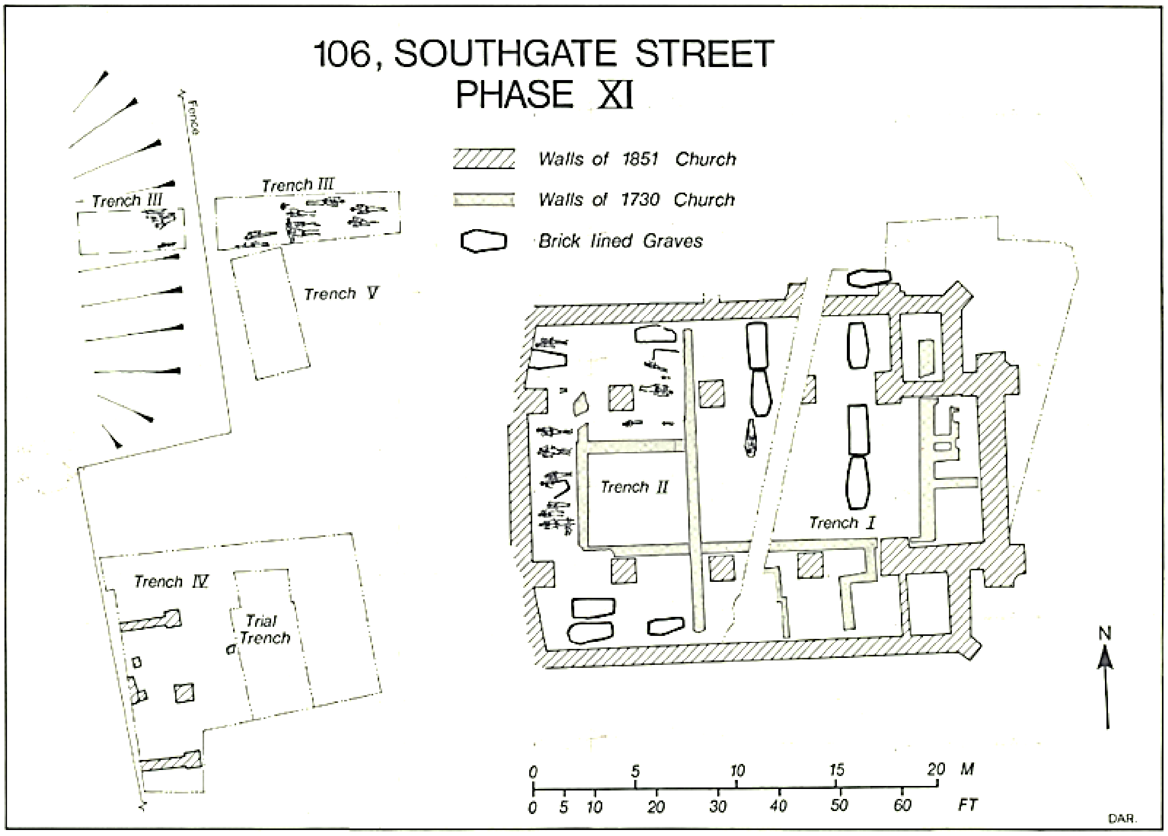

Figure 5.6. Plan of the 1983 excavation at Southgate Street, Gloucester, indicating the locations of trenches I, II, III, IV and V. ©Gloucester City Museum.

The burials assessed from the material recovered from this excavation included a number of disarticulated skulls from trenches III, IV and V. As it could be determined that they did not belong to any other burials recovered from this trench, they were assessed as separate individuals. This ensured that the demographics included as many members of the sample as possible, but without the duplication of biological profiles. The total number of individuals recovered from the 1983 excavation are detailed, by trench and cemetery site, in Table 5.2.

Table 5.2. The number of burials recovered during the 1983 excavation, listed by trench and associated cemetery.

Excavation	Trench	No of burials	Cemetery
13/83	I	1	Southgate Congregational Church
13/83	II	38	Southgate Congregational Church
13/83	III	16	Southgate Congregational Church
13/83	III	22	Gloucester Infirmary Chapel
13/83	IV	3	St. Owens
13/83	V	5	Southgate Congregational Church

5.5. Curation

Since the initial post excavational analysis following recovery, the material from the 1983 excavation had been stored in brown paper or waxed bags and placed in boxes stuffed with newspaper. In some cases, the remains had been placed directly into the box, with no padding or protection. Some of the skeletons had elements placed in several boxes (Figure 5.7) and there were several boxes with more than one individual present within a skeletal context. Permission was sought from Gloucester City Museum to clean, re-bag and re-box the material at Liverpool John Moores University following the Standards for the Recording of Human Remains (Brinkley and McKinley, 2004). The aim of this was to reunite individuals that had been separated out to numerous boxes, separate out commingled individuals and to ascertain which individuals came from each trench, thereby separating them out into the three different burial grounds. The 13/83 excavation had also produced 41 boxes of disarticulated material, which was cleaned, re-bagged, re-boxed and inventoried. This material was produced when machinery had to be brought onto site to finish excavating the trenches. At this point, trench IV was completely excavated in this manner, causing all stratigraphic information to be lost. It was possible to recover three intact crania from which biological profiling could be carried out, enabling inclusion in the resultant analysis.

Figure 5.7. Skeleton III200 housed within three boxes; elements are mixed and becoming damaged through inadequate packaging. ©CAL Davenport

Methodology

Prior to the repackaging of all material, each box and its contents were photographed to keep a record of the conditions in which the remains were received at the university. Articulated remains were sorted into numerical order of contexts and then each skeleton re-boxed to the following guidelines:

a. Photograph the remains from each box separately
b. Inventory the remains from each box and photograph in anatomical position.
c. Re-bag the remains with the red box number associated with those elements recorded in red on the bag.
d. Re-use the boxes; place a pencil line across the information on the Gloucester side of the box, turn box around and affix a label containing the information for that individual, including red box number represented in the box (Figure 178).

Disarticulated remains were also re-boxed as there were mixed contexts in bags in each box, making it very difficult to track the material taken from each trench (21 boxes contained a portion of IV568). The bags of remains were sorted by trench and context number and then boxed accordingly. The remains had not had any treatment post-excavation and required washing before any further recording took place. Washing involved the use of brushes and lukewarm water to remove the adhering mud. Any remains that had preserved hair, skin or other adhering artefacts were not cleaned. Once dried at room temperature for two days, the remains from each context were inventoried, photographed and repacked.

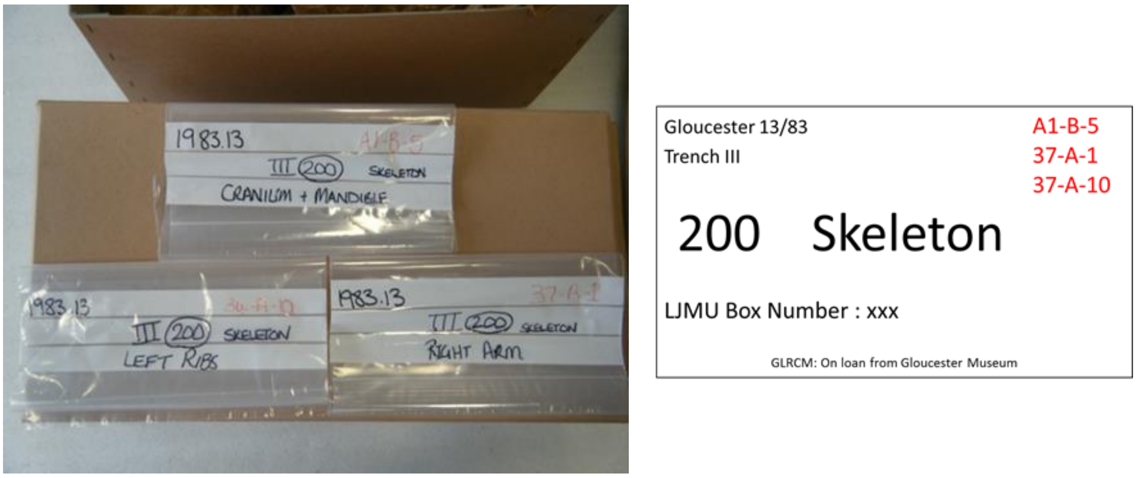

Figure 5.8. Examples of the bag labelling for skeleton III200 with the appropriate 'red box number' to indicate which box each element came from (left). New box labels indicating site code, trench, skeleton context and red box numbers for III200. ©CAL Davenport

5.6. Digitisation

The skeletal material from the 1983 excavation was transferred to the Liverpool John Moores University, from University College London, to ensure that all of the Southgate Street material was housed in one location. During the analysis of this material, it was noted that very little documentation had been provided regarding the excavation and context of the human remains. The university had previously received copies of the plans for the excavation, but it was not possible to interpret the burials fully without the excavation reports and context sheets. In February 2016, the author travelled to Gloucester City Museum to digitise the archive of information available for the 1983 excavation to provide additional research material for both Liverpool John Moores University and Gloucester City Museum. The contextual information for the site was available in hardcopy and had not previously been digitised by the museum. To support the work on the skeletal material, all context records, finds catalogues and photographic slides were scanned and organised corresponding to the skeleton, trench and cemetery.

A large number of skeletons from the 1983 excavation had individual plans drawn during excavation, which included eastings and northings, which allowed the location of the burials to be mapped onto the overall plan of the church. However, a number of burials had no plans available and the context records were needed to recover the location information for those individuals. The location information was particularly informative in trench III, as communication with one of the archaeologists working on trench III during the 1983 excavation (Neil Hampson, His Right Worshipful Mayor of Gloucester, 2016) revealed that the trench lay over the dividing wall between the cemeteries for Southgate Congregational Church and Gloucester Infirmary Chapel. It was possible to determine which of the two cemeteries some of the skeletons came from using the available location information to plot the burials (Figure 5.9). Although, this has not been possible with all the burials, it provided further understanding as to the reasons behind the preservation differences for different skeletons that were noted in this trench.

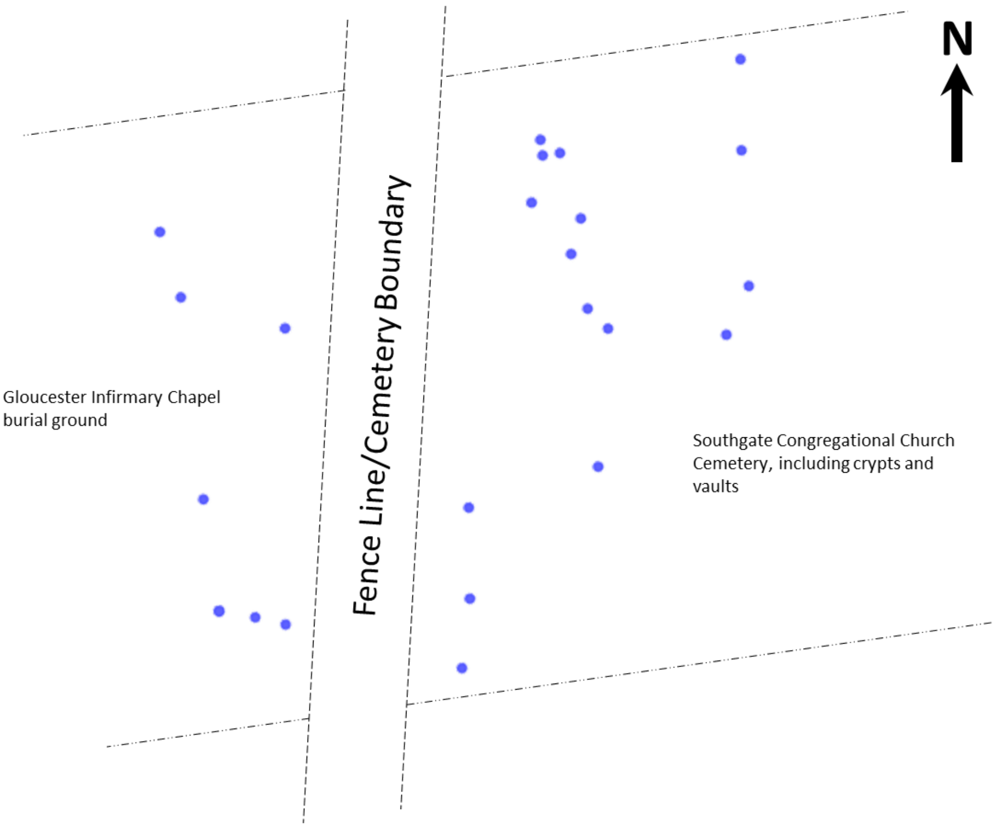

Figure 5.9. Plot of the burials with location information from trench III, enabling distinction between the cemeteries of Southgate Congregational Church and Gloucester Infirmary Chapel. ©CAL Davenport.

Further information was provided from the finds numbers associated with the skeletons, which included a large amount of coffin material. This enabled the interpretation of burial practices within Southgate Congregational Church and the influence each practice had on the preservation of the human skeletal remains.

5.7. 1989 excavation

In 1989, a further nine-month excavation was carried out at the site in Southgate Street, under the site code 3/89 (Atkin, 1990; Atkin and Garrod, 1990). This excavation focussed on the extension of trenches III, IV and V, which completed the excavation of Southgate Congregational Church and continued the excavation of Gloucester Infirmary burial ground and St Owens Church. Although 228 burials were recovered during this excavation, archaeological sites reports state that the excavations are not complete. There were number of burials that were truncated by section walls and therefore, not fully excavated. The breakdown for this excavation comprises of the skeletons held at Liverpool John Moores University and that were available for inclusion in this thesis (Table 5.3).

Table 5.3. Breakdown of the articulated burials excavated in 1989 and associated cemeteries.

Excavation	Trench	No of burials	Cemetery
3/89	III/V Crypts/Vaults	10	Southgate Congregational Church
3/89	III/V extension	3	Gloucester Infirmary Chapel
3/89	IV extension	214	St. Owens

The extension of trenches III and V produced 77 articulated burials, of which 13 were available for analysis. This included the crypt and vault burials from Southgate Congregational Church, and individuals identified as being outside the boundary of St Owens Church and therefore most likely belonging to the later Gloucester Infirmary burial ground. The extension of trench IV produced 214 burials primarily from St Owens church. From the site plans, it was been noted that the Gloucester Infirmary burial ground overlays St Owens Church and therefore, without further investigation into the burial records from the 19th century, it was not possible to identify those from the later cemetery. However, one skeleton (SK1554) was identified as having Phossy Jaw, a pathological condition that occurs due to phosphorous poisoning. Most commonly exhibited as necrosis of the mandible and prevalent in the late 18th and early 19th centuries among match factories workers due to white/yellow phosphorous exposure, it has been possible to start separating the burials. At the time of writing, this individual was undergoing further analysis as part of a separate project, which will include direct radiocarbon dating.

5.8. Site breakdown

The total number of skeletons available from each cemetery site is detailed in Table 5.4. Without further radiocarbon dating evidence for the St Owens burials, it is not possible to separate out those from the Infirmary. As this information becomes available it should be noted that the numbers from St Owens could decrease, and those from the Infirmary increase.

Table 5.4. Total number of burials available for analysis from each of the Southgate Street Gloucester cemeteries.

Cemetery	No of burials
St. Owens	217
Southgate Congregational Church	70
Gloucester Infirmary Chapel	25

5.9. St Owens, Southgate Street, Gloucester

The Church of St Owens was built outside the South Gate between the end of the Norman Conquest in 1066 and the *c.* 1100 surveys that were carried out (Figure 5.10). The church was founded by the first hereditary sheriff of Gloucester, Roger de Pitres, who held the position between 1071 and 1082, though the precise dates are not recorded (Herbert, 1988; Morris, 1918). The parish of St Owens was also founded at this time, with the church serving the local population that resided within the parish.

The church was pulled down along with 88 houses during the First English Civil War in 1643 (Herbert 1988). The cleared and fired ground meant that the attacking Royalist army of King Charles I had no cover during the siege of Gloucester. The parish of St Owens merged with St Mary de Crypt in 1646, allowing the parishioners to worship in the church there. The Restoration in 1660 listed St Owens as a separate parish with a churchwarden and overseer. However, the church was not rebuilt, with the parishioners still registering at St Mary de Crypt and attending services there (Herbert 1988).

5.9.1. Site plans

The plans for St Owens are comprised of a collection of separate layer plans and individual features (Figure 5.11). There is no overall plan for the entire excavation and not all burials are plotted, with led to a loss of information for those individuals. In some cases, it was possible to retrieve some of this information from the context records and logs. However, it was not been possible to digitise the plans up to now due to time constraints. There are plans to fully geo-reference the plans using ArcGIS, which will enable the exploration of the skeletal and taphonomic data spatially.

5.9.2. Archaeothanatology

There were 217 burials available for analysis in the collections held at Liverpool John Moores University, with 211 of these articulated burials available for assessment to identify arm position, burial type, burial practice and orientation. This allowed statistical analysis to determine whether there were any relationships between age (adult vs. non-adult) and sex (male, female and unknown adult) where possible, for each of the traits identified. All articulated skeletons (n=217) were assessed to determine the position of the arms during internment. Of these, 87 (41.2%) skeletons did not provide sufficient information for analysis, so could not be included in any further statistical analysis assessing arm position (Table 5.5).

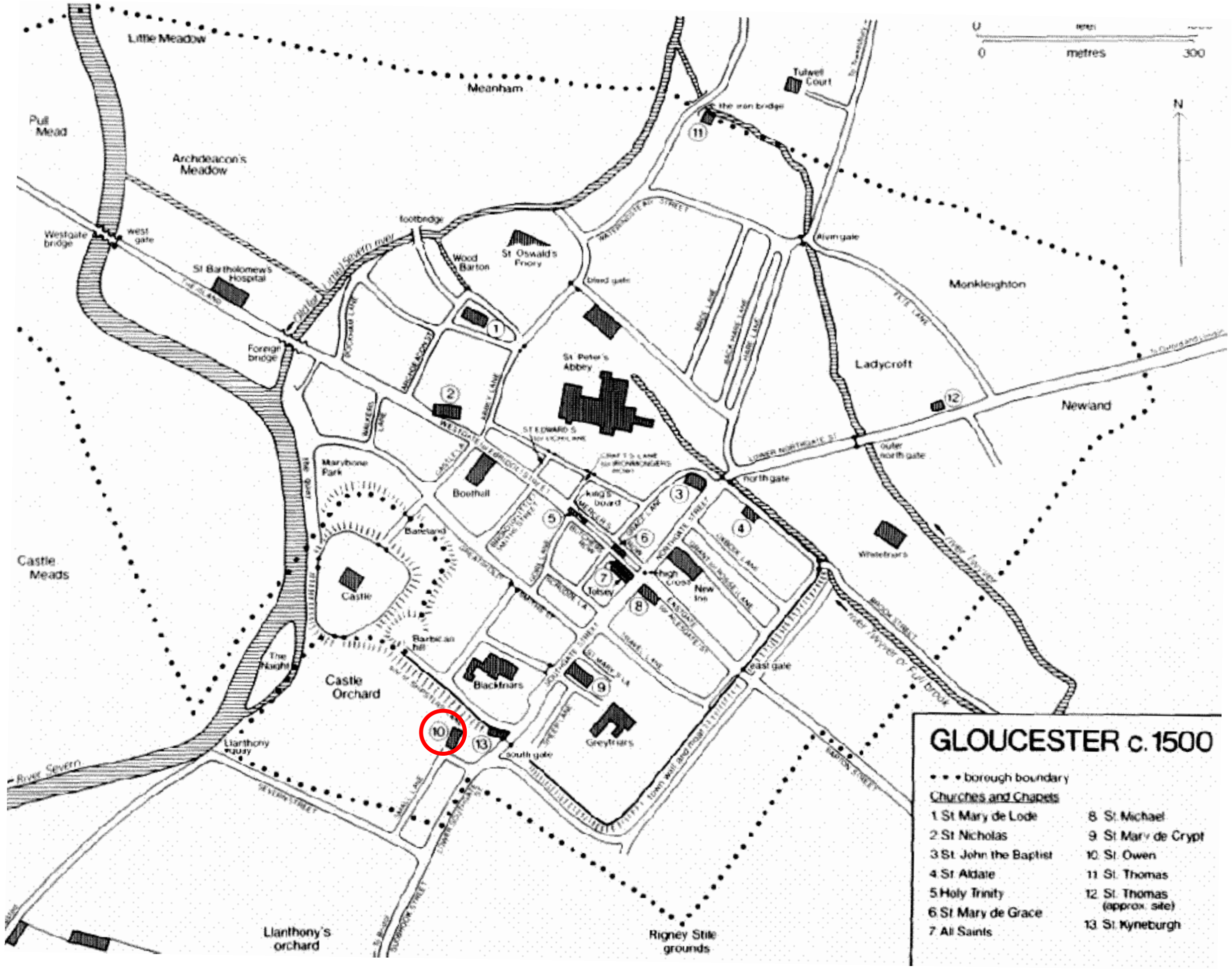

Figure 5.10. Map of the town of Gloucester *c.*1500 showing the locations of the churches and chapels serving the community during this time. St Owens Church is located at number 10, highlighted by the red circle (Atkin, 1990).

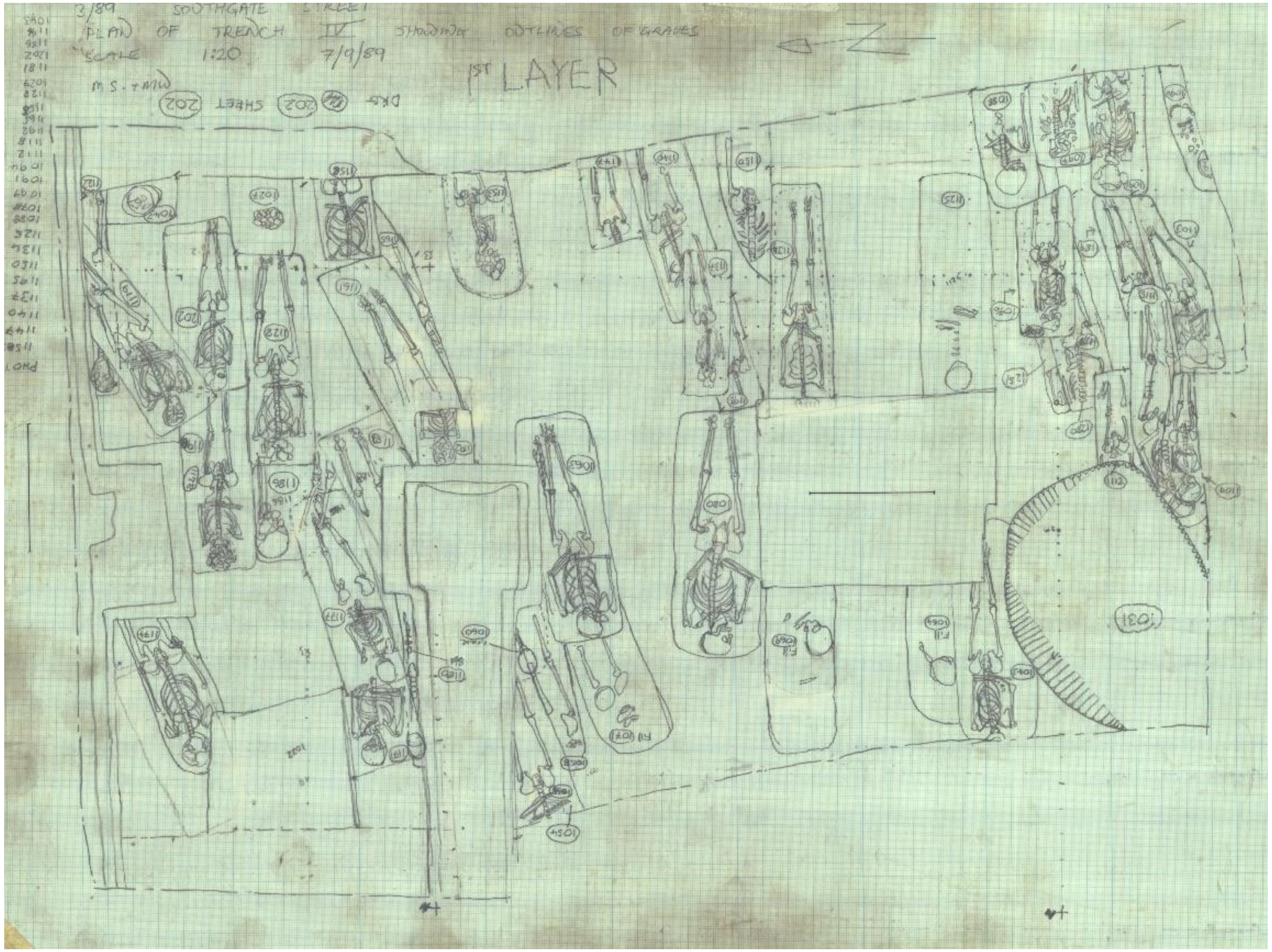

Figure 5.11. Original plan from the 1989 excavation of Trench IV, showing the burials from St Owens church identified in the 1st layer. ©Gloucester City Museum

Table 5.5. Arm position codes assigned to the St Owens Church burials giving overall percentage, along with sample breakdowns for the individual arm positions.

Arm Position Code	*N*	%	Sample breakdown by arm position (%) Male	Female	Non-adult	Unknown
1	8	3.7	50.0	25.0	25.0	-
2	24	11.1	37.5	33.3	29.1	-
3	79	36.4	38.0	30.4	30.4	1.3
4	12	5.5	41.7	25.0	33.3	-
7	2	0.9	50.0	50.0	-	-
8	5	2.3	40.0	60.0	-	-
9	87	40.09	36.8	26.4	32.2	4.6
Total	**217**	**100.0**	-	-	-	-

There were no relationships identified between biological profile of the skeleton, burial parameters and the arm position used during the interment (Kruskal Wallis and Spearmans rank correlations; $p>0.05$). However, there was a significant positive relationship identified between arm position and the completeness of the skeletons ($r_{s(130)}=0.209$, $p=0.17$), with the more complete individuals having the arms folded over the chest, lumbar region, or pelvis (Figure 5.12).

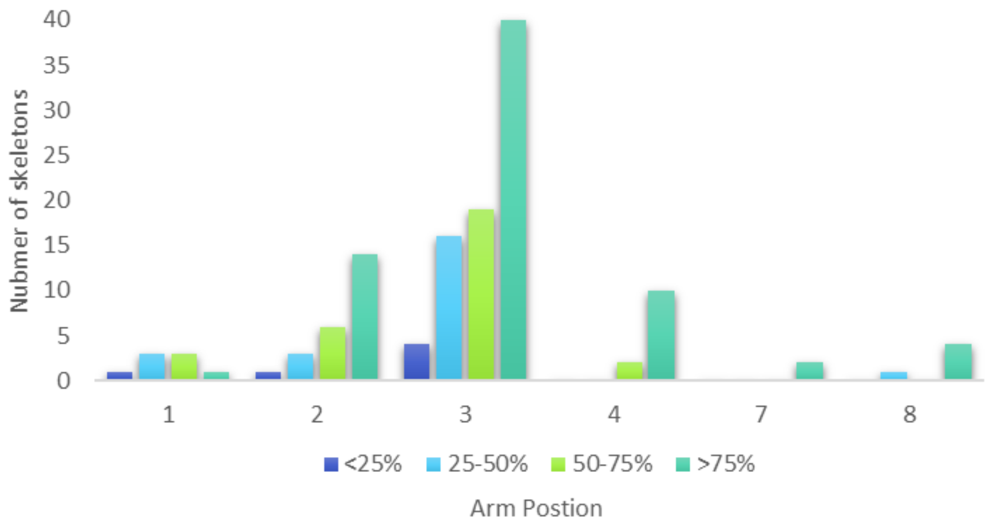

Figure 5.12. Arm positions observed at St Owens Church separated into skeletal completeness categories.

All articulated skeletons (n=211) were assessed to determine the position of the arms during internment. All the skeletons were interred on a west/east alignment (head to the west and feet to the east) bar two individuals; skeleton 1369 was interred on an east/west alignment (head to the east, feet to the west) and the skeleton 1277 was placed NEE/SWW. Skeleton 1369 was identified as an adult female supine burial, with the arms folded over the lumbar region. Skeleton 1277 was a 9-10 years old non-adult supine burial that had been badly truncated, resulting in less than 25% of the skeleton remaining, and removing the possibility of identifying the arm position. Burial practice could not be assessed for many of the skeletons due to the lack of information provided on the context records relating to the type of burial and the limited number of photographs to assess. The plan drawings, although detailed, but do not provide the information to discern movement of the skeleton within the grave. All articulated skeletons (n=217) were assessed to determine the type of burial used during internment. Of these, seven (3.32%) skeletons did not provide sufficient information for analysis. The burial types identified during the excavation of the St Owens skeletons were primarily supine, with only one flexed burial identified (Skeleton 1256). There were six disturbed burials present, with three that appeared to have be redeposited after later burials. The remaining three burials were located in Trench IV and consisted of crania only.

5.9.3. Cemetery sample analysis

The material available for analysis from St Owens comprises of 211 articulated and 6 disturbed human burials. Of the articulated burials, 152 were adult and 65 were non-adult. A further 122 boxes of disarticulated human material and coffin remains were excavated and are housed at Liverpool John Moores University. The articulated burials were assessed for completeness of material and the data compiled into Table 5.13. The number of complete burials were limited by the section walls, which prevented complete retrieval of the skeleton in some cases.

Figure 5.13. Approximate skeletal completeness of the articulated burials recovered from St Owens.

	>75%	50-75%	25-50%	<25%	Total
N	91	37	46	43	217

When assessing for differences in the distribution of the skeletal completeness, it was noted that although there was no sex bias in completeness, the majority of adults analysed were represented by more than 75% of the skeleton ($\chi^2_{(9)}$=41.659, p<0.001). Age showed a positive significant relationship with completeness, with the completeness of the skeleton increasing as age increased ($r_{s(193)}$=0.174, p=0.016). Although there were no relationships between biological profile and burial characteristics (Kruskal Wallis tests and Spearmans rank correlations; p>0.05), skeletons with higher levels of fragmentation had higher levels of abrasion/erosion ($r_{s(179)}$=0.342, p<0.001). Fragmentation levels were found to increase significantly in adults ($r_{s(179)}$=0.189, p=0.011), with few non-adults having extensive fragmentation ($\chi^2_{(4)}$=17.260, p=0.002; Figure 5.14).

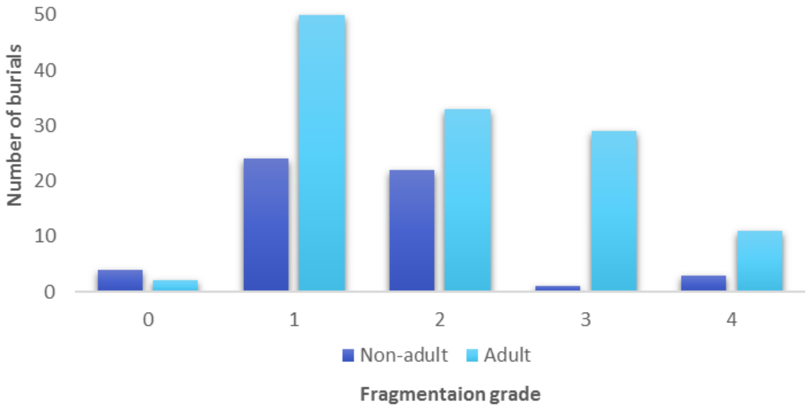

Figure 5.14. Post-mortem fragmentation of the St Owens Church skeletal material.

Collagen extraction was carried out on rib fragments from five skeletons, which produced collagen yields between 3.17% and 8.06% (Table 5.6). No relationship was found between the resultant collagen yield and any of the biological or burial variables, most likely due to the small sample size.

Table 5.6. St Owens Church skeletons selected for collagen extraction and the resultant yields.

Skeleton	Bone	Bone weight (g)	Collagen weight (g)	Collagen yield (%)
1303	Rib	0.65	0.04	6.15
1530	Rib	0.63	0.02	3.17
1554	Rib	0.56	0.02	3.57
1572	Rib	0.65	0.03	4.62
1764	Rib	0.62	0.05	8.06

The field portable XRF analysis on bone was carried out on the first rib from 27 skeletons from St Owens Church, using the mineral settings to test for levels of calcium, iron and potassium. The skeletons were selected to investigate the burial practices observed at this site, to ascertain whether the resultant collagen yield was affected by the presence of a coffin. The levels of each element were found to be significantly different when analysed using one sample t-tests (all results $p<0.001$). There were no relationships identified between the levels of element present in the bone and age, however, adult males had lower levels of iron present in the bone than females ($r_{(24)}=-0.418$, $p=0.042$). Higher calcium levels were seen when the skeleton was complete due to the lack of truncation, which would increase the surface area vulnerable to degradation ($F_{(3,23)}=3.301$, $p=0.038$). When assessing the burial parameters, only burial practice had an influence on the levels of calcium present, with coffin interments inhibiting the movement of the potassium held in the protein mineral matrix ($r_{(27)}=-0.771$, $p<0.001$). The levels of iron in the bone increased as the levels of potassium rose, due to the presence of coffin burials introducing higher levels of iron into the burial matrix ($r_{(27)}=0.540$, $p=0.004$).

5.9.4. Skeletal analysis – biological profiling

Sex determination

Of the 152 articulated adult burials assessed, there were 83 males, 64 females and 5 adult individuals of unknown sex (Figure 5.15). The ratio of males to females at this site was even ($\chi^2_{(1)} = 3.000$, p=0.83), showing no skewing of the sexes.

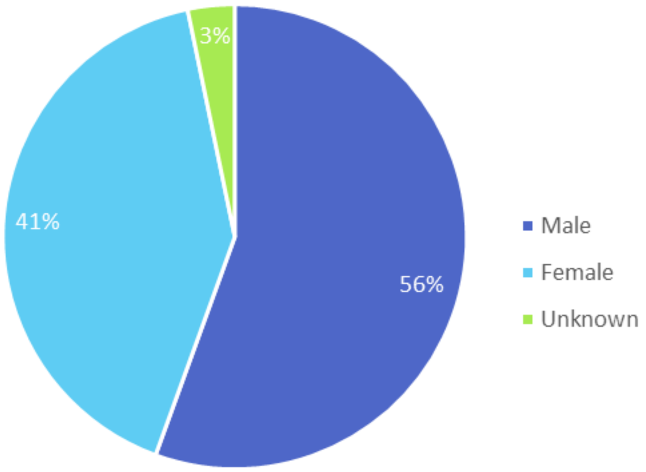

Figure 5.15. Sex determination distribution for the adult skeletons assessed from St Owens Church.

Sex could not be determined for 3.3% of the articulated adult individuals due to the traits required for sex determination not surviving. The most commonly available pelvic element for sex determination was the greater sciatic notch, which also led to high survivability of the pre-auricular sulcus. Of the individuals recovered with a pelvis, approximately 40% retained the pubic traits required for sex determination. However, this was often detached from the rest of the innominate, leading to the complete obturator foramen not being observable in all cases (Figure 5.16).

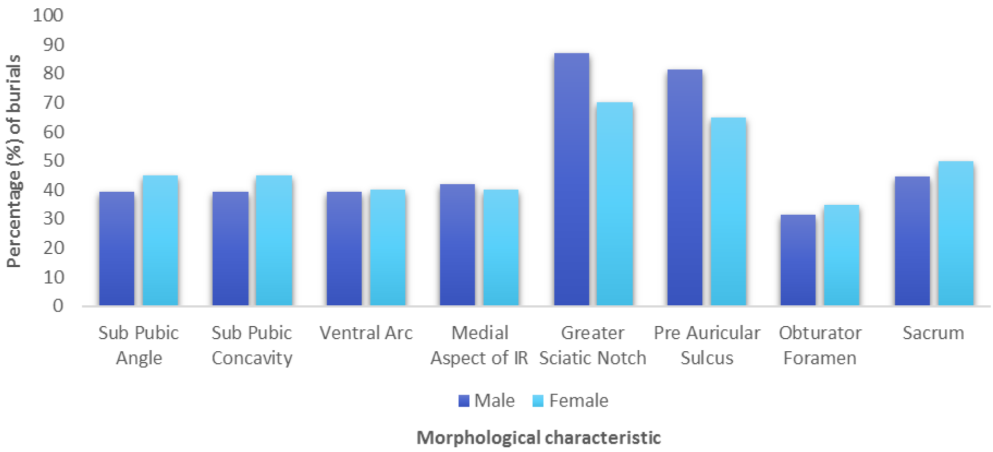

Figure 5.16. Preservations rates of the pelvic morphological characteristics from the male (n=38) and female (n=20) St Owens Church burials.

The survivability of the elements did not differ significantly between males and females, leading to a similar number of techniques being available for each sex ($t_{(16)}$=-0.254, p=0.803). However, a large percentage of skeletons did not have any pelvic traits available for use, which meant that cranial morphology and metric measurements were used for sex determination. The most commonly available cranial elements for sex determination were the mastoid processes, which were present in over 60% of adult skeletons. The mandible was also available for analysis in over 60% of the individuals, with all three traits available for analysis (Figure 5.17).

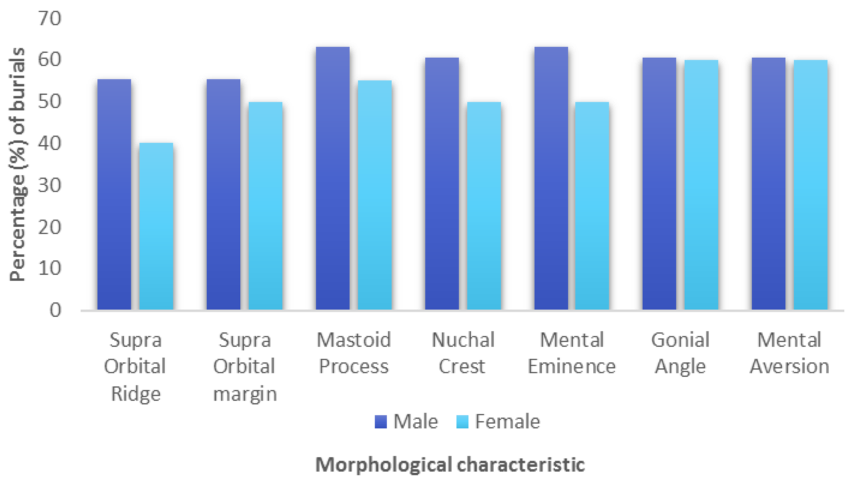

Figure 5.17. Preservation rates of the cranial and mandibular morphological characteristics from the male (n=38) and female (n=20) St Owens Church burials.

The survivability of the elements did not differ significantly between males and females leading to a similar number of techniques being used to for determination of each sex ($t_{(12)}$=-0.294, p=0.774). Cranial and mandibular assessments showed that over 34% of males and 36% of females provided elements for all seven sex determination techniques. The most commonly available metric measurement for sex determination was the femoral head (76% of the adult sample), with the humeral head being present in 69% of the total adult sample. Of those that could be assessed for sex, the percentage of burials preserving elements providing metric measurements for analysis are shown in figure 5.18.

The survivability of the elements did not differ significantly between males and females leading to a similar number of techniques being used to for determination of each sex ($t_{(10)}$=0.023, p=0.982). Metric measurements showed that over 32% of males and 30% of females provided elements for all five sex determination techniques. The pre-auricular sulcus was examined for all adult skeletons in the subsample where the landmark was preserved (n=44) to determine whether it was a groove of pregnancy (GP) or groove of ligament (GL). Only one male (3.2%) exhibited a pre-auricular sulcus, which was identified as a groove of ligament (Figure 5.23). It was possible to observe a pre-auricular sulcus on half of the female subsample, with 3 (15%) identified as a groove of pregnancy.

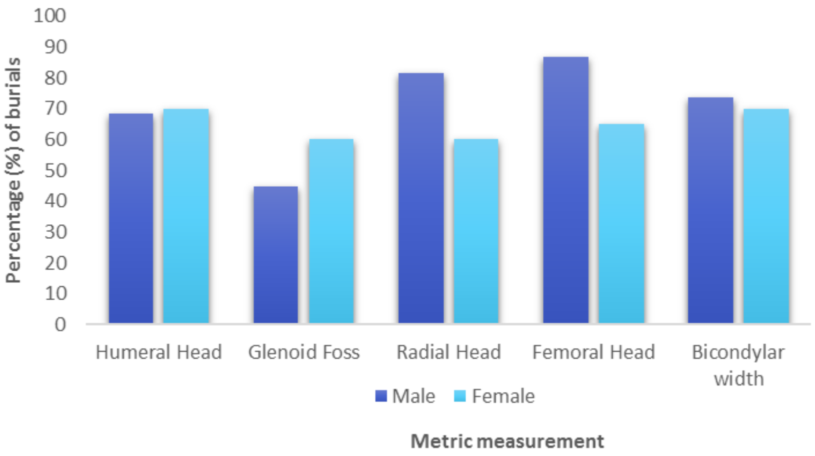

Figure 5.18. Preservation rates of the anatomical structures providing metric measurements from the male and female St Owens Church burials.

Age estimation

There were 217 burials (152 adults, 65 non-adults) available for assessment of age, with 193 providing characteristics required for the estimation. Of those that could not be placed into age categories (11%), all were classified as adult. The age-at-death distribution (Figure 5.19) shows that 31.8% of the sample did not live past 20 years of age.

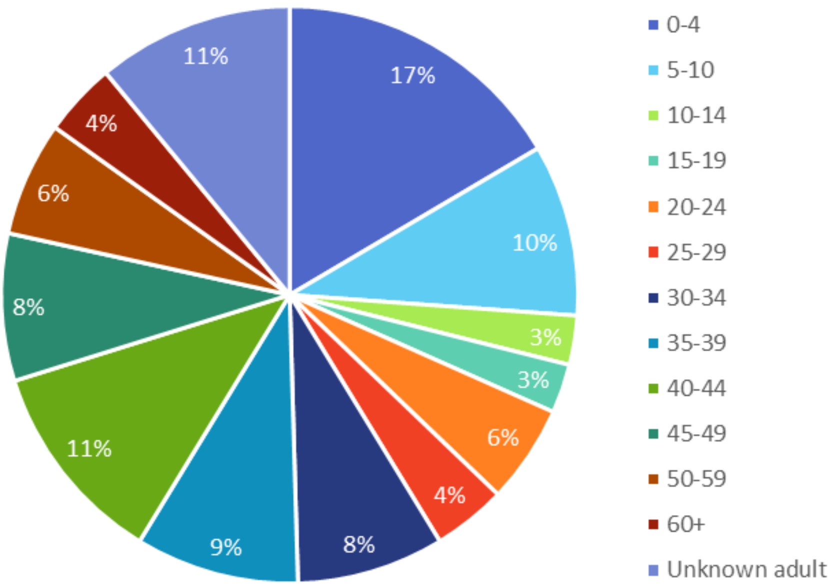

Figure 5.19. Age-at-death distributions for the St Owens Church burials (n=217).

The preservation of the elements for age assessment did not vary significantly between males and females ($t_{(12)}$=0.697, p=0.499), with both sexes similarly having poor preservation cranial sutures. Figure 5.20 shows the percentage of articulated burials that could be aged using each macroscopic aging technique.

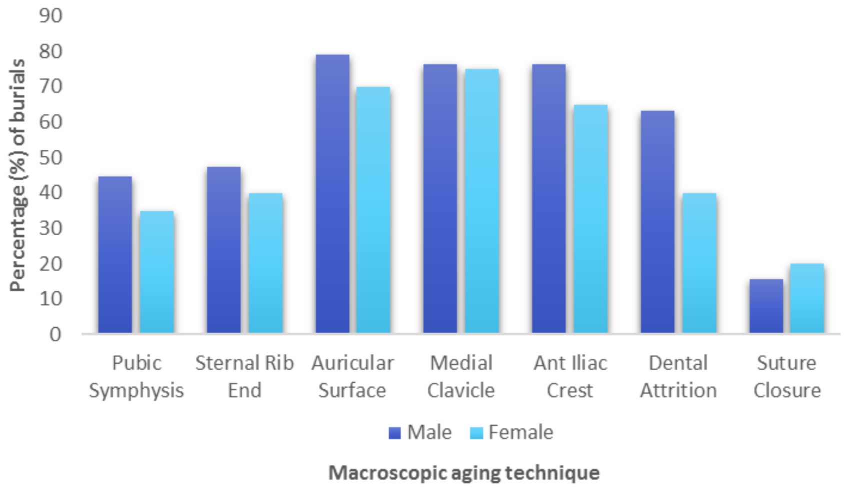

Figure 5.20. Preservation rates of the anatomical regions enabling age assessment through macroscopic aging techniques, of the male (n=38) and female (n=20) St Owens Church burials.

Of the aging techniques available, none used all seven, with the majority (35%) of individuals using five techniques. The auricular surface was the most commonly used method due to the robusticity of this element, although the medial clavicle and anterior crest also survived well.

The percentage of non-adult burials using each available aging technique was high (Figure 5.21), most likely due to the increased number of elements available for use in each case. The non-adult skeletal elements showed preservation comparable to the adult sample (U=4170.500, p=0.056), which conflicts with previous literary evidence stating that non-adults are under-represented in the archaeological record due to poor preservation (Molleson 1991; Crawford 1991;1993). The majority of burials (67.7%) were able to use methods from all three age estimation techniques, with only 3.2% (n=1) of burials using only one.

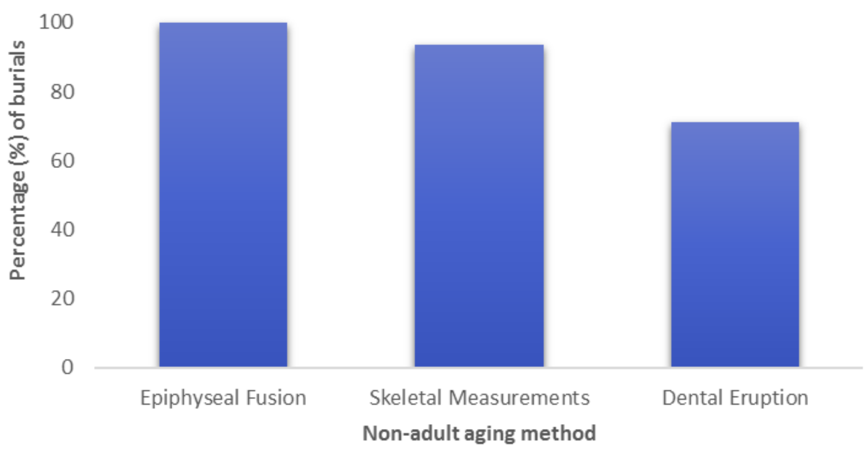

Figure 5.21. Preservation rates of the anatomical structures enabling assessment of age from the non-adult St Owens Church burials.

Stature estimation

A subsample of the adult burials (n=113) from St Owens Church were assessed for long bone length, with all available measurements recorded. Of those assessed for sex, all produced measurements from at least one long bone for the estimation of stature, with the recovery rates of long bones similar for both sexes ($t_{(10)}$=0.299, p>=0.771; Figure 5.22).

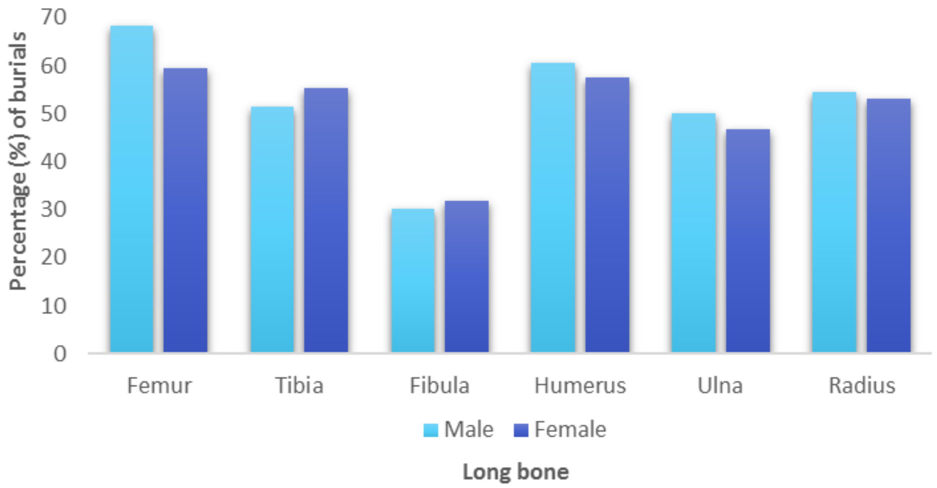

Figure 5.22. Preservation rates, given as a percentage, of the complete long bones available for stature estimation from a subsample of the adult male (n=66) and female (n=47) St Owens Church burials.

To ensure consistency, maximum femur length was used to estimate stature for the St Owens Church burials. Average femur length for males was 45.08 ± 4.61cm (n=45) and for females was 41.96 ± 2.49cm (n=28), demonstrating the sexual dimorphism present within the sample ($t_{(70)}$=7.194, p<0.001). Female stature ranged from 147.47cm to 162.78cm, with female mean height (157.78 ±3.89cm) in line with that expected for the medieval period, which has been estimated at around 158.60cm (Cafell and Holst, 2005). Male stature ranged from 156.13cm to 178.98cm, with a mean male stature of 168.48 ± 4.92cm, which was significantly higher than the female mean height ($t_{(70)}$=9.732, p<0.001).

Fragmentary femora data were collected from complete femora to assess whether the regression equations produced by Simmons *et al.* (1990) could be used on the St Owens Church sample for stature estimation. The technique was assessed on both male (n=51) and female (n=15) individuals.

Male measurements

Correlations showed that the individual fragmentary measurements correlated well with femoral length/stature (VHD - $r_{(23)}$=0.770, p<0.001; VHA - $r_{(22)}$=0.700, p<0.001; LCH - $r_{(21)}$=0.609, p=0.003). Using scatterplots, it was apparent that 59.3% of the variation in stature was due to the variation in vertical head diameter measurements, 49.0% of stature variation was due to proximal femoral breadth (VHA) and 37.1% was due to lateral condyle width (Figure 5.23). The stature estimations from complete femoral length were tested against the stature estimations derived using the formulae by Simmons *et al* (1990). The estimations provided using vertical head diameter were not significantly different from those given using complete femoral length ($t_{(51)}$=0.958, p=0.342). However, those for proximal femoral breadth and lateral condyle height differed significantly ($t_{(48)}$=2.873, p=0.006 and $t_{(44)}$=2.114, p=0.040), suggesting that the formulae need to be adjusted for this sample. Linear regression was carried out on both vertical head diameter and lateral condyle height. The ANOVA and coefficients indicated a strong linear relationship with both landmark measurements (p<0.001). The resultant regression equations for the estimation of male stature using proximal femoral breadth and lateral condyle height are presented in Table 5.7.

Table 5.7. Suggested regression equations for estimating stature from proximal femoral breadth and lateral condyle height of the St Owens Church males.

	Slope		Intercept
Predictor variable: VHA			
White Males	2.66 x	VHA	+ 55.31
Predictor variable: LCH			
White Males	1.15 x	LCH	+ 123.33

Female measurements

Correlations showed that only the landmark measurement for lateral condyle height (LCH) correlated significantly with the maximum femoral length ($r_{(13)=}$0.754, p=0.003). Using scatterplots, it was apparent that 7.0% of the variation in stature was due to the variation in vertical head diameter measurements, 8.0% of stature variation was due to proximal femoral breadth (VHA) and 56.8% was due to lateral condyle width (Figure 5.24). The stature estimations from complete femoral length were tested against the stature estimations derived using the formulae by Simmons *et al* (1990). The estimations provided for all measurements were significantly different from those given when estimating stature using complete femoral length ($F_{(3,51)}$=4557.232, p<0.001), suggesting that the formulae need to be adjusted for this sample. When assessing the landmarks measurements separately, it was found that although there was no relationship identified between vertical head diameter (VHD) and femoral length/stature, the resultant height estimations from VHD were similar to those predicted from complete femoral measurements ($t_{(26)}$=1.068, p=0.295). The remaining landmark measurements, LCH and VHA, both gave significantly different

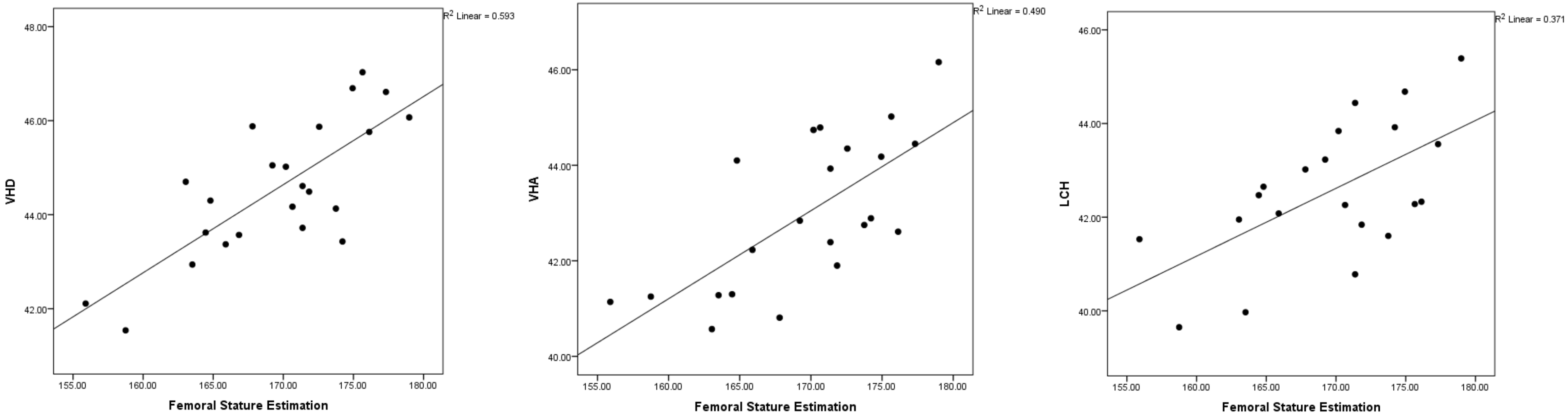

Figure 5.23. Scatterplots showing the variation for each measurement (R^2 linear) for the St Owens Church adult male sample.

femoral length and stature estimations using the regression formulae suggested by Simmons *et al* (2010). Linear regression was carried out on both VHA and LCH, with VHA showing no relationship with femoral length or stature ($p>0.05$). For LCH, both the ANOVA and coefficients indicated a strong linear relationship ($p<0.001$). The resultant regression equation for the estimation of female stature using lateral condyle height is presented in Table 5.8.

Table 5.8. Suggested regression equations for estimating stature from proximal femoral breadth and lateral condyle height of the St Owens Church females.

	Slope		Intercept
Predictor variable: LCH			
White Females	1.73 x	LCH	+ 98.13

Inter-observer error

Cohen's κ was run to determine if there was agreement between the two observers sex assessments for 150 skeletons from St Owens, Gloucester. All individuals included in this study were ones for which age and/or sex could be estimated. According to the benchmarks set out by Landis and Koch (1977), there was almost perfect agreement on the determination of sex, $\kappa = 0.930$, $p< 0.001$.
The differences in the statistical analysis arise from one individual being classed as female by the author that had been classified as non-adult by the independent observer. A further six skeletons were identified as female by the second observer and male by the author. This is most likely due to the skeletons in question being incomplete and a reduced number of factors being accounted for by the independent observer.

Agreement between the two observers age assessments for 150 skeletons from St Owens, Gloucester was also tested, with all individuals included having both age and sex estimation completed. Age estimations provided from each study fell into a five-year age range for adolescents and adults, with one-year age ranges given for those under ten years of age. According to the benchmarks set out by Landis and Koch (1977), there was substantial agreement on the estimation of age, $\kappa = 0.763$, $p< 0.001$. Both observers agreed on the age range produced in 117 cases, with a further 22 cases being within one age range. The remaining cases fell within two (seven cases) or three (five cases) and were all adult age ranges. The differences are most likely due to two factors. Firstly, the multivariate analysis carried out by the author takes into account an increased number of aging variables and secondly, as adult age estimation is based on senescence and not development, it can be more difficult to carry out age estimation. Further studies on bias in adult age estimation have determined it is often the case that non-adults are over-aged, and adults under-aged (Merritt, 2013). Without known age-at-death for the individuals at St Owens, it is not

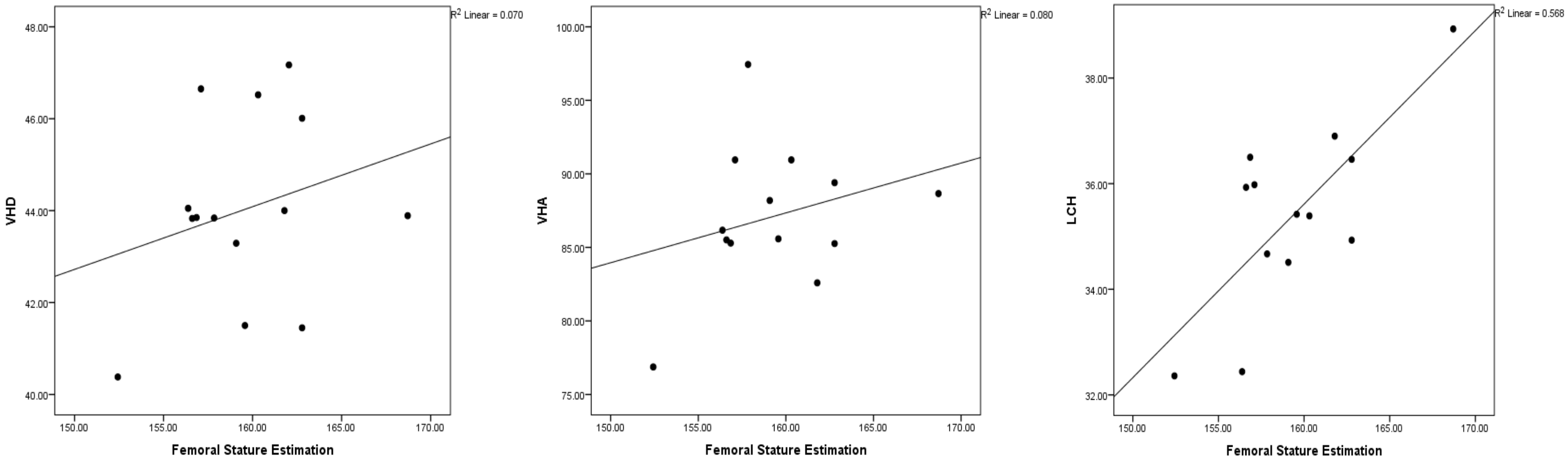

Figure 5.24. Scatterplots showing the variation for each measurement (R^2 linear) for the St Owens Church adult female sample.

possible to determine whether either observers are biased when aging human skeletal remains.

Intra-observer error

Cohen's κ was run to determine if there was agreement between the observations for sex determination taken by the author for 150 skeletons from St Owens, Gloucester. All individuals included in this study were ones for which both age and sex could be estimated. According to the benchmarks set out by Landis and Koch (1977), there was almost perfect agreement on the determination of sex, $\kappa = 0.980$, $p < 0.001$. The differences in the statistical analysis arise from two individuals being given sex classifications during the first assessment, but due to age (15-19 year age category), were classified as non-adult in the second assessment. This is due to the division between adult and non-adult ages becoming clearly defined as part of this research in the later stages of data collection. Therefore, all individuals in the 15-19 year category were later classified as non-adult unless they could provide a tighter age estimate (18-19 years).

Agreement between the age estimations for 150 skeletons from St Owens, Gloucester was also tested, with all individuals included having both age and sex analyses completed. Age estimations provided from each study fell into a five-year age range for adolescents and adults, with one-year age ranges given for those under ten years of age. According to the benchmarks set out by Landis and Koch (1977), there was almost perfect agreement on the estimation of age, $\kappa = 0.928$, $p < 0.001$. Both assessments produced the same age range in 140 cases, with the remaining 10 cases being within one age range. The differences noted in the age range assessments were all present in the adult skeletons, most likely as adult age estimation is based on senescence and not development. This can often lead age estimations to be subject to a greater degree of interpretation, especially when fewer skeletal elements are present when assessing the age range. There were an equal number of cases over- and under-aged, meaning that there is unlikely to be a bias present on this assessment (Merritt, 2013).

5.9.5. Geochemical studies on human material

Dental calculus

Dental calculus samples from St Owens Church (n=26) were sent for carbon and nitrogen stable isotope testing to the University of Nevada, Reno. The mean δ13C values (-21.34 ±0.79‰) for the St Owens chapel calculus samples were consistent with a diet focused on C_3 plants, which was supported by the documented evidence on trade and agriculture in Gloucester during the medieval period (Herbert, 1988; Figure 5.25).

Corn was an important foodstuff during this period, but consumption of this cereal is not indicated in the dietary analysis, indicating that it was either reserved for the higher classes, or consumed in very small quantities and exported from the markets. Mean $\delta^{15}N$ values (12.53 ± 0.19‰) were consistent with a shift of 1-2 level trophic shift (6.72‰) above the herbivore baseline (5.81 ± 0.19‰, n=51); indicating that the diet contained animal and marine sources, along with a regular intake of omnivore or freshwater fish protein. This is also supported by the literature on Gloucester, which reports that the local trade in fish came from the sea, fishing weirs adjoining the town and from nearby riverside parishes (Herbert, 1988). Gloucester's importance as a market centre contributed to the wide range of foods available to the townspeople, with it reported that the market trade included high numbers of welsh cattle, fruit, honey, wine, salt and corn.

There were no significant differences ($p>0.05$) identified between the mean $\delta^{15}N$ values retrieved from the calculus samples and dental collagen samples retrieved from two of the comparison samples from York; All Saints and Fishergate (Müldner and Richards, 2007). However, the mean $\delta^{13}C$ calculus values showed a significant decrease of 1.64-2.32‰ when compared with the dental collagen values ($p<0.0001$). This is most likely due to calculus being a biofilm and therefore comprising of food remains, bacteria and DNA (Salazar-García *et al*, 2014). Dental notches present in the St Owens sample indicate non-masticatory use of the dentition, which would further introduce foreign material into the calculus. Further differences in the results will be due to the dental collagen providing an assessment of the diet consumed during tooth formation, rather than the continuous build up and wear of the calculus over the lifespan of the individual (Salazar-García *et al*, 2014). Due to the presence of food particles and other materials derived from plant material being trapped in the calculus and C_3 plants materials having a $\delta^{13}C$ value of approximately -26‰ (Mays, 1997), it is likely that this has contributed to the lowered values obtained.

The dental calculus samples were assessed before and after acid extraction, with the results plotted in Figure 5.26. The acid extraction adjusted the $\delta^{13}C$ further, showing that that it is approximately 2‰ lighter when considering just the organic carbon content. This is to be expected as the carbonate (inorganic) component of the $\delta^{13}C$ is isotopically heavier that the organic component (*pers. comms* Simon Poulson). Statistical analysis has not been carried out on the acid extraction samples due to this further shift in values.

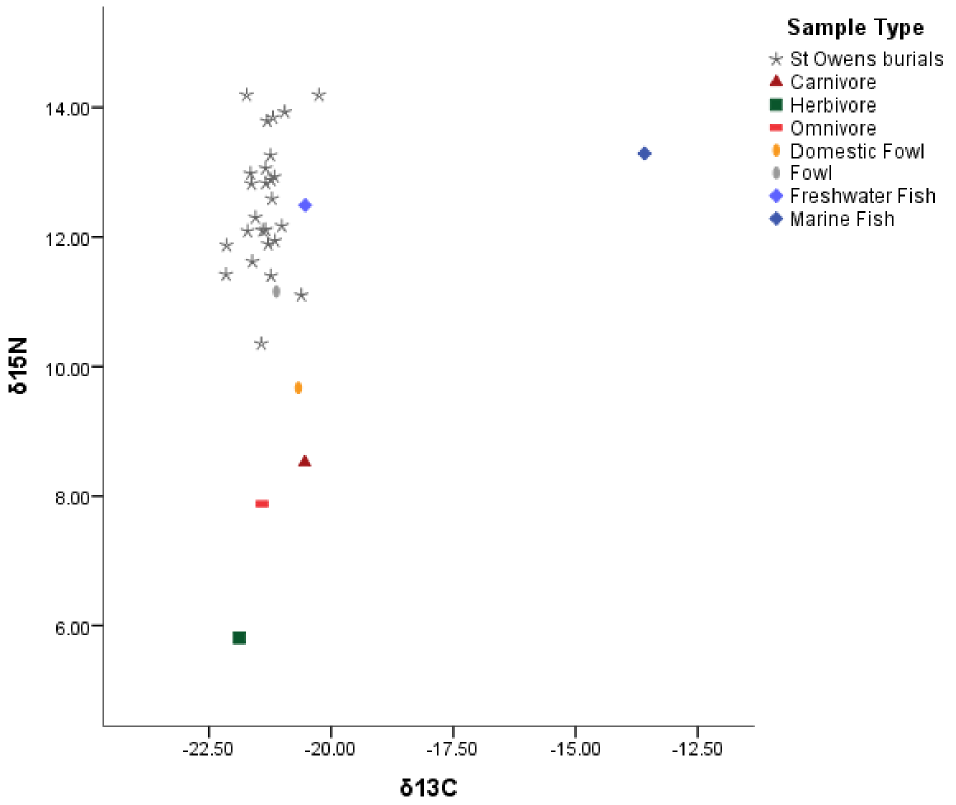

Figure 5.25. Isotope data for the calculus samples collected from the St Owens Church burials (n=26) in comparison with faunal, freshwater and marine values available from the medieval period (Müldner and Richards, 2007a; 2007b; Müldner *et al,* 2009).

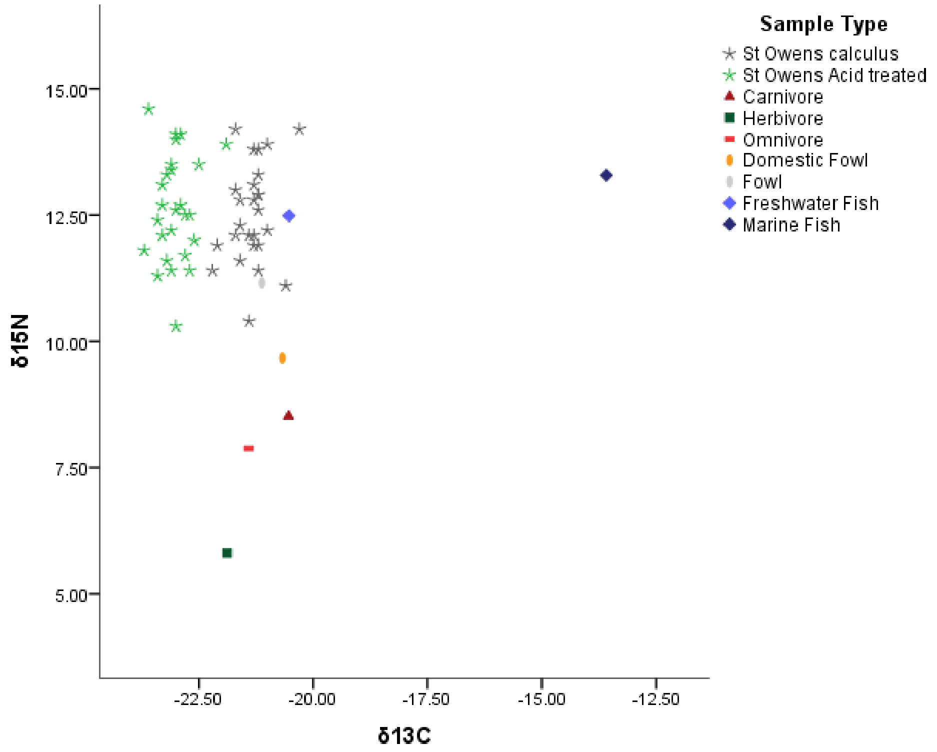

Figure 5.26. The St Owens Church calculus samples (n=26), demonstrating the shift in values between isotopic source materials and the acid treated calculus sample. Faunal, freshwater and marine data is shown for comparison (Müldner and Richards, 2007a; 2007b; Müldner *et al,* 2009).

* This subchapter has been included in a publication submitted for review (Towle *et al*, 2018); please see Appendix A8 for more information

5.9.6. Demographics

Age estimations from 192 burials were used to produce the life table (Table 5.9). The life table shown here is a simplified version of the complete life table, which can be seen in the Appendix.

Table 5.9. Simplified standard life table displaying the demographics for the St Owens Church burials.

Age x	Individuals dx	Survivorship lx	% of Deaths	Mortality Qx	Expectation of Life ex
0	36	192	18.75	0.19	28.54
5	21	156	10.94	0.13	29.55
10	6	135	3.13	0.04	27.68
15	6	129	3.13	0.05	25.90
20	12	123	6.25	0.10	21.02
25	9	111	4.69	0.08	18.02
30	17	102	8.85	0.17	14.39
35	20	85	10.42	0.24	11.76
40	25	65	13.02	0.38	9.62
45	17	40	8.85	0.43	9.06
50	14	23	7.29	0.61	8.91
60	9	9	4.69	1.00	5.00
Sum	**192**				

The large percentage in deaths below five years of age demonstrates how life expectancy from a young age was low, with over 29% of the population not surviving past 10 years of age. Those who survived past the age of ten could expect to live a further 27 years on average based on the demographic analysis, although expectancy of life gradually decreases at each interval from this age onwards. The survivorship curve shows the proportion of individuals surviving at the end of each five-year period (Figure 5.27). Although the sharp decrease in the sub-adult population is evident at the start, the rate of death decreases considerably until approximately 30 years old, when the rates starts to increase again.

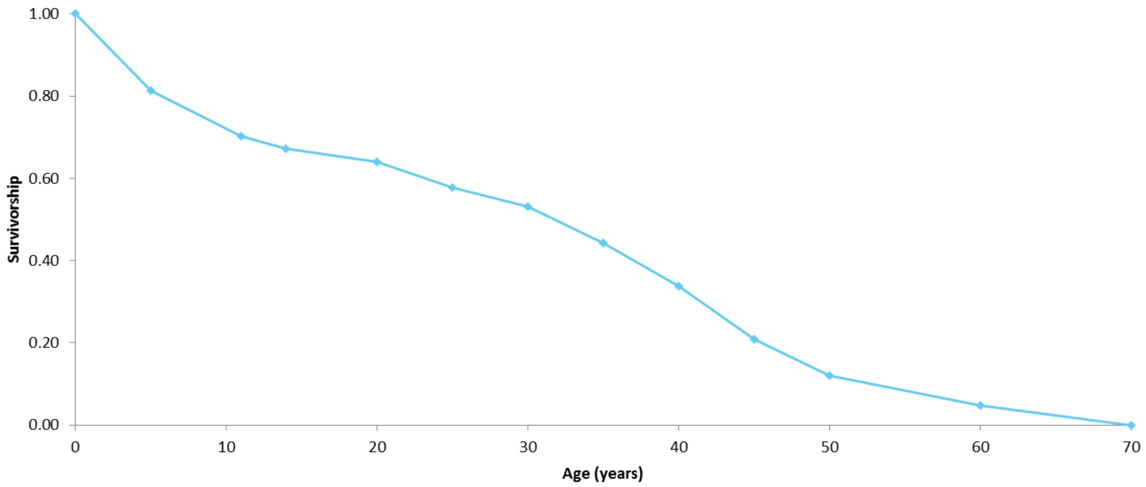

Figure 5.27. Survivorship curve for the St Owens Church burials (n=192).

The mortality curve shows the percentage of the sample lost at the end of each five-year period (Figure 5.28). Plotting this on a graph gives an indication of the ages at which mortality peaks, in this case, following the high rates of mortality during childhood, there is a small peak at approximately 20 years of age, followed by a significant increase in mortality at 40 years of age.

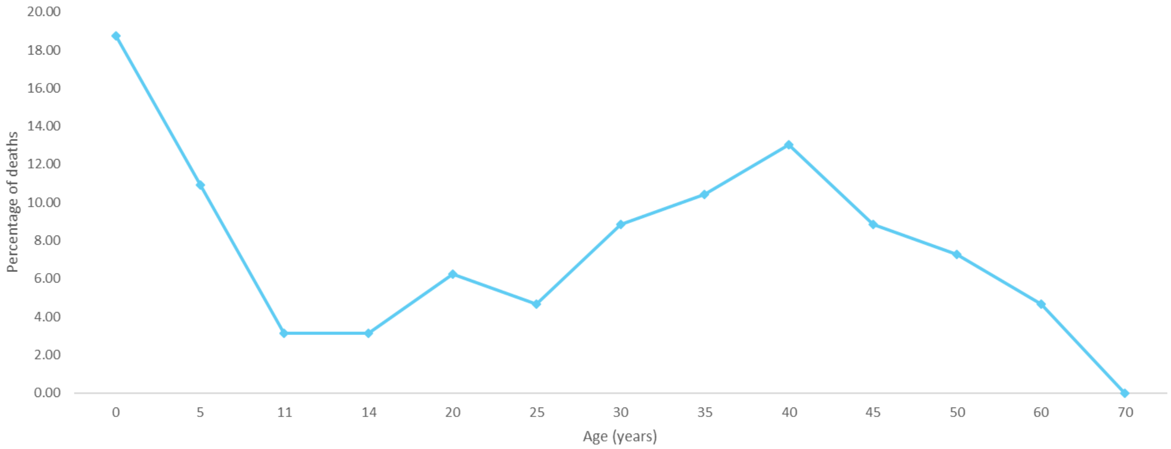

Figure 5.28. Mortality curve for the St Owens Church burials (n=192).

The crude mortality rate for estimated from life expectancy at birth (28.54 years) based on the 192 individuals in the demographic analysis was 35 deaths per 1000 within this sample. The length of time the cemetery was in use has been estimated at 567 years, based on the midpoint of the term the founder, Roger de Pitres, held the position of Sheriff of Gloucester (1071-1082) and the 1643, when the church was pulled down prior to the siege of Gloucester. The sample estimate was based on the material analysed during this PhD research, however, it should be noted that the site of St Owens had undergone extensive construction prior to excavation, which may have significantly reduced the number of burials available for analysis. The site is not fully excavated and therefore, the sample estimated provided here is to be taken as a minimum number only. The population size required to sustain the current number of burials over the lifespan of the cemetery is approximately 9 individuals (9.67).

The overall demographics give an insight into the population as a whole, but do not take into account the different risk factors that can affect the sexes. As a port town with surrounding farmland and an army in residence, there were many different occupations that could contribute to sex-specific mortality. During the medieval period, due to the high mortality rates, it was common for women of childbearing age to be pregnant often. However, this also increased the risk of the mother not surviving the pregnancy or childbirth, with post-partum infections also being common. Therefore, demographic analysis has also been carried out on the adult males and females separately to highlight any differences in the profile between the sexes.

Male demographics

The male articulated burials (n=71) were represented in all age categories, with the majority providing estimates in the categories of 35-39 and 45-49 years at death. This compares with the overall demographics, which showed that the survivorship rate began to decrease at a slightly faster rate at this time. The male life expectancy at 15 years of age was 22.8 years (Table 5.10).

Table 5.10. Simplified standard life table displaying the demographics for the male burials (n=146) from St Owens Church.

Age x	Individuals dx	Survivorship lx	% of Deaths	Mortality Qx	Expectation of Life ex
20	6	71	8.45	0.08	22.82
25	6	65	8.45	0.09	19.69
30	7	59	9.86	0.12	16.44
35	11	52	15.49	0.21	13.32
40	12	41	16.90	0.29	11.22
45	10	29	14.08	0.34	9.83
50	12	19	16.90	0.63	8.68
60	7	7	9.86	1.00	5.00
Sum	**71**				

The life expectancy decreases gradually as an individual reaches with each five-year age group. The survivorship curve shows the proportion of individuals surviving at the end of each five-year period (Figure 5.29). The slow decrease in the male sample is evident at the start of the curve, with the rate of death increasing from approximately 35 years old.

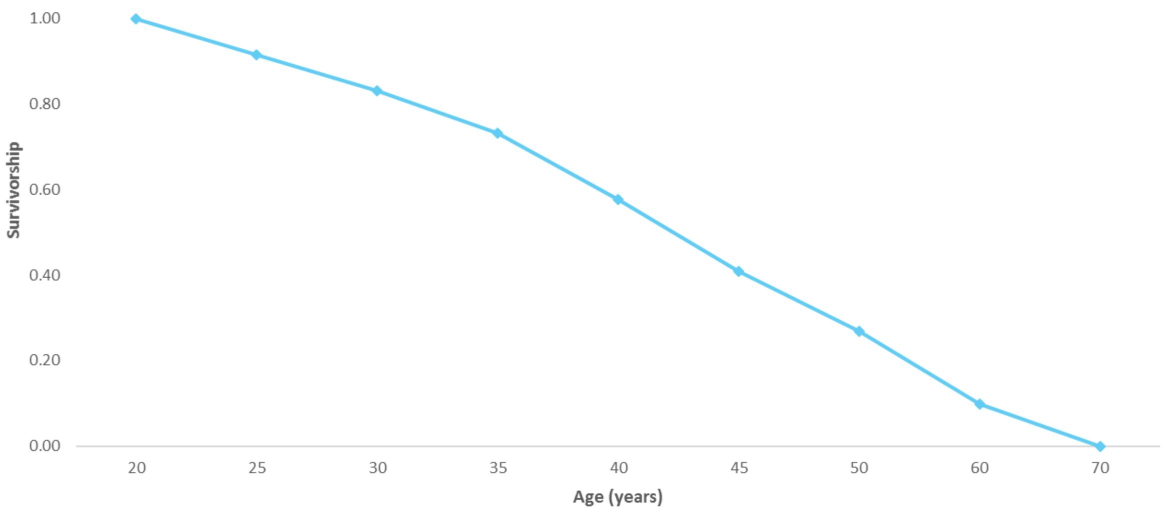

Figure 5.29. Survivorship curve for the male St Owens Church burials (n=71).

For the St Owens Church males, the mortality levels remain consistent until approximately 30 years of age, where they remain at increased levels until 60 years, with over 62% of the sample lost between 35 and 50 years of age (Figure 5.30). As there would have been many different occupations in a port town, all of which carry risks, it is not possible to comment on what roles specifically the St Owens Church males would have undertaken. However, it is likely that the combination of family responsibilities, occupational responsibilities and living in close quarters in a city, would all have contributed to the high mortality rates in the town of Gloucester.

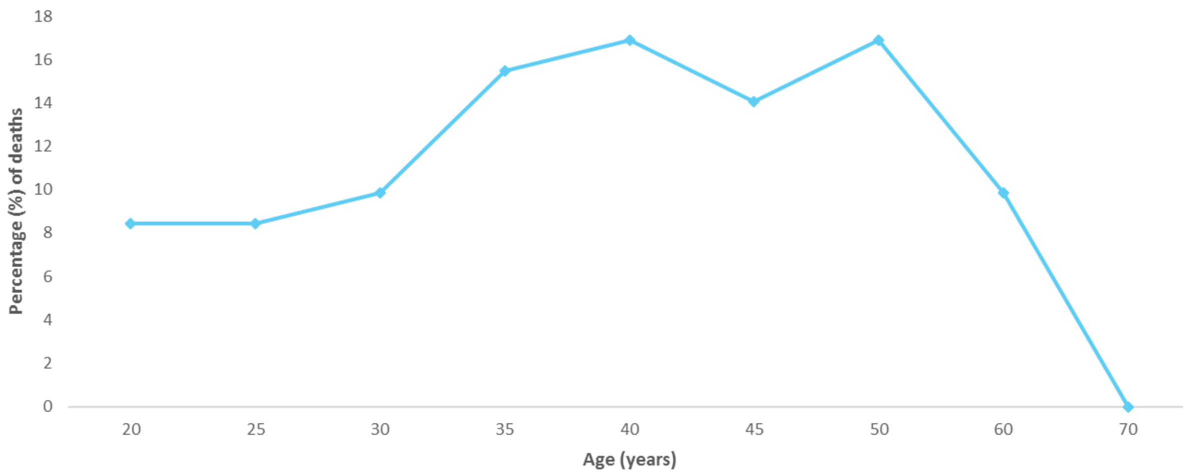

Figure 5.30. Mortality curve for the male St Owens Church burials (n=71).

Female demographics

The female articulated burials (n=53) were represented in all age categories, with the majority (24%) providing estimates in the category of 40-44 years of age. This compares with the overall demographics, which showed a rise in mortality at this age. The life expectancy for the adult articulated burials is only given from 20 years of age due to the lack of information regarding non-adult sex estimation, with females having a life expectancy at birth much lower than the males. Females were expected to live for another 18.73 years once they reached 15 years of age (Table 5.11). As with the males, life expectancy decreases gradually as an individual reaches each five-year age group, until 50 years of age, when there is an increase in life expectancy.

Table 5.11. Simplified standard life table displaying the demographics for the female burials (n=53) from St Owens Church.

Age x	Individuals dx	Survivorship lx	% of Deaths	Mortality Qx	Expectation of Life ex
20	6	53	11.32	0.11	18.73
25	3	47	5.66	0.06	15.80
30	10	44	18.87	0.23	11.70
35	9	34	16.98	0.26	9.41
40	13	25	24.53	0.52	6.90
45	8	12	15.09	0.67	6.67
50	2	4	3.77	0.50	10.00
60	2	2	3.77	1.00	5.00
Sum	**53**				

The survivorship curve shows the proportion of individuals surviving at the end of each five-year period (Figure 5.31). Although there is continual decrease in the sample as expected, the rate of survivorship fluctuates throughout the female lifespan. The slow decrease in sample is evident at the start of the curve, with the rate of death increasing from approximately 30 years old, before slowing down again at around 50 years of age.

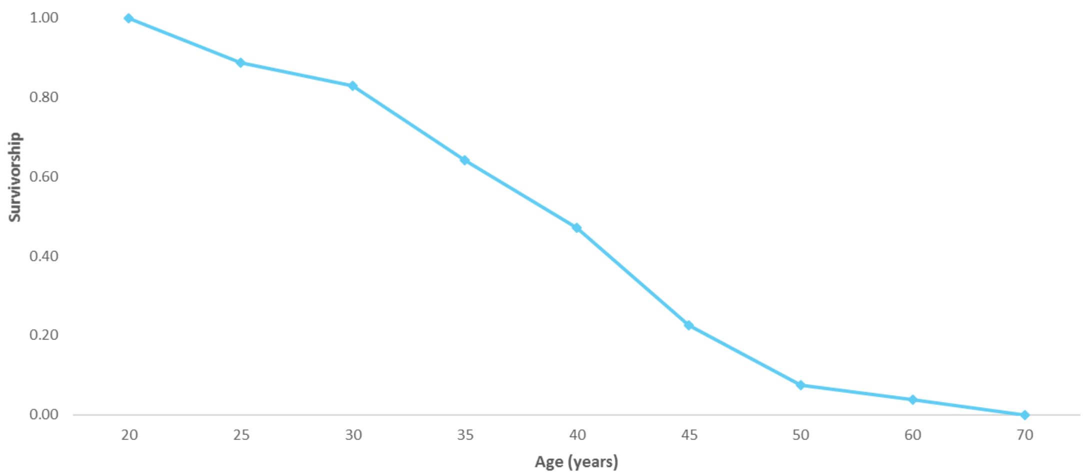

Figure 5.31. Survivorship curve for the female St Owens Church burials (n=53).

The mortality curve shows the percentage of the sample lost at the end of each five-year period (Figure 5.32). For the St Owens Church females, following the high rates of mortality seen during early childhood, the increasing mortality levels seen in the males up until the age of 40 years is not seen. In contrast, the female demographics show a decline in mortality at the ages of 25, 35, and 50 years of age.

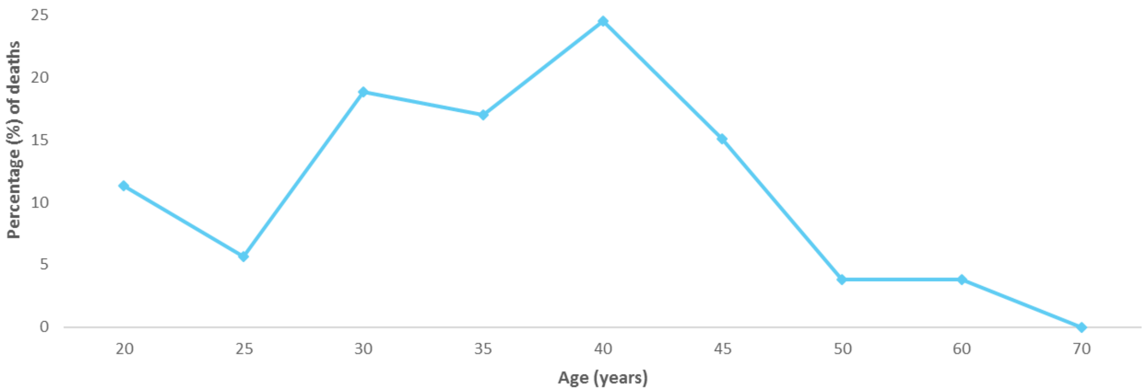

Figure 5.32. Mortality curve for the female St Owens Church burials (n=53).

Peak mortality is reached at 40 years of age, with 24.53% of the female sample lost during this interval. The peaks in the female demographics are likely due to childbirth, rather than the risks associated with occupation, which would have produced a similar demographic to the males (Figure 5.33). The initial peak in mortality was at twenty years, which may have coincided with the first obstetric event. Pregnancy carried many risks during the medieval period, with less access to medical care and unsanitary conditions cited as common factors in loss of the mother and/or child during labour. The next peak in mortality for females is seen at 30 years of age, before a slight dip at 35 years. The decline in the female sample is considerably greater than that of the males between 30 and 45 years of age, with 60% of the adult female sample is lost within a 15-year span (Figure 5.41). This sharp decline in the sample highlights the increased risk of pregnancy faced during childbearing years. For those that survived to 50 years of age, there is a sharp decrease in mortality, with a life expectancy of 10 years; this could coincide with menopause in women, which would remove the risk of dying in childbirth.

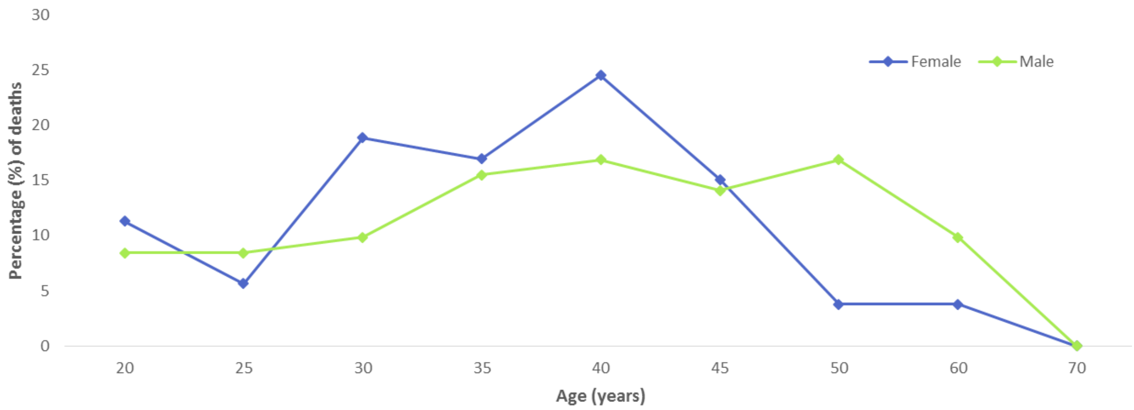

Figure 5.33. Comparison of the male and female mortality profiles, showing the increase in female mortality during childbearing years.

5.9.7. Summary of site results

The cemetery of St Owens Church was in use for approximately 567 years (1076-1643), however the continual development of the Gloucester Docks and later buildings on the site has limited the potential for investigation into the population that were buried in this cemetery. As the excavations were carried out in the 1980's, the loss of information through the time constraints placed on the archaeologists has further limited the potential for interpretation.

The osteological analysis of the remains recovered from the cemetery and housed at Liverpool John Moores University, consisted of 211 articulated (152 adults, 65 non-adults) and six disturbed burials, with an average life expectancy of 28.58 years at birth. The mortality profiles show that 28% of the overall sample did not survive past 10 years of age, indicating good preservation and retrieval rates of non-adult human remains. In comparison to other cemetery sites the number of non-adult burials is high (36% under 20 years) when compared with other medieval urban samples. As life expectancy at birth is not necessarily representative of the mortality profile, it could be an indication of the fertility and population growth present at the site (Buikstra *et al*., 1986; Johansson and Horowitz, 1986; Milner *et al*., 1989). St Mary Spital in London reports a non-adult sample size of 29%, with the total excavated sample size being over 13,000 individuals (Connell *et al*, 2012). As the cemetery sample of St Owens Church studied in this PhD thesis is not complete, this is an indication of sample bias, rather than the true population demographics.

The distribution of sex at St Owens Church is fairly even, which is in agreement with other studied medieval sites (Bardsley, 2014). All pelvic elements were available for sex determination in nearly 40% of the sample, with over 70% retaining the greater sciatic notch. In the cranium, the mastoid processes and mental eminence were the most commonly preserved elements, with all traits available in over 45% of the sample. There was no difference in the retention rate of the elements by either sex.

It was not possible to analyse the influence the soil environment had on the bone at this site due to the limited number of soil samples available (n=2). However, the differing burial practices observed allow an insight into the degradation process influencing the bone when subjected to varying environmental conditions. It was noted with this sample that the calcium rates were much lower in coffin internments, indicating that the coffin itself is inhibiting the uptake of calcium and displacement of potassium from the bone.

Taking into account all the factors analysed at this site, if you were to select an individual for further analytical testing on the bone based on the data collected so far (such as radiocarbon dating and stable isotope analysis), there would be a greater chance of success with a skeleton interred in a coffin. Skeletons interred in coffins are likely to be more complete, with lower rates of truncation and therefore higher rates of collagen. However, the rates of fragmentation and abrasion/erosion on the epiphyseal surfaces of the bone may be greater. Skeletons with arms close proximal to the thorax are more likely to have been shrouded burials and therefore will have less abrasion/erosion and fragmentation, though this was found to have no relationship with collagen yield.

5.10. Southgate Congregational Church

Southgate Congregational Church was based at the northern end of Lower Southgate Street, close to the former South Gate. The City Gaol, which closed in 1858, stood to the northeast of the church, with the Infirmary (opened in 1761, demolished in 1984) located southeast, on the opposite side of the road (Herbert, 1988; Figure 5.34). The original meeting house was built in 1730, enlarged in 1830, before construction of the new church between 1849-1851 (Herbert, 1988). The cemetery of the church was incorporated into the northeast corner of the docks development when construction started in 1794, leading to the loss of a number of burials. An area at the rear of the church grounds was used for the internment of the sick from the infirmary, with the main churchyard used for the burial of the parishioners. Southgate Congregational Church was demolished in 1981, with the site currently being used as a carpark for the docks development.

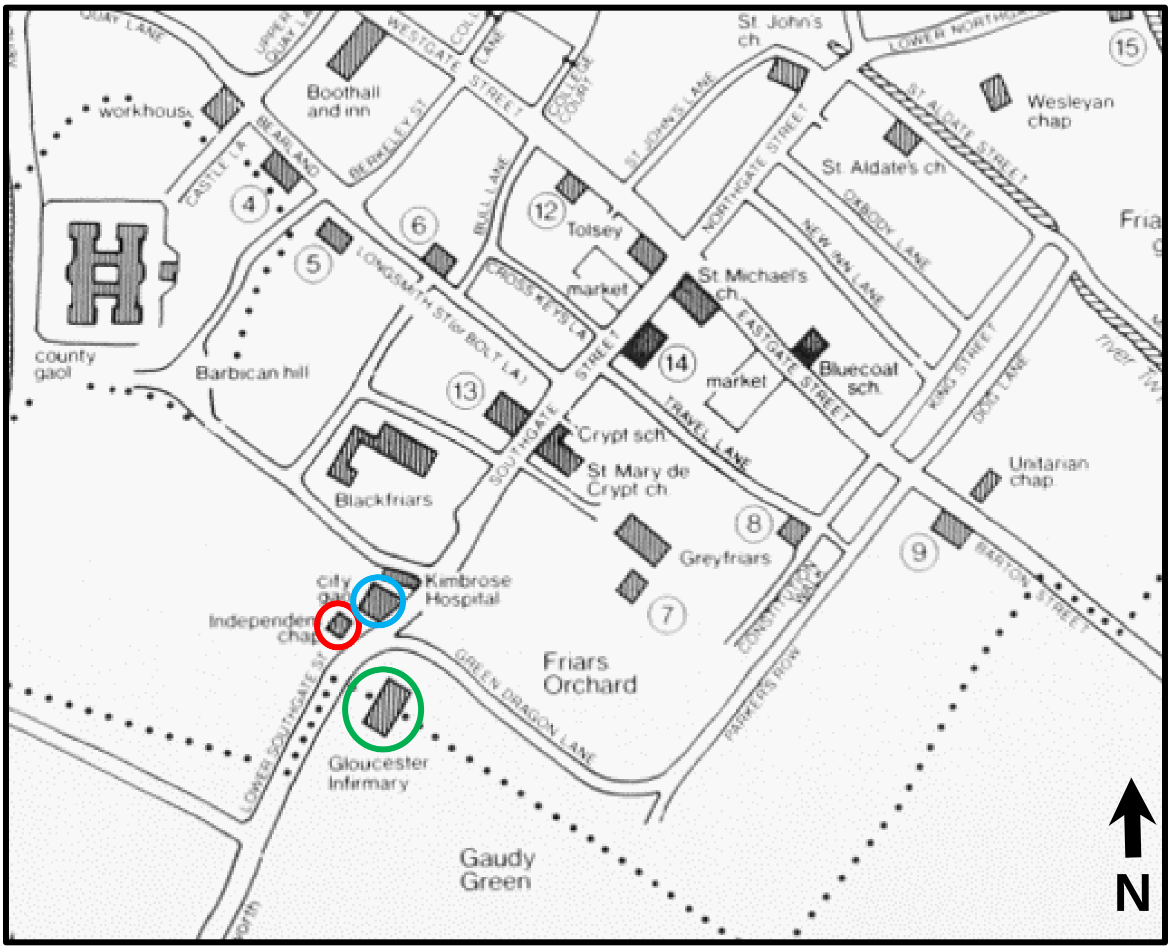

Figure 5.34. Map of Gloucester City in 1792, showing the location of Southgate Congregational Church (labelled Independent Chapel, red circle), the City Gaol (blue circle) and Gloucester Infirmary (green circle). Map adapted from Atkin (1990).

5.10.1. Site plans

The individual site plans produced during the excavation of Southgate Congregational Church were detailed, but each covered a different area of the site, preventing the assessment of the church overall. The individual plans were compiled into one image, to allow the church plan to be viewed overall (Figure 5.35).

5.10.2. Archaeothanatology

All skeletons (n=70) were assessed to determine the position of the arms during internment (see Figure 2.1, page 46 for arm position reference). Of these, 43 (61%) skeletons did not provide sufficient information for analysis, and the remaining 27 were interred with the arms placed by the sides. When assessing burial alignment, 21 (30%) burials did not have enough information complete the assessment due to incomplete context records and plans. Of the remaining skeletons, 47 were interred on a west/east alignment (head to the west

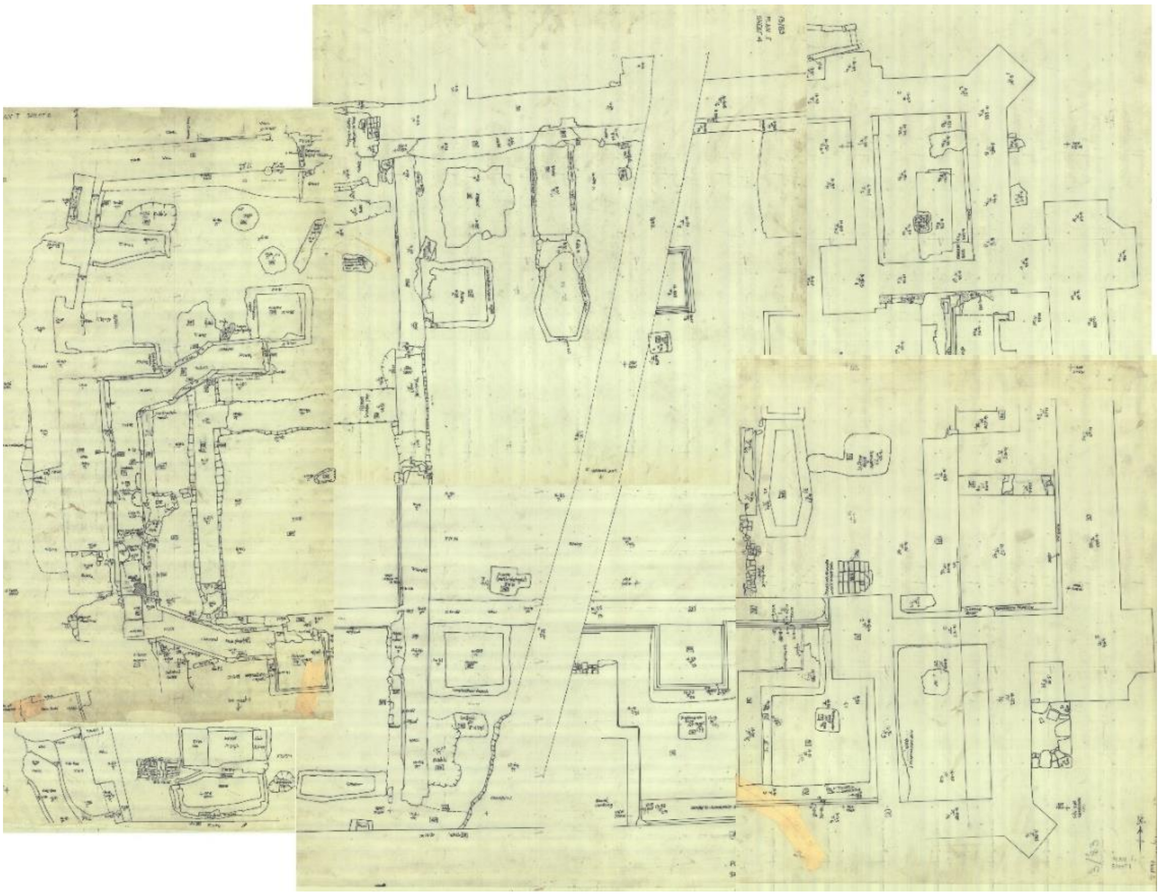

Figure 5.35. Original plan overlay of Southgate Congregational Church. ©Gloucester City Museum.

and feet to the east), one skeleton (III311) was on an east/west alignment (head to the east, feet to the west) and the last one (II250) was placed in the centre of the church on a north/south alignment. Burial practice was identified for 51 of the skeletons. Of these, 13 of the individuals were identified as shrouded burials, with the remaining 38 indicating internment within a coffin (Figure 5.36). Statistical analyses showed that there were no differences in the burial methods used for either sex, or for differing ages (Kruskal Wallis, all p>0.05).

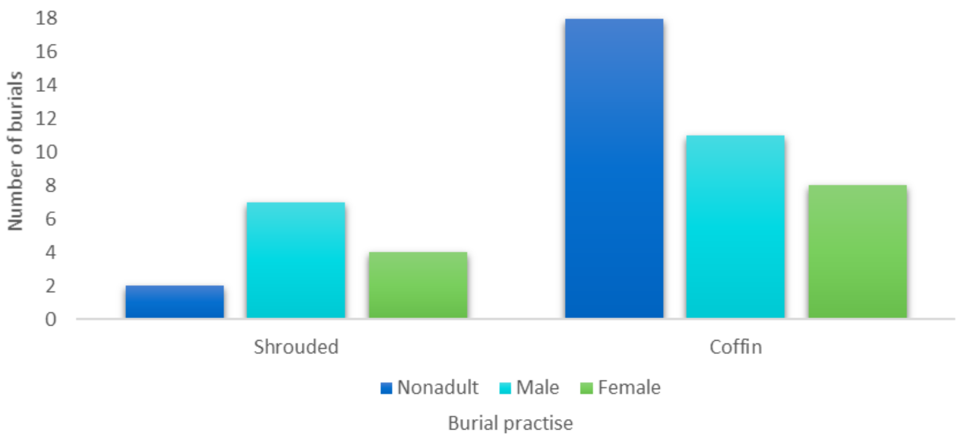

Figure 5.36. Frequency distribution of the non-adult (n=3), male (n=5) and female (n=8) skeletons exhibiting the different burial practices at St Owens Church.

The burial types identified during the excavation of the Southgate Congregational Church skeletons were primarily supine (n=46), with only one flexed burial (II133) present. The remaining 23 skeletons did not have enough information recorded on the context records or plans to determine the burial type used.

5.10.3. Cemetery sample analysis

The collection held at Liverpool John Moores University consists of 70 articulated burials (43 adults and 27 non-adults) and six boxes of disarticulated material. The articulated burials were assessed for completeness of material and the data compiled into Table 5.12. The number of complete burials were limited by the section walls and a number of construction phases that had been carried out during the building of the docks and expansion of the church. Age and sex did not influence skeletal completeness at this site (Kruskal Wallis analyses; p>0.05), with all groups represented at all levels of completeness.

The abrasion/erosion grades identified for the Southgate Congregation Church burials did not vary by age or sex (Kruskal Wallis analyses; p>0.05). There were also no significant differences in the grades assigned and the burial parameters, most likely due to the consistent practices at this site. There was a significant positive relationship between abrasion/erosion grades and fragmentation ($r_{s(70)}$=0.563, p<0.001), indicating that the taphonomic damage to the bones caused both to increase simultaneously (Kruskal Wallis analyses; p>0.05). The fragmentation grades identified for the Southgate Congregation Church burials also did not change by age or sex (Kruskal Wallis analyses; p>0.05). There were no significant differences in the fragmentation grades assigned and the burial parameters.

Table 5.12. Approximate skeletal completeness of the articulated burials recovered from Southgate Congregational Church.

	>75%	50-75%	25-50%	<25%	Total
N	26	7	21	16	70

Collagen extraction was carried out on rib fragments from 13 skeletons. The skeletons were selected to investigate the burial practices observed at this site, to ascertain whether the resultant collagen yield was affected by the presence of a coffin. All skeletons tested produced collagen yields above the proposed cut-off limit for further analysis (Van Klinken, 1999). There were no relationships identified with the age or sex of the skeleton when assessing collagen yield (Kruskal Wallis analyses; p>0.05). Burials parameters did not affect the yield. However, the results from the field portable XRF showed that the level of calcium in the bone decreases as the amount of collagen increases ($r_{s(18)}$=-0.687, p=0.010).

Field portable XRF analysis was carried out on the first ribs from 18 skeletons from Southgate Congregational Church. There were no differences in the levels of calcium, iron or potassium present when assessing by sex or age (Mann Whitney and Kruskal Wallis tests; p>0.05). When assessing the burial parameters, burial practice was found to have an influence ($r_{s(18)}$=-0.700, p=0.001), with shrouded burials having higher levels of calcium present in the bone. As noted in the previous section, the level of calcium in the bone decreases as the amount of collagen increases ($r_{s(18)}$=-0.687, p=0.010), which provides further evidence for the inhibition in the uptake of calcium in coffin burials due to the lack of access to this element.

Table 5.13. Southgate Congregational Church skeleton selected for collagen extraction and the resultant yields.

Skeleton	Bone	Bone weight (g)	Collagen weight (g)	Collagen yield (%)
LC1	Rib	0.50	0.13	26.00
LC1A	Rib	0.75	0.11	14.67
LC2	Rib	0.71	0.15	21.13
III183	Rib	0.63	0.05	7.94
II191	Rib	0.77	0.08	10.39
III199	Rib	0.77	0.03	3.89
III200	Rib	0.73	0.14	19.18
II206	Rib	0.78	0.13	16.67
II207	Rib	0.73	0.15	20.55
III248	Rib	0.68	0.13	19.11
II250	Rib	0.64	0.07	10.94
II259	Rib	0.61	0.07	11.48
II295	Rib	0.73	0.11	15.07

5.10.4. Skeletal analysis – biological profiling

Sex determination

Of the 70 adult burials assessed, there were 23 males, 19 females and 1 unknown adult individual (Figure 5.37). Sex could not be determined for 2% of the articulated adult individuals due to the traits required for sex determination not surviving, or the morphological characteristics having been damaged by post-depositional processes.

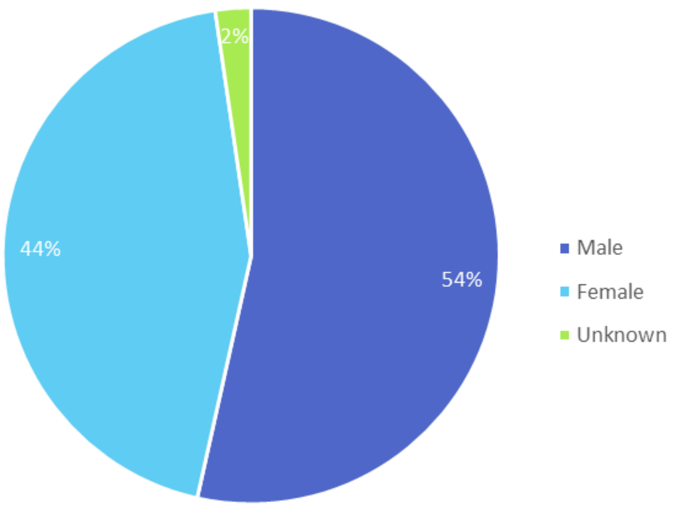

Figure 5.37. Sex determination distribution for the adult skeletons analysed from Southgate Congregational Church.

The ratio of males to females at this site was even ($\chi^2_{(1)}$ = 0.381, p=0.537), showing no skewing of the sexes. The most commonly available pelvic element for sex determination was the greater sciatic notch, which also led to high survivability of the pre-auricular sulcus. Of the individuals that were recovered with a pelvis, over 28% retained the pubic traits required for sex determination. However, this was often detached from the rest of the innominate, leading to the complete obturator foramen not being observable in all cases (Figure 5.38). The survivability of the elements did not differ significantly between males and females, leading to a similar number of techniques being available for each sex (U=40.000, p=0.964).

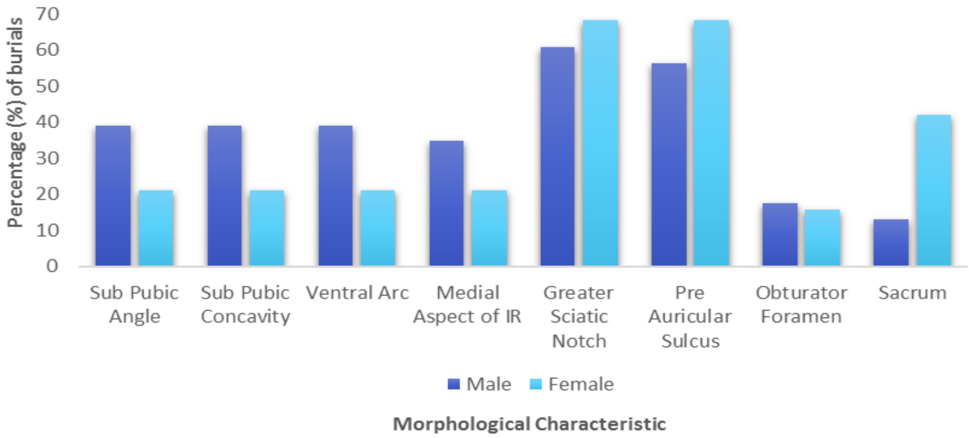

Figure 5.38. Preservation rates of the pelvic morphological characteristics from the male and female Southgate Congregational Church burials.

The most commonly available cranial elements for sex determination were the mastoid processes and supraorbital regions due to their robusticity, with the nuchal crest available in 65% of individuals. The mandible was available for analysis in over 50% of the individuals, with all three traits available for analysis (Figure 5.39).

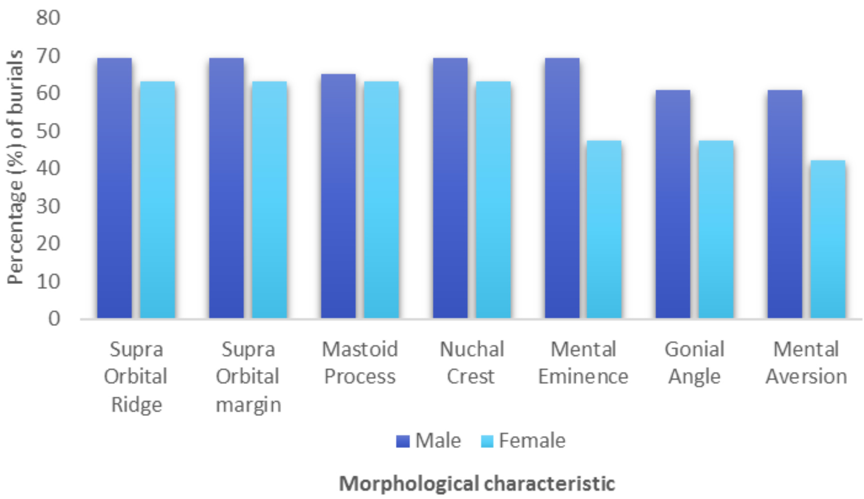

Figure 5.39. Preservation rates of the cranial and mandibular morphological characteristics from the male and female Southgate Congregational Church burials.

The survivability of the elements did not differ significantly between males and females leading to a similar number of techniques being used to for determination of each sex (U=30.000, p=0.831). Of the skeletons that could be assessed using the cranium and mandible, 48% of males and 76% of females provided elements for all seven sex determination techniques.

The most commonly available metric measurement for sex determination was the femoral head (60% of the adult sample), with the humeral head being present in 54% of the total adult sample (Figure 5.40). The survivability of the elements did not differ significantly between males and females leading to a similar number of techniques being used to for determination of each sex (U=17.000, p=0.872). Of the skeletons that could be assessed using metric measurements, 53% of males and 43% of females provided elements for all five sex determination techniques.

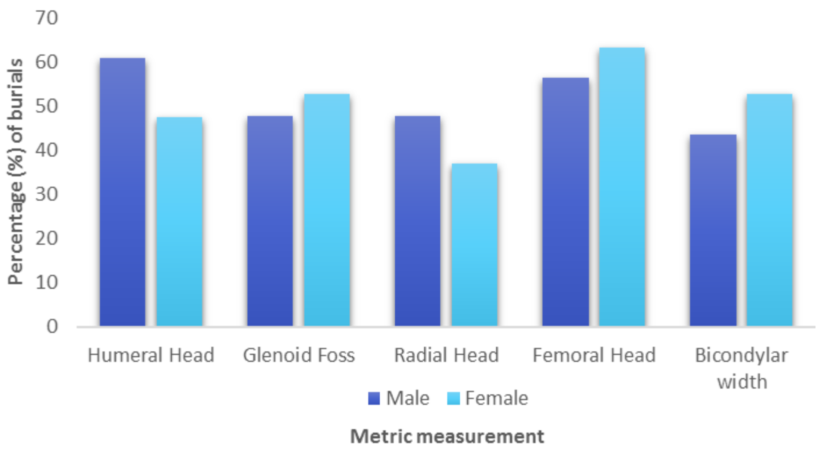

Figure 5.40. Preservation rates of anatomical structures providing metric measurements from the male and female Southgate Congregational Church burials.

The pre-auricular sulcus was examined for all adult skeletons where the landmark was preserved (n=26) to determine whether it was a groove of pregnancy (GP) or groove of ligament (GL). Only one male (8%) exhibited a pre-auricular sulcus, which was identified as a groove of ligament. It was possible to observe a pre-auricular sulcus on 10 females, with all identified as a groove of ligament, which demonstrates that this trait is more commonly seen on females (U=26.000, p<0.001).

Age estimation

There were 70 articulated burials (43 adults, 27 non-adults) available for assessment of age, with 66 providing characteristics required for the estimation. Of those that could not be placed into age categories (6%), all were classified as adult. The age-at-death distribution (Figure 5.41) shows the high number of non-adult individuals in this sample, with 36% of the articulated burials under 20 years old.

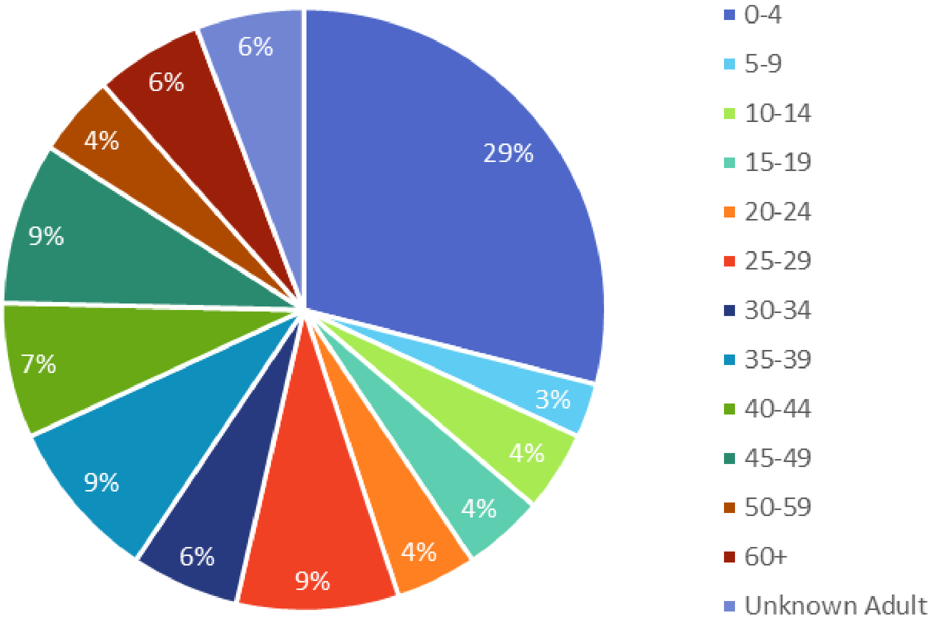

Figure 5.41. Age-at-death distributions for the Southgate Congregational Church burials.

The preservation of the elements for age assessment did not vary significantly between males and females (U=23.000, p=0.848), with both sexes similarly having poor preservation of the pubis and ribs (Figure 5.42). Although the cranium survived in many cases, heavy fragmentation of this region occasionally prevented the observation of the sutures. Of the techniques available, only two individuals used all seven age estimation methods, with the majority (19%) of individuals using only two techniques. The auricular surface was the most commonly used method, followed by the iliac crest, most likely due to the robusticity of this innominate.

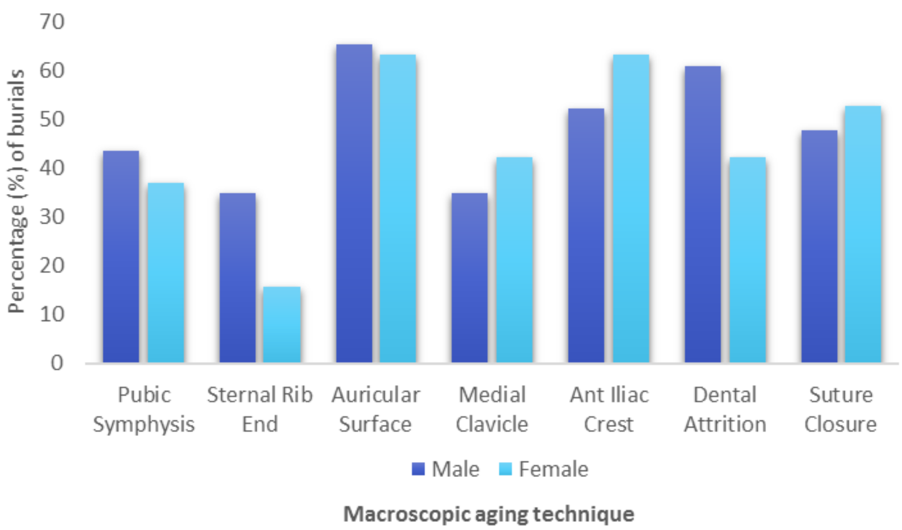

Figure 5.42. Preservation rates of the anatomical regions enabling assessment of the macroscopic aging techniques from the adult male and female Southgate Congregational Church burials.

The percentage of non-adult burials using each aging technique was high, most likely due to the increased number of elements available for use in each case (Figure 5.43). The non-adult skeletal elements showed abrasion/erosion and fragmentation rates comparable to the adult sample ($\chi^2_{(6)}$=4.750, p=0.576 and $\chi^2_{(6)}$=6.458, p=0.167 respectively), which conflicts with previous literary evidence stating that non-adults are under-represented in the archaeological record due to poor preservation (Molleson 1991; Crawford 1991;1993).

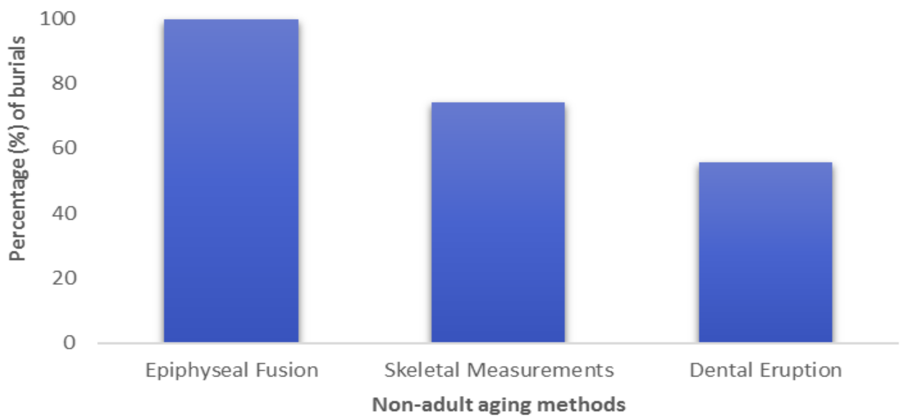

Figure 5.43. Preservation rates of the anatomical structures enabling assessment of the macroscopic aging techniques from the non-adult Southgate Congregational Church burials.

The rate of truncation was higher in non-adult burials, leading to skeletal completeness being higher in the adults ($\chi^2_{(3)}$=10.288, p=0.016). The 37% of burials were able to use all three age estimation techniques, with only 7% of burials using only one method for aging. Of the 7%, skeletal measurements and dental aging could not be taken from any of the burials.

Stature estimation

All adult burials (n=43) were assessed for long bone lengths where possible. Of those assessed for sex, 32 produced measurements from at least one long bone for the estimation of stature, with the recovery rates of long bones similar for both sexes (U=13.000, p=0.422; figure 5.44). Average femur length for males was 45.54 ± 1.09cm (n=8) and for females was 43.34 ± 1.81cm (n=11), demonstrating the sexual dimorphism present within the sample ($t_{(17)}$=3.043, p=0.007). Female stature ranged from 155.12cm to 168.71cm, with female mean height of 161.14 ±4.47cm. Male stature ranged from 165.42cm to 173.27cm, with a mean male stature of 169.78 ± 2.60cm, which was significantly higher than female ($t_{(17)}$=4.876, p<0.001).

Ten individuals from Southgate Congregational Church could not be assessed for stature by complete long bone length, with only one providing femoral landmark measurements. The remaining eight skeletons were truncated, or too fragmented for the analysis. Given the small sample size for comparison data, it was not possible to determine the accuracy of the fragmentary femora regression formulae by Simmons *et al* (1990) for this sample. Skeleton LC1d was a male aged 60+ years, who provided a measurement for lateral condyle height (LCH), producing an estimate of 170.13 ± 6.24cm.

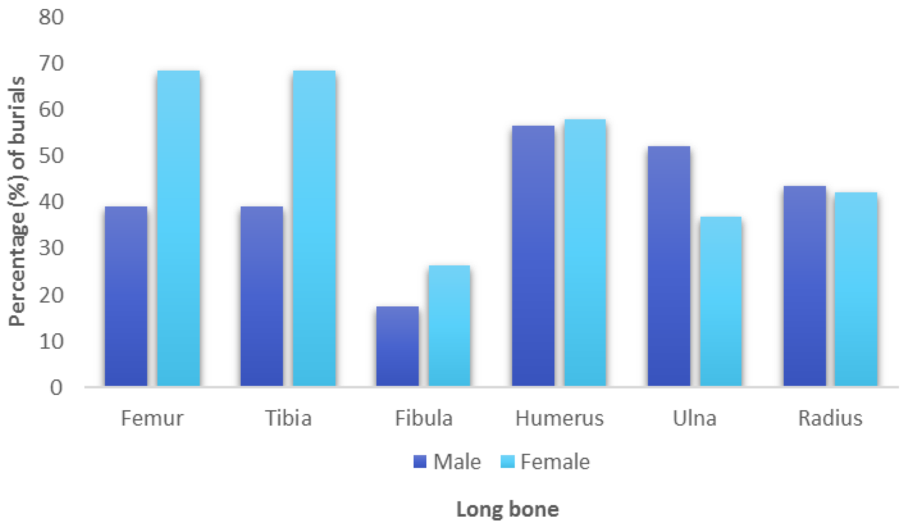

Figure 5.44. Preservation rates of complete long bones available for stature estimation from the male and female Southgate Congregational Church burials.

5.10.5. Geochemical studies on human material

Dental calculus

Four dental calculus samples were obtained at random from the adult Southgate Congregational Church Collection held at Liverpool John Moores University (Table 5.14). The dental calculus samples were assessed before and after acid extraction, with the results plotted against those for the dental collagen shown in figure 5.45. It should be noted that skeleton II191 had a limited amount of calculus available, preventing acid treatment on this sample.

Table 5.14. Stable isotope analysis results from four dental calculus samples from Southgate Congregational Church.

Skeleton number	δ13C	δ15N
II191	-20.76	12.84
II208	-21.49	13.52
II259	-20.68	12.43
III183	-21.84	13.08

The mean δ13C values (-21.20 ±0.54‰) for the Southgate Congregational Church calculus samples were consistent with a diet focused on C_3 plants. Mean $\delta^{15}N$ values (12.95 ± 0.47‰) were consistent with a shift of two trophic levels (7.14‰) above the herbivore baseline (5.81 ± 1.48‰, n=61); indicating that the diet contained terrestrial animal sources, with a marine and/or freshwater fish component consumed on a regular basis.

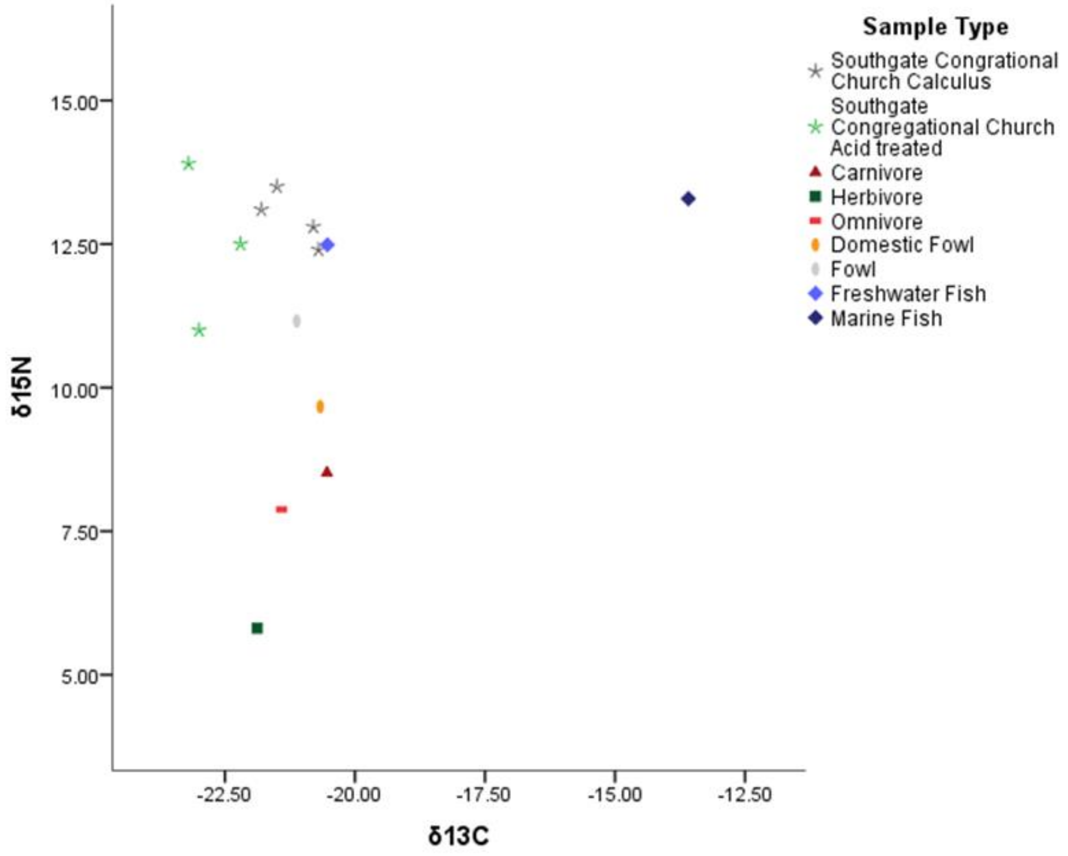

Figure 5.45. The Southgate Congregational Church calculus samples (n=4), demonstrating the shift in values between isotopic source materials and the acid treated calculus samples (n=3). Faunal, freshwater and marine data is shown for comparison (Müldner and Richards, 2007a; 2007b; Müldner *et al,* 2009).

The dental calculus samples were assessed before and after acid extraction, which adjusted the $\delta^{13}C$ further, showing that carbon values were approximately 2‰ lighter when considering just the organic carbon content. This is to be expected as the carbonate (inorganic) component of the $\delta^{13}C$ is isotopically heavier that the organic component (*pers. comms* Simon Poulson). Statistical analysis has not been carried out on the acid extraction samples due to this further shift in values.

Hair

When preparing the calculus samples to send to the University of Nevada, the potential for a comparison to the calculus values arose and a hair sample was collected from skeleton II191 from Southgate Congregational Church. It should be noted that the analysis of hair requires an adjustment of the results to account for the difference in amino acid composition between collagen and keratin in hair samples, requiring a correction for the stable isotope ratio offset (Britton *et al*, 2016; O'Connell *et al*, 2001). Paired analyses have shown this offset to be minimal (0–2‰ in both $\delta^{13}C$ and $\delta^{15}N$), with little impact on the overall dietary trend. To provide values comparable to that of bone collagen, a predicted mean collagen value has been added to both keratin carbon and nitrogen isotopic values (+1.41‰ for carbon and +0.86‰ for nitrogen). The original data and adjusted isotopic hair values were plotted alongside the calculus values for skeleton II191 in Figure 5.46.

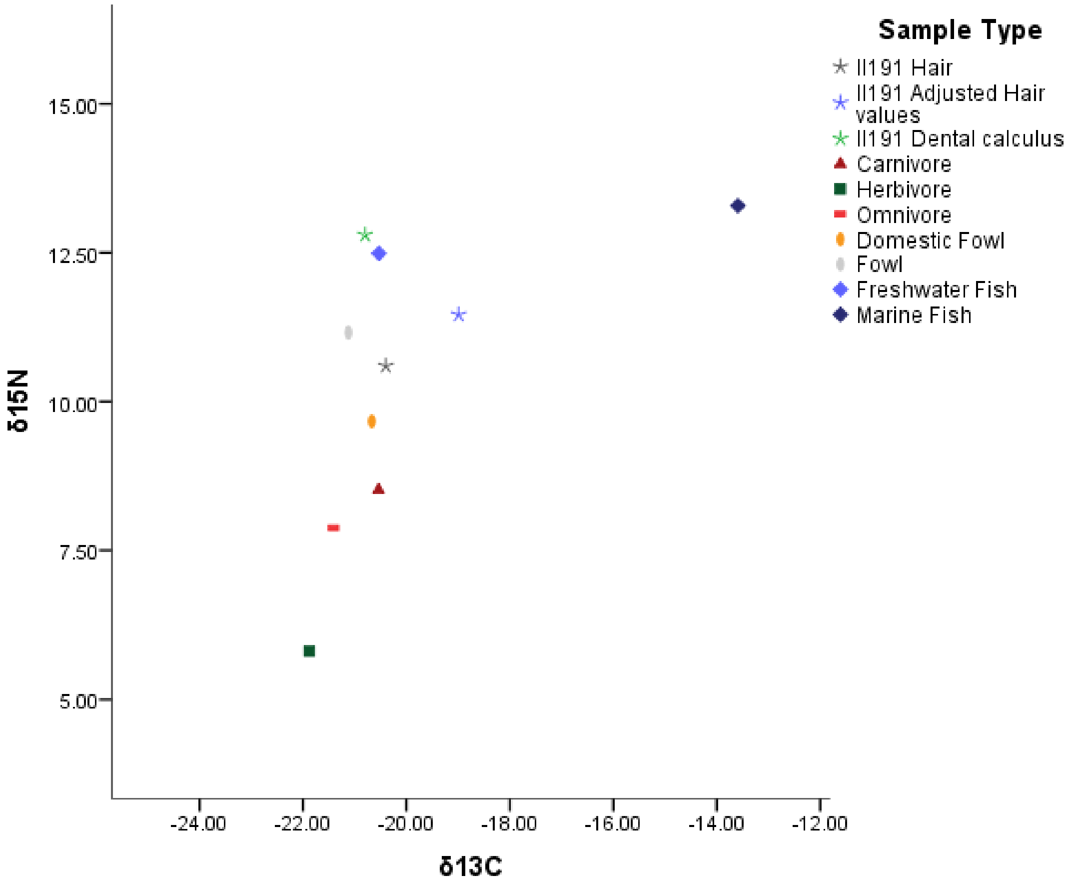

Figure 5.46. The hair sample from skeleton II191, showing the original and adjusted values. Also plotted is the calculus sample tested from this individual. Faunal, freshwater and marine data is shown for comparison (Müldner and Richards, 2007a; 2007b; Müldner *et al,* 2009).

5.10.6. Demographics

The data provided by the age estimations for the burials were analysed to produce a life table (Table 5.15). The life table shown here is a simplified version of the complete life table, which can be seen in Appendix A6. Over 33% of the sample did not survive past 10 years of age. Conversely, those who survived to ten years of age could expect to live a further 27 years on average based on the demographic analysis, although life expectancy gradually decreases from this age onwards. The survivorship curve shows the proportion of individuals surviving at the end of each five-year period (Figure 5.47). Although the sharp decrease in the non-adult sample is evident at the start, the rate of death decreases until adulthood, suggesting that there were greater risks during the first five years of life.

Table 5.15. Simplified standard life table displaying the demographics for the Southgate Congregational Church burials.

Age x	Individuals dx	Survivorship lx	% of Deaths	Mortality Qx	Expectation of Life ex
0	20	65	30.77	0.31	25.62
5	2	45	3.08	0.04	30.89
10	3	43	4.62	0.07	27.21
15	3	40	4.62	0.08	24.06
20	3	37	4.62	0.08	20.81
25	6	34	9.23	0.18	17.43
30	4	28	6.15	0.14	15.63
35	6	24	9.23	0.25	12.81
40	5	18	7.69	0.28	11.25
45	6	13	9.23	0.46	9.62
50	3	7	4.62	0.43	10.71
60	4	4	6.15	1.00	5.00
	65				

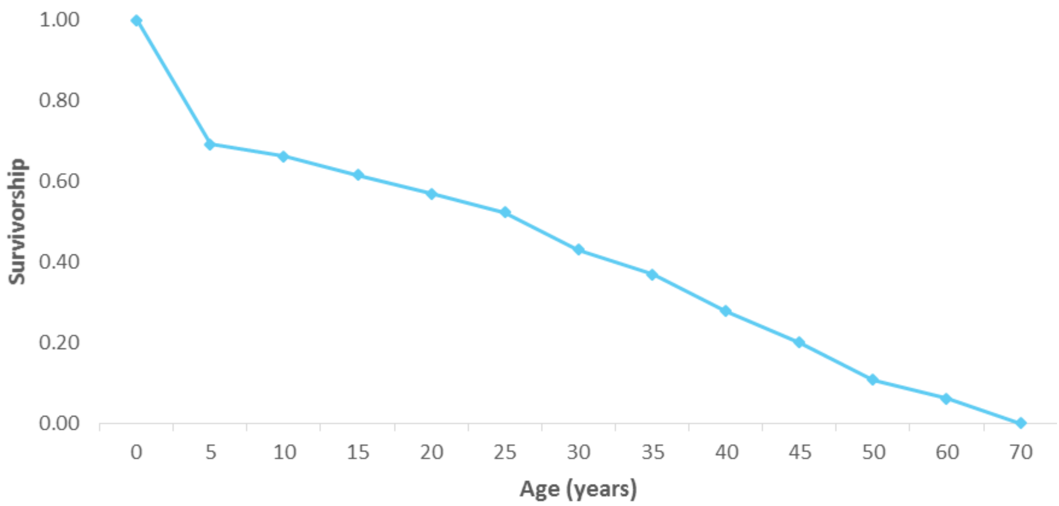

Figure 5.47. Survivorship curve for the Southgate Congregational Church burials (n=65).

The mortality curve shows the percentage of the sample lost at the end of each five-year period (Figure 5.48). This gives an indication of the ages at which mortality peaks, in this case, following the high rates of mortality during early childhood the rates rise again during adulthood. Due to the small sample size for this sample, it is not possible to comment on the individual peaks present as all groups are represented by only 3-6 individuals.

The crude mortality rate for estimated from life expectancy at birth (25.62 years) based on the 65 individuals in the demographic analysis was 39 deaths per 1000 within this population. The length of time the cemetery was in use has been estimated at was 127 years, based on the founding of the church in 1730 and the transition from burials at the Church to Wootton Cemetery, following the Burial Act of 1857. The population size required to sustain the current number of burials over the lifespan of the cemetery is approximately 13 individuals (13.11).

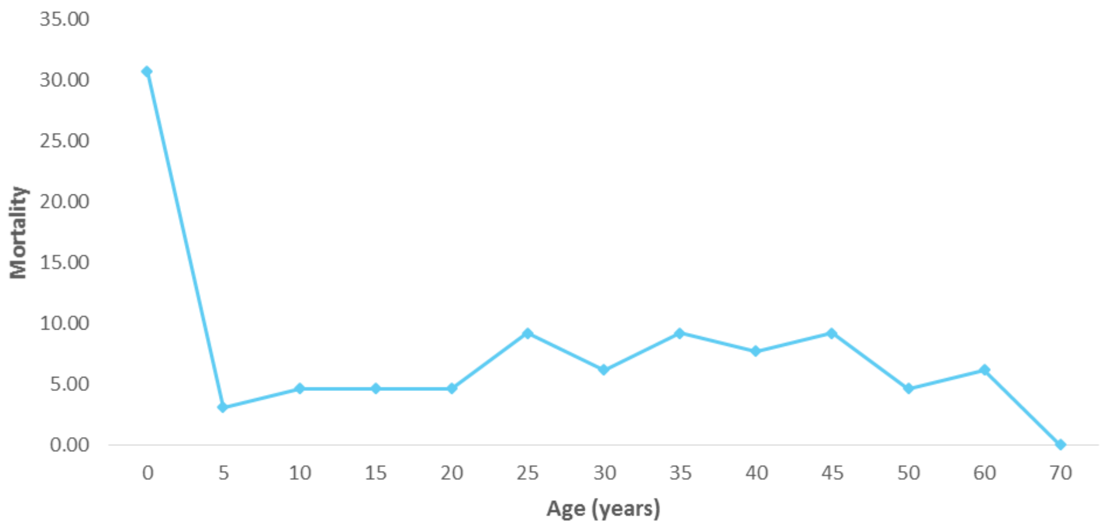

Figure 5.48. Mortality curve for the Southgate Congregational Church burials (n=65).

The overall demographics give an insight into the population as a whole, but do not take into account the different risk factors that can affect the sexes. As the sample size is small, it does not give a true representation of the local parish community and splitting the demographics by sex would cause further issues. However, it was possible to gain further information through the burial records for the church, with parish register from 1786-1837 (Table 5.16). There were 295 entries into the burial register, with 271 providing age and sex information for demographic analysis. The demographics for the burial records enabled the investigation of both male and female demographics from birth. The survivorship curve shows that although both sexes follow the same pattern ($t_{(30)}$=-0.389, p=0.700), the male survivorship rate is slightly lower at all age ranges, except 60-69 years (Figure 5.49).

Table 5.16. Simplified standard life table displaying the demographics for the Southgate Congregational Church burial records.

Age x	Individuals dx	Survivorship lx	% of Deaths	Mortality Qx	Expectation of Life ex
0	76	271	28.04	0.28	37.44
5	6	195	2.21	0.03	46.05
10	6	189	2.21	0.03	42.43
15	12	183	4.43	0.07	38.74
20	16	171	5.90	0.09	36.29
25	11	155	4.06	0.07	34.77
30	11	144	4.06	0.08	32.24
35	4	133	1.48	0.03	29.70
40	9	129	3.32	0.07	25.54
45	9	120	3.32	0.08	22.27
50	27	111	9.96	0.24	18.87
60	32	84	11.81	0.38	13.33
70	36	52	13.28	0.69	8.46
80	14	16	5.17	0.88	6.25
90	2	2	0.74	1.00	5.00
	271				

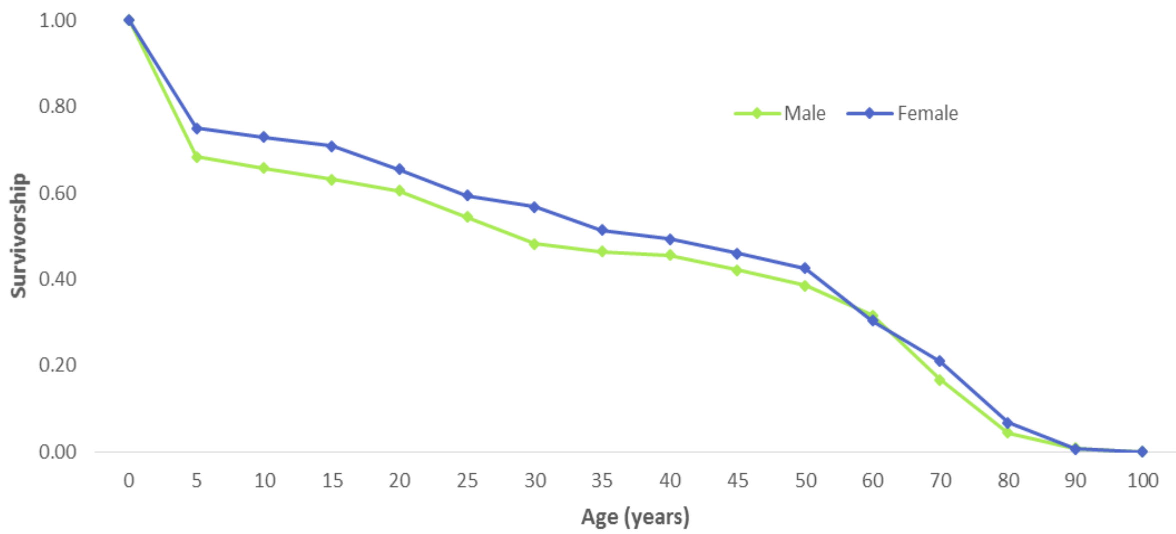

Figure 5.49. Male and female survivorship curve for the burial record demographics from Southgate Congregational Church.

The mortality curve shows that over 30% of males and 25% of females did not survive past five years old (Figure 5.50). The demographic profiles obtained from the burial records show that mortality follows a similar pattern for both sexes (U=126.500, p=0.956), with only slight variations at the individual ages. The crude mortality rate for estimated from life expectancy at birth (37.44 years) based on the 271 individuals in the demographic analysis was 26 deaths per 1000 within the population represented by the records. The length of time the parish records analysed covered was 51 years. The population size required to sustain the current number of burials represented over the lifespan of the documented use of the cemetery is approximately 204 individuals (204.37).

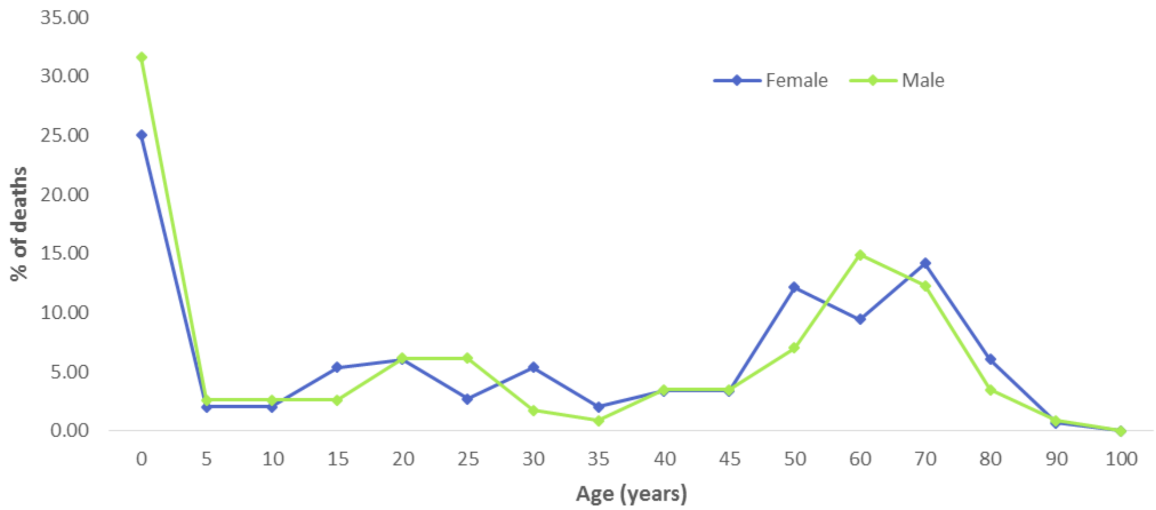

Figure 5.50. Male and female mortality curve for the burial record demographics from Southgate Congregational Church.

The fluctuations in mortality between the sexes could be a result of working conditions, and/or obstetric events. However, as the differences are not statistically significant it suggests that the risk of pregnancy was not as high as in the medieval period. As the burial records cover all locations within the cemetery of Gloucester Congregational Church and the members of the parish who were buried elsewhere (Appendix A7), it eliminates the potential for under-representation of the sexes, and/or other demographic groups.

5.10.7 Summary of site results

Southgate Congregational Church was in use for approximately 127 years (1730-1857); however, the continual development of the Gloucester Docks and later buildings on the site limited the potential for investigation through osteological analysis. As the excavations were carried out in the 1980's, the loss of information through the time constraints placed on the archaeologists has further limited the potential for interpretation. The osteological analysis of the remains recovered from the cemetery and housed at Liverpool John Moores University, consisted of 70 articulated (43 adults, 27 non-adults) burials, with an average life expectancy of 25.62 years at birth. The mortality profiles show that over 33% of the overall sample did not survive past 10 years of age, indicating good preservation and retrieval rates of non-adult human remains. The number of non-adult burials is high (43% under 20 years) when compared with other urban samples. This high rate of mortality is also shown in the burial records, with 36.89% of deaths represented by non-adults. St Mary Spital in London reports a non-adult mortality rate of 29%, with the total excavated sample size being over 13,000 individuals (Connell *et al*, 2012), which is considerably lower than that seen at this site from both the osteological and burial record demographics. The presence of a skeleton with a post-mortem calvaria cut (III179), indicated that individuals treated at the infirmary and with the means to pay for a burial within the Congregational Church were also interred in the cemetery. The distribution of sex at Southgate Congregational Church is fairly even, which is in agreement with other studied sites (Bardsley, 2014). All pelvic elements were available for sex determination in 10% of the sample, with over 67.5% retaining the greater sciatic notch. In the cranium, the mastoid processes, nuchal crest and supraorbital regions were the most commonly preserved elements, with all traits available in 45% of the sample. There was no difference in the retention rate of the elements by either sex.

The burial practices observed at Southgate Congregational Church were mainly coffin burials, with a small number of shrouded burials, which allowed an insight into the degradation processes influencing the bone when subjected to varying environmental conditions. It was noted with this sample that the calcium rates were much lower in coffin internments, indicating that the coffin itself is inhibiting the uptake of calcium and displacement of potassium from the bone. As bone becomes mineralised, the calcium displaces the potassium present in the bone as the protein mineral matrix breaks down (Gill-

King, 1999; Forbes, 2003; Dent *et al*, 2004). The presence of the coffin would prevent the calcium in the soil from accessing the bones, leading to reduced levels of mineralisation in the skeletal elements. The calcium that is leached from the bone during the decomposition process, through the burial leachate or intrusion of water to the burial, would be dispersed from the grave at a much slower rate, leading to increased values in the soil taken from within the grave. As soil was recovered from the coffin burial of LC1a, it suggests that there was damage to the coffin enabling the soil to filter inside the grave.

If you were to select an individual for further analytical testing on the bone based on the data collected so far (such as radiocarbon dating, stable isotope analysis or mitochondrial DNA), there would be a greater chance of success with a skeleton interred in a coffin, due to the higher rates of collagen present in these burials. Analytical testing is for nuclear DNA, would be better on a shrouded burial due to the higher levels of inorganic bone material present. The burial parameters were not found to have a direct influence on the collagen yield; however, the presence of a coffin produced lower rates of calcium in the bone, which indicated higher levels of collagen present. However, the rates of fragmentation and abrasion/erosion on the epiphyseal surfaces of the bone may be greater, indicating that samples should be taken from the diaphysis of the petrous portion of the temporal. The age or sex of the burial did not influence the potential for sample selection or preservation.

The combination of both isotopic and documentary evidence provides an insight into the varied dietary intake of the Gloucester population, due to the accessibility of the city from within England, across the Welsh border, and from further afield via the River Severn. Documentary evidence reports that the city of Gloucester continued to function as a supplier of goods to the region, with much of the trade coming via the River Severn (Herbert, 1988). Imports of wine, spirits, sugar, citrus fruits and salt, all contributed to the diversity of the goods available at the marketplace. Export of food products from the city included cheese, fish, malt, cider and corn. Weekly markets took place, with up to 50 butchers holding stalls in the 1750s and four annual fairs held to provide to allow the sale of salmon from the River Severn and cheese from the Vale of Gloucester. The market continued to thrive during this period, with the popularity leading to the building of two new marketplaces in 1786 due to the congestion caused by stallholders attending the events. When considering the geochemical data, the calculus sample values show higher levels of nitrogen, and lower levels of carbon when compared with the hair sample. Human hair grows at a rate of approximately 1cm per month, with the sample sent for testing being approximately 3cm long, giving a short timeframe for the dietary analysis carried out on this sample. Dental calculus can accumulate over a long period, with a continual cycle of build-up and wear contributing the values attained through the analysis. This could account for the shift in values, however until further work is carried out on dietary analysis on calculus to correct for this shift, it is not possible to fully investigate these differences. However, the overall dietary interpretation is not affected by the shift in values, with an intake based on C_3 plants, animal protein and a regular intake of freshwater and/or marine fish. Dental calculus is a biofilm, comprising of food remains, bacteria and DNA (Salazar-García *et al*, 2014). This can lead to carbon values that are lower than would be expected from dental collagen, due to the continual build up and wear of the calculus over the lifespan of the individual (Salazar-García *et al*, 2014). As food particles and other materials derived from plant material are trapped in the calculus, and C_3 plants materials having a $\delta^{13}C$ value of approximately -26‰ (Mays, 1997), it is likely that this has contributed to the lowered values obtained.

5.11. Gloucester Infirmary burial ground

Gloucester Infirmary opened in 1755 at a temporary location on Lower Westgate Street, with an aim to provide aid to the ill and infirm from any country that did not have the means to pay for treatment (Herbert, 1988). It was supported by voluntary contributions and donations, with the doctors and surgeons providing their services free of charge. The lease for the Southgate Street site was secured in 1756, with the first patients admitted to the new site in 1761. The land behind Southgate Congregational Church was given to the Infirmary for use as a burial ground in 1780, with the ground consecrated the following year (Herbert, 1988). The burials at the Gloucester Infirmary burial ground are believed to have continued until the implementation of the Burial Act 1857, after which, all dead were interred at Wootton Cemetery.

5.11.1. Site plans

The site plans produced during the excavation of Gloucester Infirmary burial ground were detailed for some of the skeletons, but missing for others. Which prevented the overall assessment of the cemetery. An overview of Trenches III and V provided an indication of the distribution of the burials and the position of the wall between the two cemeteries of Southgate Congregational Church and Gloucester Infirmary (Figure 5.51).

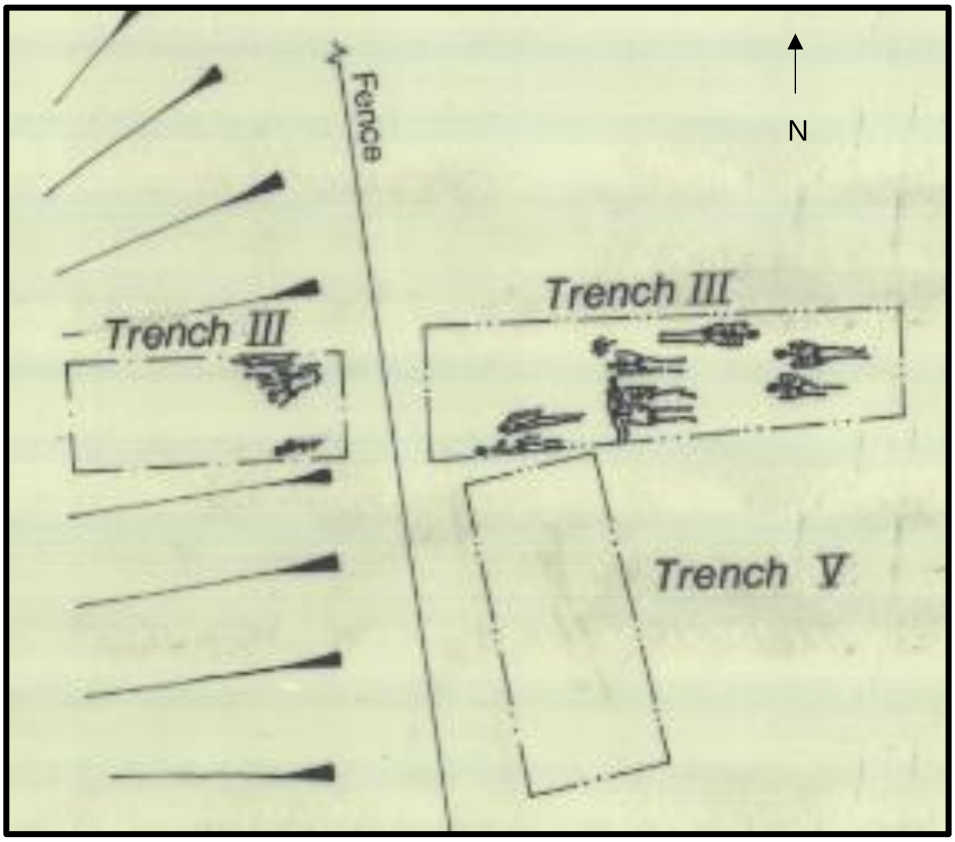

Figure 5.51. Original overview plan of Trenches III and V, which contain burials from the Southgate Congregational Church (right of fence line) and Gloucester Infirmary burial ground (left of fence line). ©Gloucester City Museum

5.11.2. Archaeothanatology

The excavation records, plans and photographs of the 25 individuals interred in Trench III of the Gloucester Infirmary burial ground were assessed for arm position, burial type, practice and orientation. Statistical analysis was not possible or all variables due to the consistency in practises in Trench III when assessing the undisturbed burials. All skeletons (n=25) were assessed to determine the position of the arms during internment (see Figure 2.1, page 47 for arm position reference). Of these, 19 (76%) skeletons did not provide sufficient information for analysis, and the remaining six (24%) all were found with the arms placed by the sides. When assessing burial alignment, five (20%) burials did not have enough information to determine the alignment due to incomplete context records, plans, or burial type. Of the remaining skeletons, the majority (n=18) were interred on a west/east alignment, one skeleton (III311) was on an east/west and the final skeleton (II250) was placed in the centre of the church on a North-South alignment. Burial practice was identified for 20 (80%) of the skeletons using position of the skeletal elements, presence of coffin nails, the burial cut and the preservation of the skeletal remains. Of these, five (20%) of the individuals were identified as shrouded, with the remaining 15 (60%) indicating internment within a coffin. The remaining five individuals were disturbed burials. Statistical analysis showed that there were no differences in the burial method used for either sex, however, coffin internments were more likely to be older members of the community ($r_{s(15)}$=0.524, p=0.045). The burial types identified during the excavation of the Gloucester Infirmary burial ground skeletons were supine (n=20), with the remaining five skeletons disturbed, or secondary burials.

5.11.3. Cemetery sample analysis

The collection held at Liverpool John Moores University consist of 25 adult burials and six boxes of disarticulated material. The context records list many more individuals, although the location of these is not yet known. The author has been working together with the curator of Gloucester City Museum, David Rice, to locate the rest of the skeletons recovered during the excavations to enable further research to be carried out on this material. The articulated burials were assessed for completeness of material and the data compiled into Table 5.17. The number of complete burials were limited by the section walls and a number of construction phases that had been carried out during the building of the docks and expansion of the church at Gloucester. As a consequence of this, none of the burials were more than 75% complete.

Table 5.17. Approximate skeletal completeness of the articulated burials recovered from Gloucester Infirmary burial ground.

	>75%	50-75%	25-50%	<25%	Total
N	0	6	5	14	25

Although there were no relationships identified for abrasion/erosion or fragmentation rates with the biological or burial characteristics, there was a significant positive relationship between abrasion/erosion grades and fragmentation ($r_{s(25)}$=0.421, p=0.036), indicating that the taphonomic damage to the bones caused both to increase simultaneously. Field portable XRF analysis was carried out on the first ribs from four skeletons from the Gloucester Infirmary burial ground. All individuals tested were male and with similar burial parameters. Due to the small sample size, no statistical analysis was carried out on this data.

5.11.4. Skeletal analysis – biological profiling

Sex determination

Of the 25 adult burials assessed, there were 20 males, 4 females and 1 unknown adult individual (Figure 5.52). No non-adult individuals were recovered from this cemetery. The ratio of males to females at this site was not even ($\chi^2_{(1)}$ = 9.000, p=0.003), showing skewing of the sexes as seen at other archaeological sites studied in the literature (Bardsley, 2014).

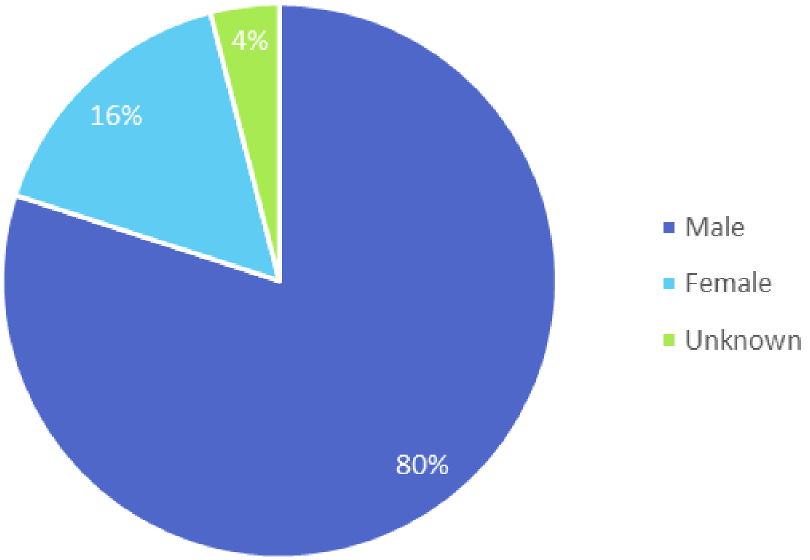

Figure 5.52. Sex determination distribution for the adult skeletons analysed from Gloucester Infirmary Chapel.

Sex could not be determined for 4% (n=1) of the adult individuals, with the sciatic notch the most commonly available pelvic element for sex determination. Of the individuals recovered with a pelvis, 27.5% retained the pubis. However, this was often detached from the rest of the innominate, leading to the complete obturator foramen not being observable in some cases (Figure 5.53). The survivability of the elements did not differ significantly between males and females, leading to a similar number of techniques being available for each sex (U=33.000, p=0.546).

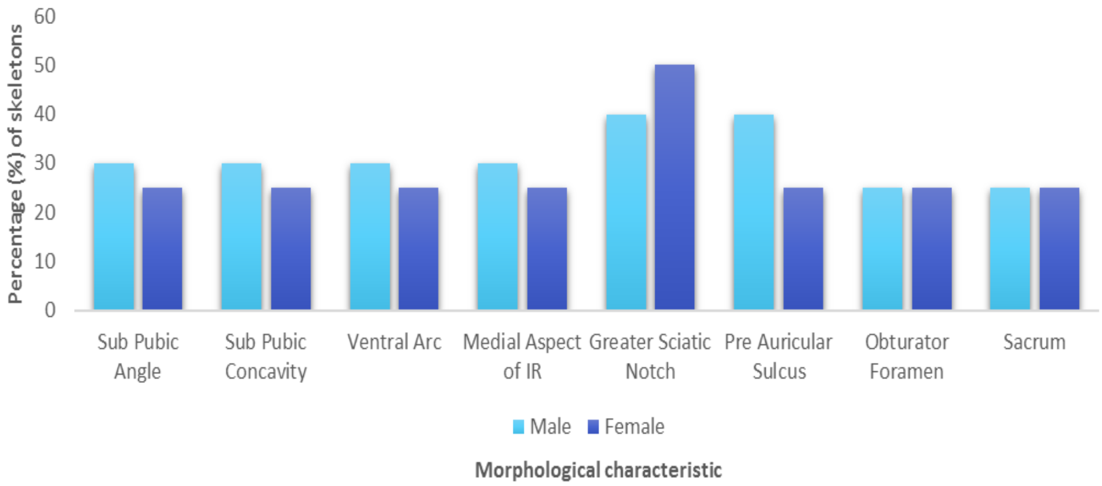

Figure 5.53. Preservation rates of the pelvic morphological characteristics from the male and female Gloucester Infirmary Chapel burials.

The most commonly available cranial elements for sex determination were the mastoid processes, which were present in 52.5% of adult skeletons. The nuchal was also available for analysis in 50% of the individuals (Figure 5.54). The survivability of the elements did not differ significantly between males and females leading to a similar number of techniques being used to for determination of each sex (U=30.000, p=0.878).

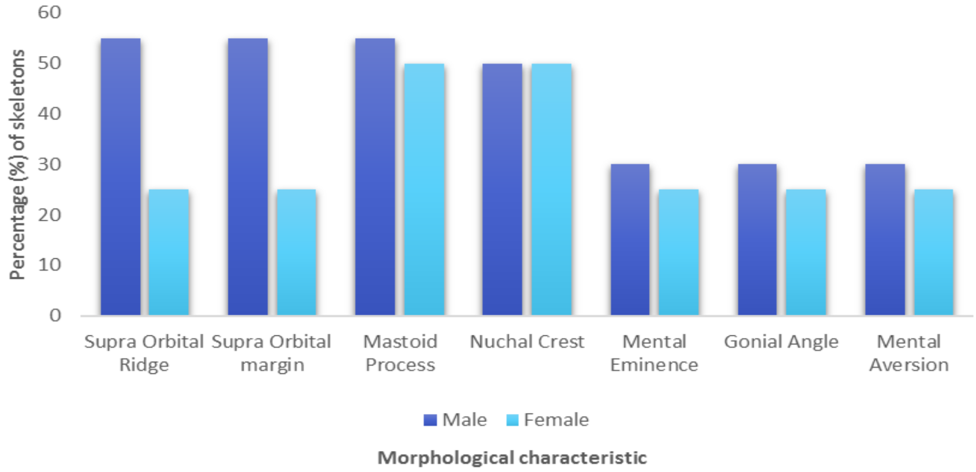

Figure 5.54. Preservation rates of the cranial and mandibular morphological characteristics from the male (n=20) and female (n=5) Gloucester Infirmary burial ground internments.

The most commonly available metric measurement for sex determination was the femoral head (47.5%), with femoral bicondylar width available in 45% of the total adult sample. Of those that could be assessed for sex, the percentage of burials preserving elements providing metric measurements for analysis are shown in figure 5.55.

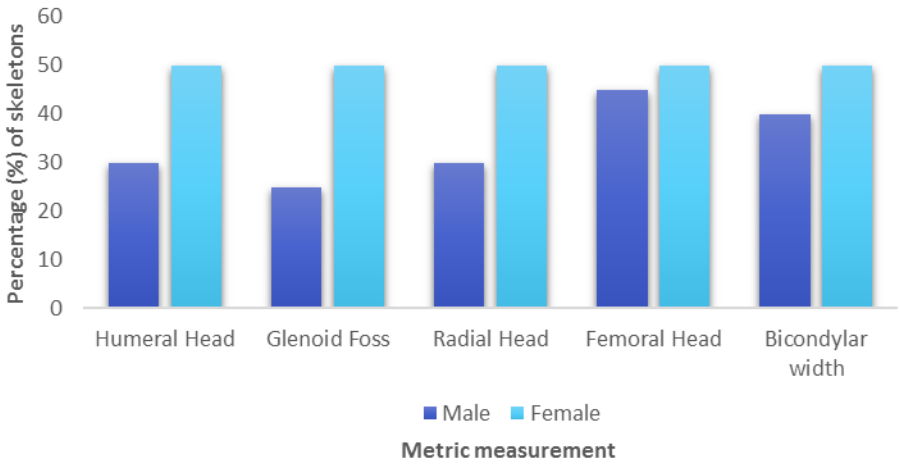

Figure 5.55. Preservation rates of anatomical structures providing metric measurements from the male (n=20) and female (n=5) interments at the Gloucester Infirmary burial ground.

The survivability of the elements did not differ significantly between males and females leading to a similar number of techniques being used to for determination of each sex (U=15.000, p=0.755). Of the skeletons that could be assessed using metric measurements, only 10% of males and 25% of females provided elements for all five sex determination techniques. The pre-auricular sulcus was examined for all adult skeletons in the subsample where the landmark was preserved (n=9) to determine whether it was a groove of pregnancy (GP) or groove of ligament (GL). All skeletons assessed (eight males and one female) were identified as not exhibiting the trait.

Age estimation

There were 25 burials available for assessment of age, with 20 providing characteristics required for the estimation. Of those that could not be placed into age categories (20%), all were classified as adult. The age-at-death distribution (Figure 5.56) shows that 24% of the sample died in the 35-39 year age range, with only 4% of the samples interred at this cemetery surviving past 60 years.

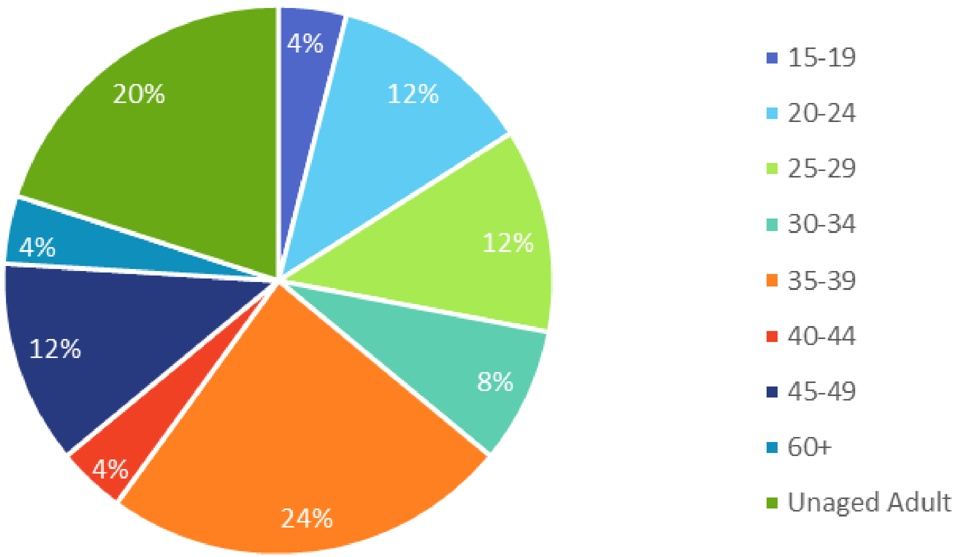

Figure 5.56. Age-at-death distributions for the Gloucester Infirmary Chapel burials. Note that no individuals in the non-adult or 50-59 year age categories were recovered from this site.

Adult age estimation was dependent on the survivability of specific skeletal elements, with greater survivability increasing the accuracy of the age assessment. Factors affecting the estimation of age within an individual were missing elements due to truncation, pathological or taphonomic damage to the cortical surface or severe fragmentation. Figure 5.57 shows the percentage of articulated burials that could be aged using each macroscopic aging technique. The preservation of the elements for age assessment did not vary significantly between males and females (U=30.000, p=0.878), with the females having poor preservation of the cranial sutures. Of the aging techniques available, none used all seven, with the majority (35%) of individuals using five techniques. The auricular surface was the most commonly used method due to the robusticity of this element, although the medial clavicle and anterior crest also survived well.

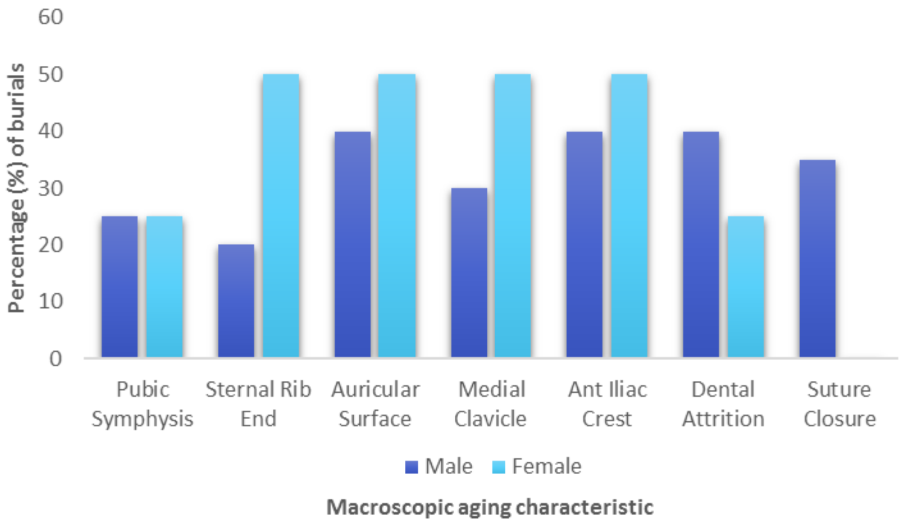

Figure 5.57. Preservation rates of the anatomical regions enabling assessment of the macroscopic aging characteristics from the male (n=20) and female (n=5) Gloucester Infirmary burial ground internments.

Stature estimation

The burials (n=25) from Gloucester Infirmary burial ground were assessed for long bone length, with all available measurements recorded. Of those assessed for sex, fourteen produced measurements from at least one long bone for the estimation of stature, with the recovery rates of long bones similar for both sexes (U=16.000, p=0.818; figure 5.58). To ensure consistency, maximum femur length was used to estimate stature for the Southgate Congregational Church burials. Average femur length for males was 44.98 ± 2.41cm (n=6) and for females was 44.70 ± 1.98cm (n=2), demonstrating that there was no sexual dimorphism present within this small sample ($t_{(6)}$=0.141, p=892). Female stature ranged from 162.53cm to 166.49cm, with female mean height of 164.51 ±1.98cm. Male stature ranged from 160.66cm to 178.98cm, with a mean male stature of 168.47 ± 5.74cm, which showed no significant difference to the female stature estimations ($t_{(6)}$=0.829, p=0.439).

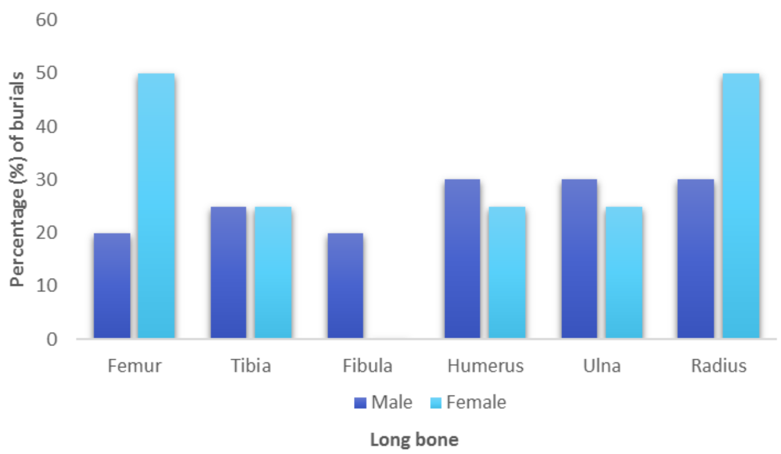

Figure 5.58. Preservation rates of complete long bones available for stature estimation from the male (n=20) and female (n=4) Gloucester Infirmary burial ground internments.

Eleven individuals from the Gloucester infirmary burial ground could not be assessed for stature by complete long bone length, with only two providing femoral landmark measurements. The remaining nine skeletons were truncated, or too fragmented to provide this information. Given the small sample, it was not possible to determine the accuracy of the fragmentary femora regression formulae by Simmons *et al* (1990) for this sample. Skeleton L1 was a male aged 60+ years, who provided a measurement for proximal femoral breadth (VHA), producing an estimate of 163.30 ± 6.10cm. Skeleton L2 was an adult male, with an estimated stature of 165.37 ± 6.10 using the measurement for proximal femoral breadth (VHA).

5.11.5. Geochemical studies on human material

Stable isotopes

At the start of the research, there were no plans to carry out stable isotope analysis on the individuals from Gloucester Infirmary. However, the collaboration with the University of Nevada, Reno, USA, offered the opportunity to investigate any differences in diet through the medieval and post medieval periods in Gloucester.

Dental calculus

Only one dental calculus sample (skeleton III725) was obtained from the Gloucester Infirmary collection held at Liverpool John Moores University due to the limited number of individuals available. The amount of calculus presented was too low to provide a useable sample in many of the skeletons with surviving dentition. The dental calculus sample from skeleton III725 was assessed before and after acid extraction, with the results plotted in Figure 5.59. The δ13C value (-21.00‰) for the calculus sample from skeleton III725 was consistent with a diet focused on C_3 plants. The $\delta^{15}N$ value (11.80‰) was consistent with a shift of 1-2 trophic levels (7.14‰) above the herbivore baseline (5.81 ± 1.48‰, n=61; Müldner and Richards, 2007a; 2007b; Müldner *et al,* 2009). This indicated that the diet contained terrestrial animal sources, with a marine and/or freshwater fish component consumed on a regular basis.

The acid treated dental calculus samples adjusted the $\delta^{13}C$ further, showing that carbon values were approximately 2‰ lighter when considering just the organic carbon content. This is to be expected as the carbonate (inorganic) component of the $\delta^{13}C$ is isotopically heavier that the organic component (*pers. comms* Simon Poulson). Statistical analysis has not been carried out on the acid extraction samples due to this further shift in values. Dental calculus is a biofilm, comprising of of food remains, bacteria and DNA (Salazar-García *et al*, 2014). This can lead to carbon values that are lower than would be expected from dental collagen, due to the continual build up and wear of the calculus over the lifespan of the individual (Salazar-García *et al*, 2014). As food particles and other materials derived from plant material are trapped in the calculus, and C_3 plants materials having a $\delta^{13}C$ value of approximately -26‰ (Mays, 1997), it is likely that this has contributed to the lowered values.

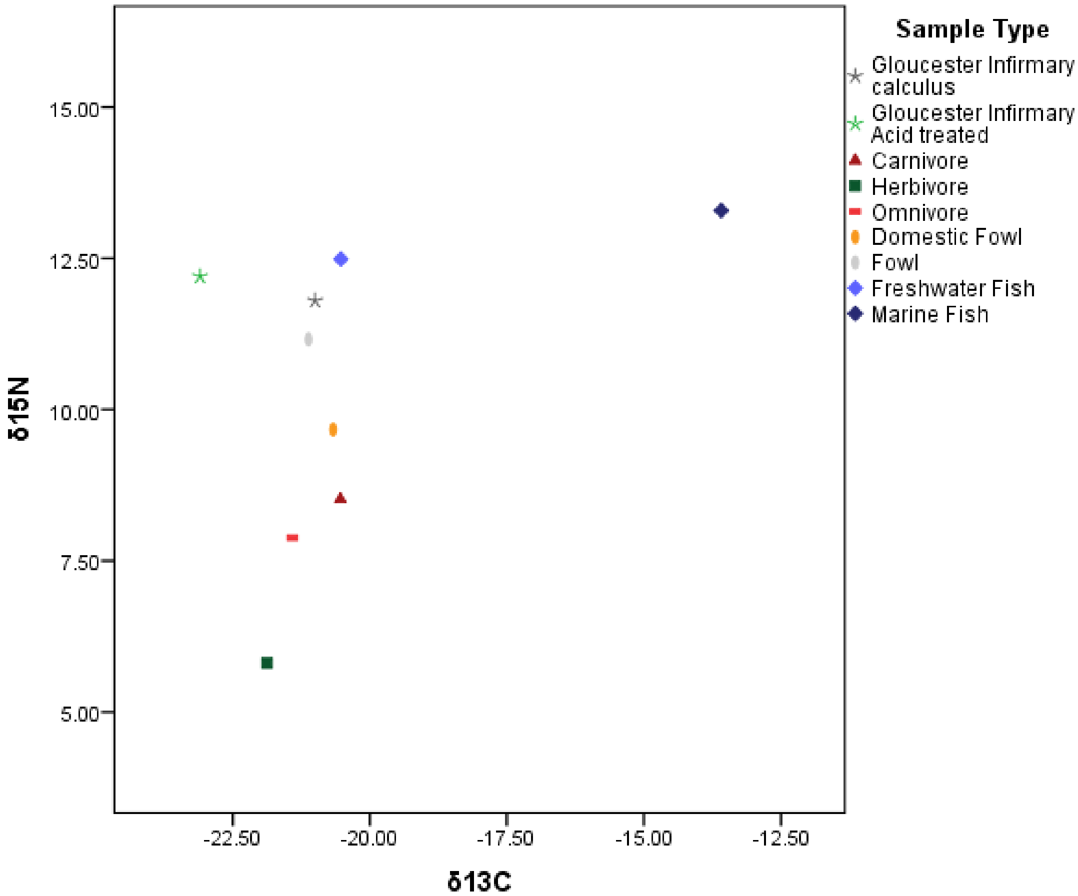

Figure 5.59. The Gloucester Infirmary burial ground calculus sample, demonstrating the shift in values between isotopic source materials and the acid treated calculus sample. Faunal, freshwater and marine data is shown for comparison (Müldner and Richards, 2007a; 2007b; Müldner *et al,* 2009).

Documentary evidence reports that the city of Gloucester continued to function as a supplier of goods to the region, with much of the trade coming from via the River Severn (Herbert, 1988). Imports of wine, spirits, sugar, citrus fruits and salt, all contributed to the diversity of the goods available at the marketplace. Export of food products from the city included cheese, fish, malt, cider and corn. Weekly markets took place, with up to 50 butchers holding stalls in the 1750s and four annual fairs held to allow the sale of salmon from the River Severn and cheese from the Vale of Gloucester. The market continued to thrive during this period, with the popularity leading to the building of two new marketplaces in 1786 due to the congestion caused by stallholders attending the events. The combination of both isotopic and documentary evidence provides an insight into the varied dietary intake of the Gloucester population, due to the accessibility of the city from within England, across the Welsh border, and from further afield via the River Severn.

5.11.6. Demographics

The sample recovered from the Gloucester Infirmary burial ground consisted of 25 adult individuals. As the sample is so small, it would not produce an accurate representation of the population through demographic analysis. However, the analysis can provide some information in the sample interred at this cemetery. Although the sample is not representative of the population of Gloucester, or the parish of St Owens, it does provide information on the individuals being treated at the Infirmary. Literary evidence for Gloucester Infirmary states that those receiving treatment were those that did not have the means to pay for their care (Herbert, 1988). The surrounding towns and villages would pay a subscription, which had no fixed fee, for their poor to be treated at the infirmary. As those being treated, did not have the means to pay for their own care, it was likely that they did not have the means to pay for a proper burial in their own towns and villages, with the Gloucester Infirmary burial ground providing a solution that was funded by subscriptions and donations (Herbert, 1988). The presence of two calvaria with post-mortem cuts indicates that post-mortem practices were carried out at the infirmary, either as part of death investigation or surgical training.

5.11.7. Summary of site results

Gloucester Infirmary burial ground was in use for approximately 96 years; however, the continual development of the Gloucester Docks and later buildings on the site limited the potential for investigation into the population through the osteological analysis of those buried in the cemetery. As the excavations were carried out in the 1980’s, the loss of information through the time constraints placed on the archaeologists has further limited the potential for interpretation. The osteological analysis of the remains recovered from the cemetery and housed at Liverpool John Moores University, consisted of 25 adult (20 males, 5 females) burials, with no non-adults identified from this site. The distribution of sexes at the burial ground were not even, presenting a further bias in the demographics. The majority of skeletons (55%) did not have any pelvic elements available for analysis, and 47.5% did not have elements present from the cranium and mandible. Although the sex bias present showed a higher number of males than females interred at this cemetery, there was no difference in the retention rate or preservation of the elements by either sex. The burial practices observed at Gloucester Infirmary burial ground were mainly coffin burials (60%), with a small number of shrouded burials (20%), which allowed an insight into the degradation processes influencing the bone when subjected to varying environmental conditions. However, low sample numbers prevented any relationship between the skeletons and burial parameters to be assessed.

Taking into account all the factors analysed at this site, if you were to select an individual for further analytical testing on the bone based on the data collected so far, there would be a greater chance of success with a skeleton interred in a coffin, due to the higher rates of collagen present in these burials. If the analytical testing was for nuclear DNA, then a shrouded burial would produce higher levels of inorganic bone material likely to provide a viable sample. However, the rates of fragmentation and abrasion/erosion on the epiphyseal surfaces of the bone may be greater, indicating that samples should be taken from the diaphysis of a long bone or the petrous portion of the temporal. The age or sex of the burial did not influence the potential for sample selection or preservation. As the burial parameters could not be assessed on the tested sample, further testing is recommended to increase the sample size, which will help obtain results for the preservation of collagen and the assessment of field portable XRF analysis on bone.

Chapter 6 – Site Comparison Results

6.1 Introduction

The site reports produced in this thesis have resulted in the production of demographic profiles for the medieval sites of Poulton Chapel and St Owens Church, which can be compared to the demographic profiles from previously published sites. The introduction to this PhD thesis provided an insight into the many different reasons palaeodemographers have given for the varying profiles obtained from the analysis of skeletal material. The age, sex and pathology of an individual are intrinsic factors that have been attributed in the past to the poor preservation of human skeletal remains. Extrinsic factors, such as the burial matrix, bioturbation and burial depth have also been proposed to influence the diagenesis of bone. This chapter aims to bring together the demographic information obtained from Poulton Chapel, St Owens Church and 20 medieval comparison populations.

6.2. Demographic comparison

The survivorship curves produced from the demographic analyses of Poulton Chapel and St Owens Church were similar, and therefore gave no indication of differences between urban and rural medieval populations. However, a detailed comparison of the mortality profiles from each sample (Figure 6.1) revealed that there was a higher percentage of deaths during childhood for the rural sample of Poulton Chapel, but a lower rate of death in adulthood. In contrast, St Owens Church showed a lower rate of death during childhood and increased mortality rates for the adult members of the sample. The number of non-adult deaths for both sites were high, with over 29% of St Owens and 39% of Poulton Chapel individuals dying before 10 years of age, with the period from birth to five years showing the highest mortality peaks for both sites.

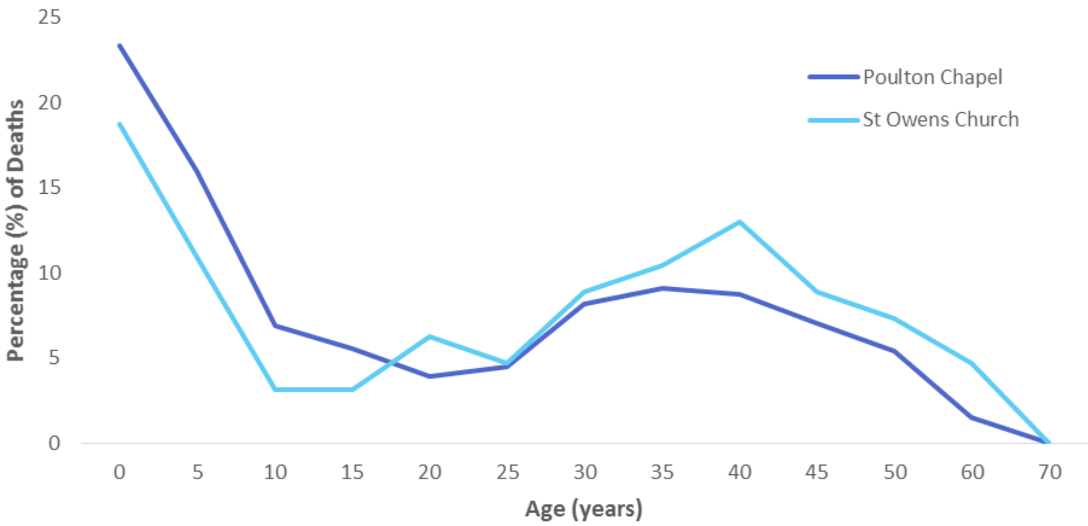

Figure 6.1. Comparison of the Poulton Chapel and St Owens Church mortality profiles.

Both samples show their second peak mortality periods at slightly different ages. Poulton Chapel shows a peak of 9.18% of the sample lost between 35-39 years, with St Owens losing 13.02% at 40-44 years of age. The calculated life expectancy at each age is shown in Figure 6.2., where it is apparent that the lower rates of non-adult mortality at St Owens have increased the life expectancy rate at all ages of the profile, when compared with Poulton Chapel. Life expectancy peaks at St Owens Church at 5-9 years of age, with an average expectancy of 29.55 years. Whereas Poulton Chapel has a peak average life expectancy of 24.37 years once the individual reaches 10 years. From this age, the average life expectancy decreases in both samples.

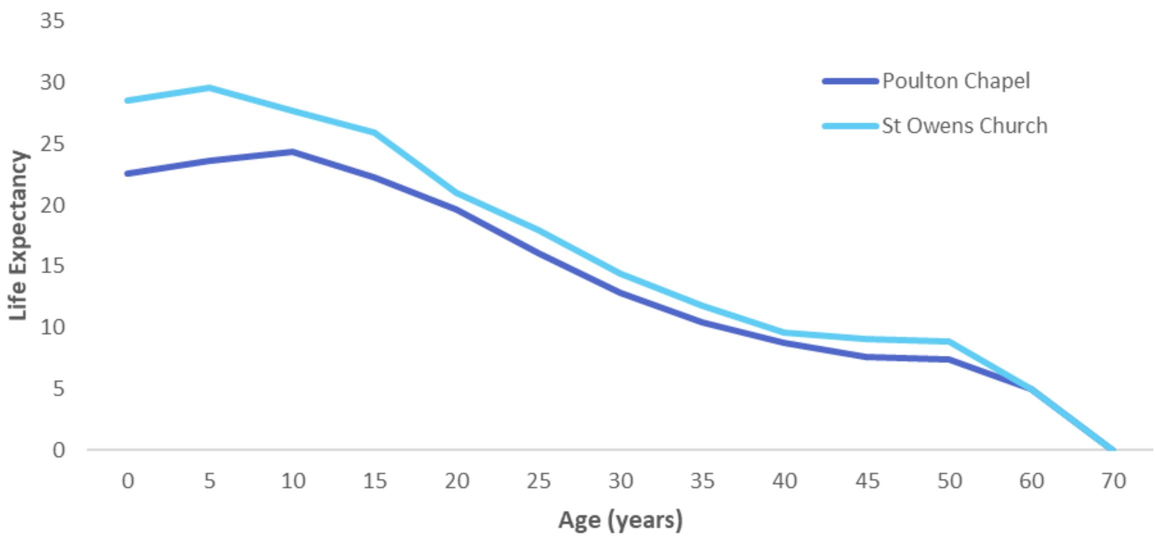

Figure 6.2. Comparison of the Poulton Chapel and St Owens Church average life expectancy rates for all age ranges.

As both samples were represented by individuals from all age categories, there was no immediate evidence of under-representation. The high number of non-adult burials retrieved from both excavations suggests that both populations were fertile and growing, though this growth was seen at a much higher rate at Poulton Chapel. There was no evidence of sex or age bias at either of the sites, for burial or preservation characteristics, except for skeletal completeness at St Owens. This showed that the adult burials were more likely to be complete; however, this had no impact on the resultant preservation of the remains, nor the potential for biological profiling.

Rural sites

The demographics for the rural samples were compared visually (Table 6.3), with all four sites identified as producing a low expectation of life at birth and therefore, having a higher rate of fertility and population expansion than seen in urban samples. On visual inspection, all rural samples display the same general demographic traits. The comparison of the rural cemetery sites indicate that the conditions favoured population growth, with all sites having low life expectancy at birth, due to the high non-adult and low elderly mortality rates. The differences in the life expectations at birth presented for each rural site demonstrate that an understanding of the completeness of the excavation, in-depth site history and multi-disciplinary techniques are crucial to gaining a more complete picture of the population demographics.

Table 6.1. Life expectancy at birth for each of the identified rural samples using the Archaeology Data Service age groupings.

Name	No. of Individuals in analysis	Life Expectancy at Birth
Linlithgow Whitefriars	173	17.30
SS Peter and Paul	117	23.10
St. Martins, Wharram Percy	591	20.14
Poulton Chapel	755	22.60

When carrying out the initial demographics on Poulton Chapel, it was noted that inclusion of the crania-only burials affected the resultant demographic profile when using the ADS demographic age categories. The crania of the skeletons could be displaced from the rest of the skeleton during later burials or the later development of the chapel, which could lead to an individual included in the analysis more than once. The life expectancy at death value given was much higher (27.93 years) than the values given for the standard and expanded demographic tables, suggesting that there were issues with the complete sample. When running the data using the articulated burials only all life expectancy values were similar, indicating that some individuals may have been included in the analysis more than once. This discrepancy would have been more apparent for the Archaeology Data Service (ADS) age ranges, as a large number of the crania could only be placed into a broad age category due to the small number of aging characteristics available for the analysis. This led to a larger number of individuals being included in the ADS method. To determine whether there were discrepancies over the sample analysed for St Martins, the expectation of life at birth was assessed using each of the life table methods and compared against the estimations from the Poulton Chapel articulated burial results (Table 6.4.).

Table 6.2. Expectation of life at birth for Poulton Chapel and St Martins for each of the three demographic life table types.

Life Table Type	Description	Site	Expectation of Life at Birth (years)
Expanded	One year intervals <10; 5 year intervals 10-50; 10 year intervals from 50+ years	Poulton Chapel	22.41
		St Martins	23.41
Standard	Five year intervals 0-50 years; 10 year intervals from 50+ years	Poulton Chapel	22.53
		St Martins	23.78
Reduced	Age ranges set by the Archaeology Data Service	Poulton Chapel	22.60
		St Martins	20.14

The results for both the expanded and standard life table types were similar for St Martins, with the reduced expectation of life showing a lower value of 20.14 years. As the Poulton life expectancy rate was much higher when the crania-only burials were included, it suggested an over-representation of individuals due to some members of the population being counted twice in the reduced life table. As St Martins shows a drop of over three years for the reduced sample, it suggests that there may be an under-representation of individuals from this site. Further examination into the age estimation techniques used at this site would benefit the interpretation of this discrepancy and allow a more accurate picture of the demographics to be presented. For the expanded and standard life tables, St Martins produced lower life expectancy values than Poulton Chapel, with this trend reversing for the reduced life table. Detailed examination of the age groups within each of the life tables could lead to identification of the age range currently under-represented in this sample.

Urban sites

The demographics for the urban samples were compared visually (Table 6.5), with all 18 sites identified as producing a higher expectation of life at birth than the rural sites, suggesting that slower rate of population growth and lower rates of fertility. From the urban site observations, it is apparent that the friaries, priories and nunneries, all have a sex bias that may influence the overall demographic analysis. However, the life expectancy at birth at all urban sites is higher than those observed at the rural sites; ranging between 24.57 and 36.39 years of age. The incomplete excavations at many of the sites will influence the demographics at the site and therefore will not be representative of the overall population. The comparison of the urban cemetery sites indicate that the conditions were not favourable to population growth with all sites having a high life expectancy at birth, due to the low non-adult mortality rates.

Table 6.3. Life expectancy at birth for each of the identified urban samples using the Archaeology Data Service age groupings.

Name	No. of Individuals in analysis	Life Expectancy at Birth
Aberdeen Whitefriars	95	26.26
Carlisle Blackfriars	107	30.25
Carmarthen Greyfriars	112	31.23
Chelmsford Blackfriars	72	31.28
Holy Trinity/St. Mary Graces	771	24.83
Hull Austin Friars	202	33.17
Ipswich Blackfriars	211	34.61
Norwich Greyfriars	136	27.20
SS James and Mary Magdalene	358	30.34
St. Andrew Fishergate	236	36.29
St. Clement	140	30.82
St. Nicholas	102	26.02
St. Oswald	329	24.57
St. James	176	32.50
St. Mary Merton	546	40.01
St. Mary Stratford	538	36.39
St. Mary Spital	5202	28.90
St. Owens Church	222	28.54

The demographic profile of a hospital cemetery, such as Gloucester Infirmary burial ground, will give an indication of some of the individuals who died at the hospital, or were sent there for investigation into a death. The Infirmary was supported by the subscriptions from the surrounding parishes, which may have permitted internment within the burial ground, should the family members not have means to pay funeral expenses. There may have also been the option to bury the remains in the local parish cemetery if the family members could afford to transport the body. Therefore, many of the individuals interred in this cemetery may not have come from the local community, but from the area surrounding Gloucester city (Herbert, 1988). The lack of records for this cemetery do not allow the limits of the sample interred at this site to be fully explored, and therefore it is not possible to comment on what kind of population this cemetery is representative of. However, it provides an example of one of the issues faced when exploring the demographics of undocumented cemetery populations, such as those explored in the medieval comparison.

6.3. Excavation methods

When assessing the demographic potential of Poulton Chapel, the issues surrounding the excavation processes employed on the research site in the earlier stages of the project were noted, especially with reference to the production of a Harris Matrix. With the excavation of burials being undertaken at many different areas of the sites simultaneously, the questions of how reliable the demographics would be and at what point would the sample be large enough to produce an overall picture of the demographics of the population interred at this cemetery. To explore this further, the demographics for the Poulton Chapel cemetery site were reassessed using two different methods. The first provided year on year demographics to investigate the number of burials excavated before the profile stabilised. A profile analysis showed that there were significant differences in the profiles produced in the year on year analysis; however, a pairwise comparison analysis was not possible due the number of profiles available. Therefore, the profiles were grouped into four year excavation ranges (pre2000-2003, 2004-2007, 2008-2011 and 2012-2015), which enabled the comparison of the profile data (Figure 6.3).

The only pairwise comparison that exhibited no significant differences in the demographic profiles was between the 2004-2007 and 2012-2015 ranges. The 2008-2011 demographics differed significantly from all profiles (pairwise comparisons; $p<0.001$), most likely due to the large number of adult and low number of non-adult burials added to the profile during this timeframe, from 2012 the number of non-adults increases considerably, with the adult burials reducing in number.

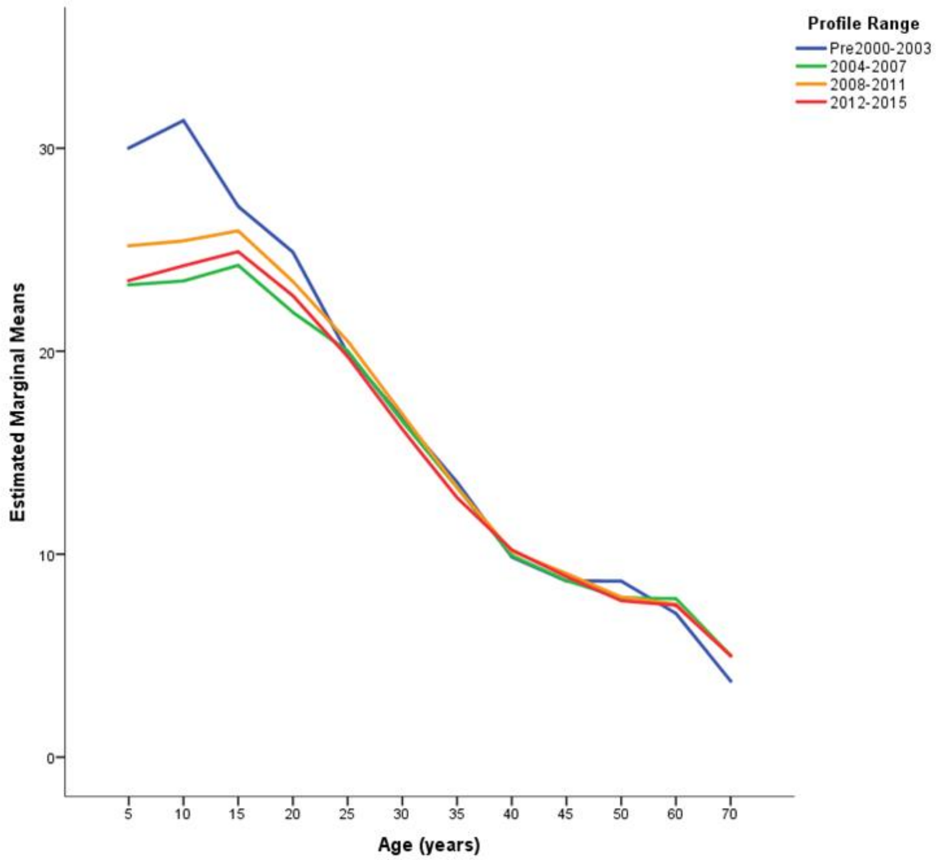

Figure 6.3. Estimated marginal means taken from the grouped demographic profiles, showing the differences in profiles at different ages.

The second method assessed the burials based on the location excavated within the cemetery to determine whether controlled stratigraphic excavation across the site would have enabled the demographic profile of this site to be determined earlier in the project. As the site is not yet fully excavated, this method only loosely simulates the steps that would have been taken using standard practices, but provides information as to how many individuals were required to produce a stable profile. The site was split into eleven sections based on the grid system in use at Poulton Chapel (Figure 6.4) Section K spans the full width of the site due to the small amount of archaeology and burials recovered in this region (skeletons were recovered from K1 and K3 only). Each section was then separated into 5 x 5 m intervals. The demographics were calculated starting from the lower left section (A1), moving across the site to the lower right (B4), with the burials from each new section added to the demographics. Sections were added alphabetically to keep and order to the process. Each section provided a number of demographics profiles that could be analysed, with the resultants means from each section used for a profile analysis.

The demographic profiles showed a distinct shift between sections E and F, as the number of adult burials increased considerably, whereas the number of non-adult internments showed little increase (Figure 6.5). It should be noted that all profiles up to E were similar to each other (pairwise comparisons; p>0.05), with all the profiles including later sections

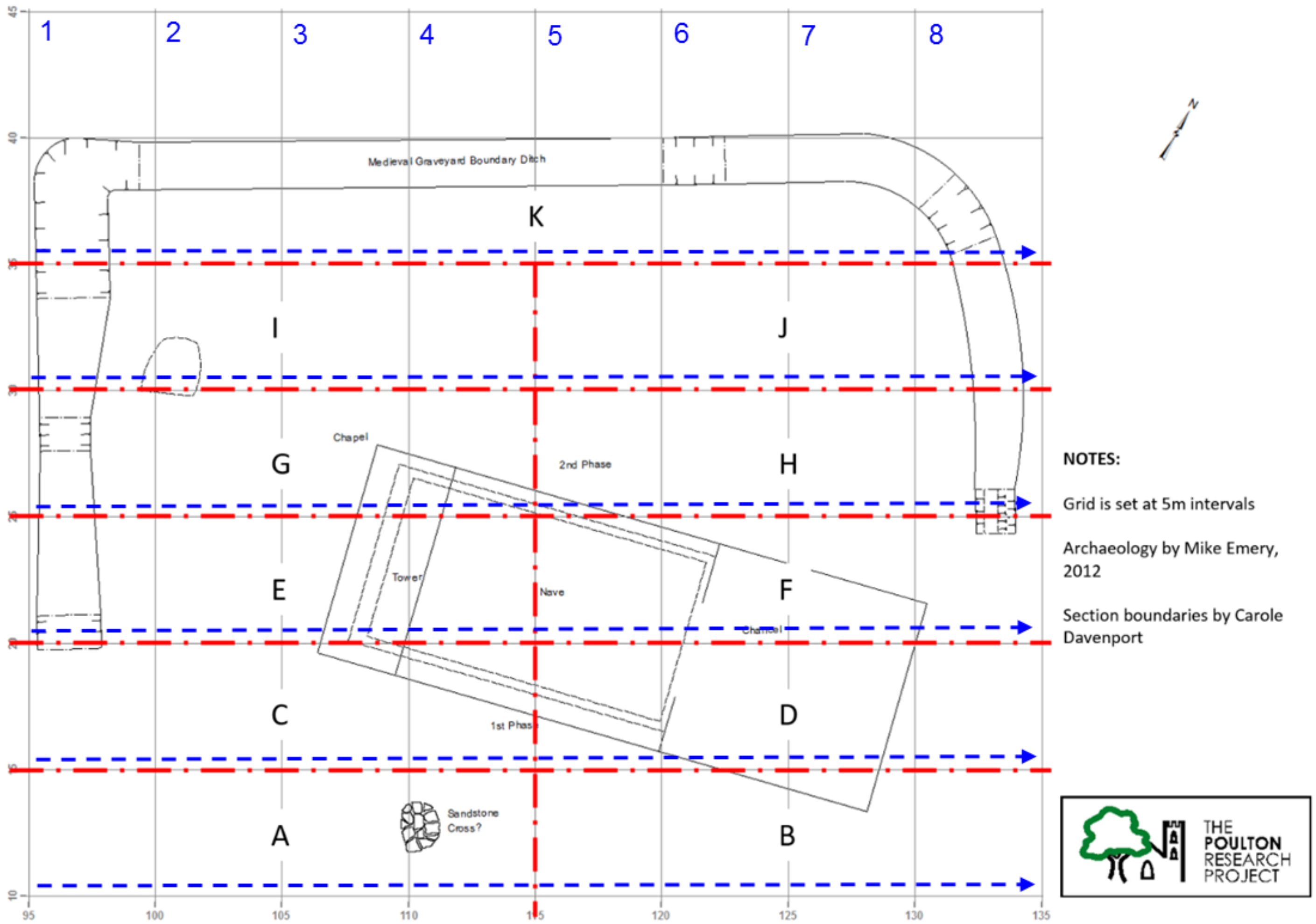

Figure 6.4. Identified section boundaries for the simulated stratigraphic demographic comparison, blue arrows identify the direction in which the sections were added to the demographic profile. ©CAL Davenport

being significantly different from the first. From section F onwards, the demographic profiles did not differ significantly from each other (pairwise comparisons; $p>0.05$), though there was a slight fluctuation noted when the data from section H was added.

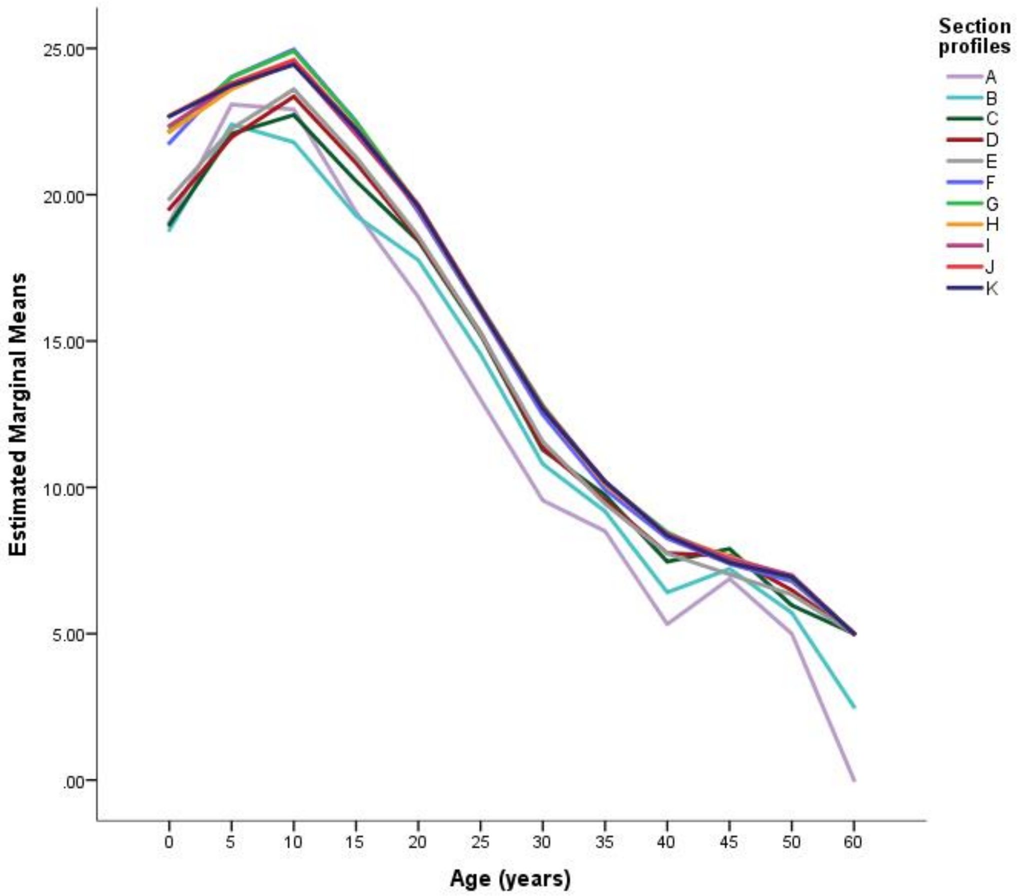

Figure 6.5. Estimated marginal means taken from the section demographic profiles, showing the differences in profiles at different ages.

Both methods of analysing the data showed a shift and slight fluctuations in the profiles as more data was added. The number of skeletons required in demographics before stabilisation using the first method was approximately 430, with the second method stabilising at 390 skeletons. This indicates that stratigraphic excavation would enable stable demographics to be provided, with fewer burials excavated. However, as this archaeological project is still ongoing, it is recommended that the analysis be carried out again once the site has been fully excavated in all sections to provide a more accurate assessment.

6.4. Completeness of the excavation

The assessment of population size is biased by the completeness of the sample excavated, with examples seen at Southgate Congregational Church showing a difference of 191 individuals. The excavation at this site consisted of two parts; the church was excavated in 1983, with the crypts and vaults excavated in 1989. Of the latter, only a handful of skeletons were available for inclusion in this analysis, meaning that the studied sample size was far smaller than the 271 individuals listed in the parish register. The parish register only covered the period of 1786-1837, rather than the full lifespan of the cemetery. There are records at Gloucester Archives, which demonstrate the cemetery was in use either side of this timeframe, indicating that the number of individuals lost during the docks development and subsequent building work on the site has led to a significant underrepresentation of the cemetery population.

A more in-depth analysis of the demographic profiles produced from the overall samples from the osteological and parish records analyses show that the levels of mortality in non-adults are over-estimated up to 15 years and from 25-45 years (Figure 6.2). All remaining age ranges are under-estimated, especially at ages that are above threshold for osteological age assessment. The number of individuals who were not represented by the osteological analysis will have a profound impact on the estimations given; however, the limitations on age estimation will further complicate the assessment. Without fully understanding the implications the maximum age that the assessment can be applied to, it is not possible to account for this bias. Furthermore, due to the osteological remains representing a longer timespan than the burial records, the demographic profiles may be representing different members of the community.

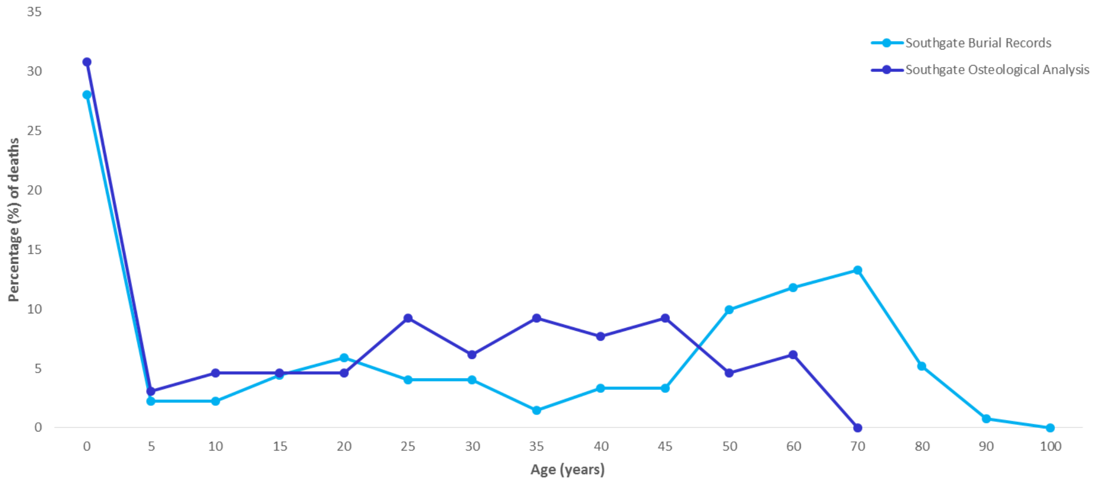

Figure 6.6.Comparison of the Southgate Congregational Church mortality profiles produced from the osteological analysis and burial records from 1786-1837).

The crude mortality rates estimated for each of the samples differed by approximately 12 years, which would be due to the number of individuals available in each sample, the limitations on osteological age estimation techniques and the incompleteness of the burials. As there was no age or sex bias for preservation or completeness of the remains from the skeletal sample, the differences in crude mortality rates and resultant population estimations are a result of an incomplete sample. The osteological sample provided a population estimate of 13 individuals required to support the number of burials excavated from the cemetery from Southgate Congregational Church, whereas the burial records provided a population size of 204 individuals over the 51 years the records covered. This difference shows that incompleteness of a cemetery sample significantly influences the resultant analysis and will not provide comparable data.

Although a more complete excavation may have further improved the demographic profile given for this cemetery, the amount of material lost to building works carried out at this site is unknown. As the majority of urban sites are only partially excavated to suit the commercial sector and planned building works, then question to be asked should really be: what should the demographics for an urban population look like? When there is documentary evidence to provide an idea of the demographics that should be shown for a cemetery sample, the differences between the assessments are clear. However, as the recording of birth and deaths in parish records were formally introduced in 1538 and many early records were lost due to being poorly stored or hidden by the clergy (Pounds, 2000), medieval records are rarely found. Without these records and with incomplete excavations, it is not possible to determine if a sex bias is representative of the population serving that particular cemetery, or the under-representation of non-adults is due to low fertility and a declining population. It has also been suggested that the taphonomic conditions may adversely affect certain age groups (non-adults and elderly) to such an extent that they will under-represented by the excavated sample. Without the records themselves, we cannot fully explore the extent of the any of the influencing factors, as we will never know the initial size of the interred population.

Chapter 7 – Discussion and Conclusions

7.1 Discussion

Palaeodemography has focussed on the osteological evidence obtained from excavations, often ignoring the wealth of information available from other sources. With excavations carried out in the 1980's, assessments were carried out many years after the initial excavation, as seen with the Gloucester sites in this thesis, due to the lack of funding, or researcher's knowledge or interest in that particular timeframe. This delay in analysing these skeletal assemblages can result in the loss of vital information over time, leading to gaps in the historical record. By identifying skeletal collections that require analysis, and utilising a multi-disciplinary method to the assessment, it is possible to begin to fill those gaps in the record with knowledge, as well as help devise protocols for future excavations. This chapter will bring together the results from the research to answer the four aims set out in the introduction, concluding with a summary of the key points and recommendations for future research pathways.

To produce demographic profiles for Poulton Chapel and St Owens Church skeletal samples recovered during the excavations.

The analysis of the human skeletal remains from Poulton Chapel and St Owens Church allowed a demographic investigation into the cemetery samples. It was noted that for both sites, there were similarities in the shape of the survivorship curves, but differences in the mortality profiles. The high rates of non-adult mortality in the profile from Poulton Chapel contrasted with the lower rates in St Owens; however, this could be due to the incomplete cemetery sample from this site. St Owens had undergone multiple development phases, with areas of the cemetery lost to the building of the docks and later churches on the site. Non-adult (<10 years) mortality was still higher at both sites (39% at Poulton Chapel and 29% at St Owens) than modern day rates, which account for 0.64% of all deaths registered in England and Wales in 2016 (Office for National Statistics, 2017). The numbers of non-adults burials recovered from each of the sites are comparable to those found at similar rural and urban locations, with the number of rural non-adult burials recovered much higher than seen in town and city locations.

Both Poulton and St Owens had fairly even numbers of males and females recovered, which was in disagreement with previous studies that suggested the difference in recovery rates between the sexes could be due to the male skeleton being more robust and therefore less susceptible to diagenetic changes (Bello *et al*, 2006). Stature also differed between the sites when compared to the expected ranges for Medieval British samples. Poulton female stature was higher than expected for the period, whereas the Poulton males were shorter on average than those from other sites. Interestingly, at the site of Chester Greyfriars, three miles away, average female stature was much less than expected, with male stature in the city as expected for the period. Both male and female stature at St Owens fell within the expected stature ranges. The differences in lifestyle pathways may influence the accessibility to regular food sources, which may impact the ability of a person to attain full stature. As each of the sites has many different variables, an in-depth assessment is needed to understand the differences in the biological profiles.

To determine if there is a difference in the demographics between the skeletal samples recovered from the medieval samples studied in this thesis, and previously published samples from rural and urban medieval sites.

When comparing the rural and urban profiles, there appears to be a higher rate of population growth outside of the towns and cities, with some urban sites having a non-adult interred sample as low as 1.5%. To verify the demographic differences between urban and rural sites a principle components analysis was run on the life expectancy values at each of the five-year intervals. The resultant factor scores were then plotted to highlight the differences in the profiles between urban and rural populations (Figure 7.1). The resultant plot clearly shows two groupings of sites representing the urban and rural differences in the population demographics. As the urban sites are not fully excavated, it could suggest that under-represented age groups are interred at a different part of the cemetery, which has not yet been excavated, or it could be due to the type of cemetery being excavated. To determine if the under-representation of age groups is a factor in the profiles obtained from urban sites, analysis needs to be carried out on an urban site that has not been disturbed since the cemetery was in use. The differences in the life expectations at birth presented for each urban site demonstrate that an understanding of the completeness of the excavation, in-depth site history and multi-disciplinary techniques are crucial to gaining a more complete picture of the population demographics.

Although there are patterns in the demographics seen from rural and urban medieval cemetery samples, the lack of complete samples from urban sites inhibits the production of a true urban demographic profile. As excavations occur more commonly on urban sites due to the continual development of towns and cities, it has enabled numerous comparisons to be made with the data. In many cases, there are a number of sites providing similar demographics, with the majority of sites showing a sex bias or an under-representation of the young or elderly members of the community. As this has occurred at many of the comparison sites, it has been presumed that the demographics given are ‘normal’ for urban populations, without considering the different issues that are influencing the biases in sex and/or age.

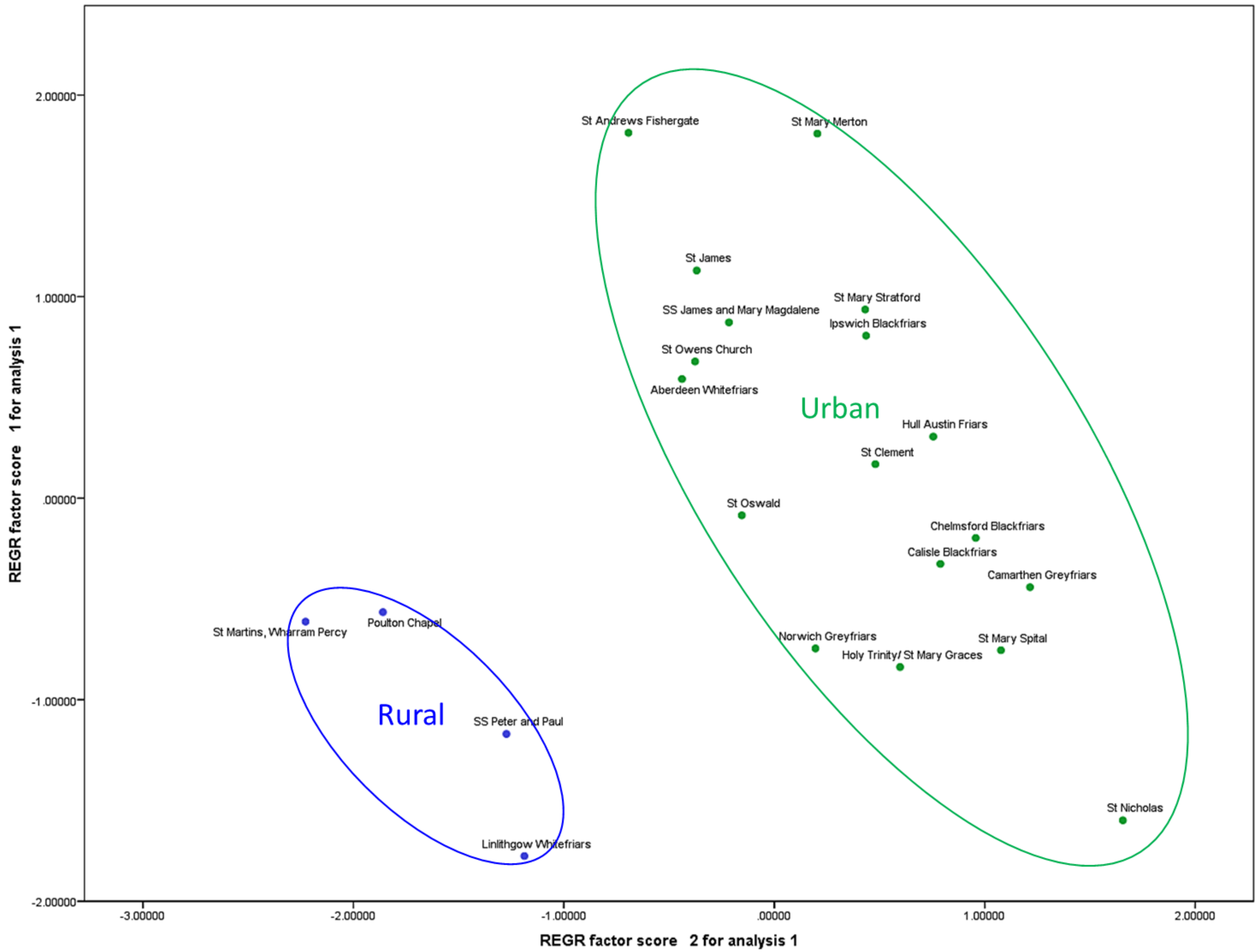

Figure 7.1.Scatterplot of the demographic differences between the urban and rural populations discussed in this chapter.

The limited number of rural sites analysed in the UK, have, by contrast, caused demographers to question whether the result produced are typical of a rural population, despite the completeness of the excavations, due to the differences shown when compared with the urban demographics. Rural cemeteries tend to be used by the whole community and the strict guidelines observed in urban populations regarding who can be interred in a cemetery appear to be more relaxed. This gives a more accurate picture of the population that lived in the area. The understanding of the medieval population is still important, with religious sites, where there will still be a separate cemetery for the monks, nuns or friars, along with the cemetery for the lay population. There may also be a separate infirmary burial ground. However, this can be used to determine the demographics of the population living in the local area, the demographics of the individuals treated at the infirmary, and the demographics of those serving the abbey. As most of the rural sites are more likely to be excavated in full, the issue of incomplete samples is rarely encountered, but as towns and cities continue to increase in size, this could change. Therefore, as with urban sites, it is important to understand the completeness of the sample. It should be noted that none of the lay cemeteries that had been excavated in full showed a sex bias, there was also no difference observed in the preservation of non-adults, when taking into account the burial practise.

Palaeodemography does not give the archaeologist a clear picture of the demographics of the local community, but of the community that had access to that cemetery whilst it was in use. When a cemetery has been in use for hundreds of years, those interred at that location could represent many generations and events in time that may not be easily identified. Unless considerable finance is available to radiocarbon date each skeleton, the ability to understand how the demographics on the site change through time is very limited. The presence of items to help identify *terminus post* or *ante quem* are unusual in medieval burials, as only those of the highest status would regularly be interred with grave goods. Therefore, cemetery sites rarely give information on the demographics of a population at a set moment in time, but a demographic overview of those interred over the lifespan of the cemetery.

To investigate the impact intrinsic and extrinsic factors have on the diagenesis/preservation of human skeletal remains.

When assessing each of the sites studied during this PhD to determine the skeletons that would provide the most reliable samples for further analytical testing (stable isotopes, radiocarbon dating and mitochondrial DNA), it was found that those interred in coffins were likely to provide higher collagen yields. However, if the aim was to carry out nuclear DNA testing, skeletons with a higher calcium percentage in the bone were likely to provide more reliable samples as the DNA regions needed were held within the inorganic portions of the bone rather than the organic collagen (pers. comm. Linus Girdland Fink, 2017).

The extent of abrasion and erosion to the epiphyseal ends of the bone is increased in coffin burials, with non-coffin internments having abrasion and erosion patterns that extend to the diaphysis. The degree of fragmentation to the skeleton increased as abrasion and erosion rate increased, due to the loss of the outer cortical surface of the bone weakening the overall structure. Abrasion and erosion to the diaphysis in non-shrouded burials will increase the surface area of the bone, making it more susceptible to extrinsic taphonomic factors, such as pH, soil chemistry and water intrusion to the grave. This will decrease the level of organic collagen in the bone as the protein mineral bond breaks down, making the bone more brittle and likely to break. Only Chester Greyfriars highlighted a bias towards adults having increased abrasion and erosion rates. As a number of the adult burials at this site were coffin internments and the non-adult burials were not, it highlights the differences in burial practises. The position of the skeleton within the grave offered protection from truncation, and slowed the rate of taphonomic influence when the arms were close to the thorax. Where burial depth was observable, there were no differences between the adults and non-adult interments, with all age ranges represented through all depths in the soil profile.

All sites showed no sex bias for burial parameters or the preservation of the remains. However, the adult burials interred at the medieval sites of Poulton Chapel and St Owens Church showed higher rates of fragmentation, than those of the non-adult burials. As the collagen extractions yielded lower levels for fragmented remains, the decreased elasticity of the bone could be responsible for the increase in breaks. However, it was also found that higher collagen extraction levels were found in the younger members of the community, which suggests that age is a factor. Chester Greyfriars did not show the same relationship between age and fragmentation, which may be due to the small sample size.

In archaeology, skeletal completeness has always referred to the amount (percentage) of the skeleton recovered and interpreted to indicate preservation, without accounting for truncation due to secondary burials, later building works or commercial excavation. While there was no evidence of sex bias in the percentage of the skeleton recovered, there were mixed results with age. While Poulton, Southgate Congregational and Gloucester Infirmary burial ground all showed no age bias, the remaining cemeteries of St Owens and Chester Greyfriars found that completeness increased with age. The completeness of the skeleton is not indicative of the preservation potential of the bone, but rather an indication of anthropogenic interference to the grave, or in some cases severe bioturbation. By assessing the osseous changes to the protein-mineral matrix, a clearer picture of the potential for further analysis on the site is gained.

Selecting a skeletal element for further analytical testing (such as stable isotopes, radiocarbon dating or DNA) is influenced by the preservation of the remains. Due to potential contamination issues, samples for DNA testing are often selected, as they are uncovered during excavation and are not cleaned until the sample is processed in the laboratory. This is an issue on particularly wet sites, where excessive mud can prevent the observation of the periosteal surface of the bone. If the site is particularly high in sand, then this surface will be eroded by the larger particles present, leading to further contamination of the bone and limiting the chance of extracting viable samples for nuclear DNA testing. Soils that contain high levels of clay will exhibit less erosion, with the inorganic component of the bone well preserved, however the organic portion of the bone does not preserve well in this environment, leading to low success rates when testing for stable isotopes, radiocarbon dating or mitochondrial DNA. It is only when the sample arrives at the laboratory that the DNA analyst gets a true indication of the samples preservation, and if the sample is poorly preserved, the chance to collect a new uncontaminated sample is lost.

The pH of the soil can influence the preservation, but the acidity or alkalinity of the environment alone is not the sole factor affecting the taphonomic response. Although acidic environments can cause the degradation of remains, if the burial matrix is oxygen poor, it will work to preserve the organic components of the human remains (for example, bog bodies in peat environments) by inhibiting further decomposition. With good rates of oxygen, the acidic environment will work to break down the hydroxyapatite, leaving the organic component of the bone vulnerable to other extrinsic factors. Conversely, alkali environments will preserve the hydroxyapatite, whilst breaking down the organic component of the bone. The loss of the organic portion leaves the bone friable and vulnerable to extrinsic factors such as bioturbation, water and sandy soils and gravels, which will break down the brittle inorganic portions leading to higher fragmentation, abrasion and erosion rates. Therefore, it is important to assess the burial environment prior to sampling, by looking at the soil profile and other indicators that could influence the sampling procedure for human remains recovered from the site. There is no one factor affecting the breakdown of human bone, but a series of factors that can influence the preservation either way.

The use of field portable x-ray fluorescence equipment to measure the chemical composition of the bone and the movement of the chemical elements from the burial substrate highlighted the potential for developing a fast technique for identifying the burial practice of unknown human remains. During the testing phase it was noted that the calcium components of human bone tended to be lower in coffin burials, however further exploration was needed to try to determine the cause. When assessing the elemental concentration of bone, Walden *et al* (2017) found the level of calcium in fresh human bone was approximately 18.96%. To investigate this further sixty skeletons of known/identified burial status (24 coffin, 36 non-coffin) from the Gloucester (*n*=49) and Chester Greyfriars (*n*=11) sites were tested using field portable x-ray fluorescence to determine if it is possible to differentiate the burial practise through the percentage of calcium, iron and potassium in the bone. The first rib was tested for each skeleton for consistency, as the difference in elemental composition of the different skeletal elements has not yet been determined. Although there were no indications of burial practise from iron or potassium, the percentage of calcium present in the bone tested was strongly correlated with the burial practice ($r_{s(60)}$=0.805, p<0.001), with only one skeleton with increased calcium showing levels that were similar to the non-coffin individuals (Figure 7.2). This individual (skeleton 1554) will be explained briefly as a case study following the discussion of the findings. The percentage of iron was seen to increase slightly in coffin burials due to the presence of coffin nails, handles and other fittings containing this element. However, as not all coffins contained iron fittings, the relationship was weak and did not clearly define those that had been interred within a coffin. There was no relationship identified with potassium, which clearly identified calcium as the element most affected by differences in burial type. As field portable x-ray flouresence has not been used previously in this manner, this line of research will continue in other projects, with the aim of presenting a technique to determine the provenance of unknown human skeletal remains in forensic and archaeological cases.

Case Study

Skeleton 1554 from St Owens Church in Gloucester was a young adult male who was identified as having phophorous poisoning, leading to skeletal changes associated with Phossy jaw. This pathological condition results in the destruction of the bone, alongside the formation of new woven and lamellar bone, which occur as a result of continual exposure to phosphorous (Figure 7.3). The use of phosphorous dates to the 19th century, when it was used to treat ailments such as rickets, and used in manufacturing products such as matches, munitions, fireworks and brass (Roberts *et al*, 2016). Increased levels of phosphorous affects not only the muculoskeletal system, but almost every part of the human body by due to the toxic levels of phosphate. Hypocalcaemia is often seen in those with increased phosphate levels, due to the phosphorous easily forming a bond with calcium, creating calcium phosphate salts.

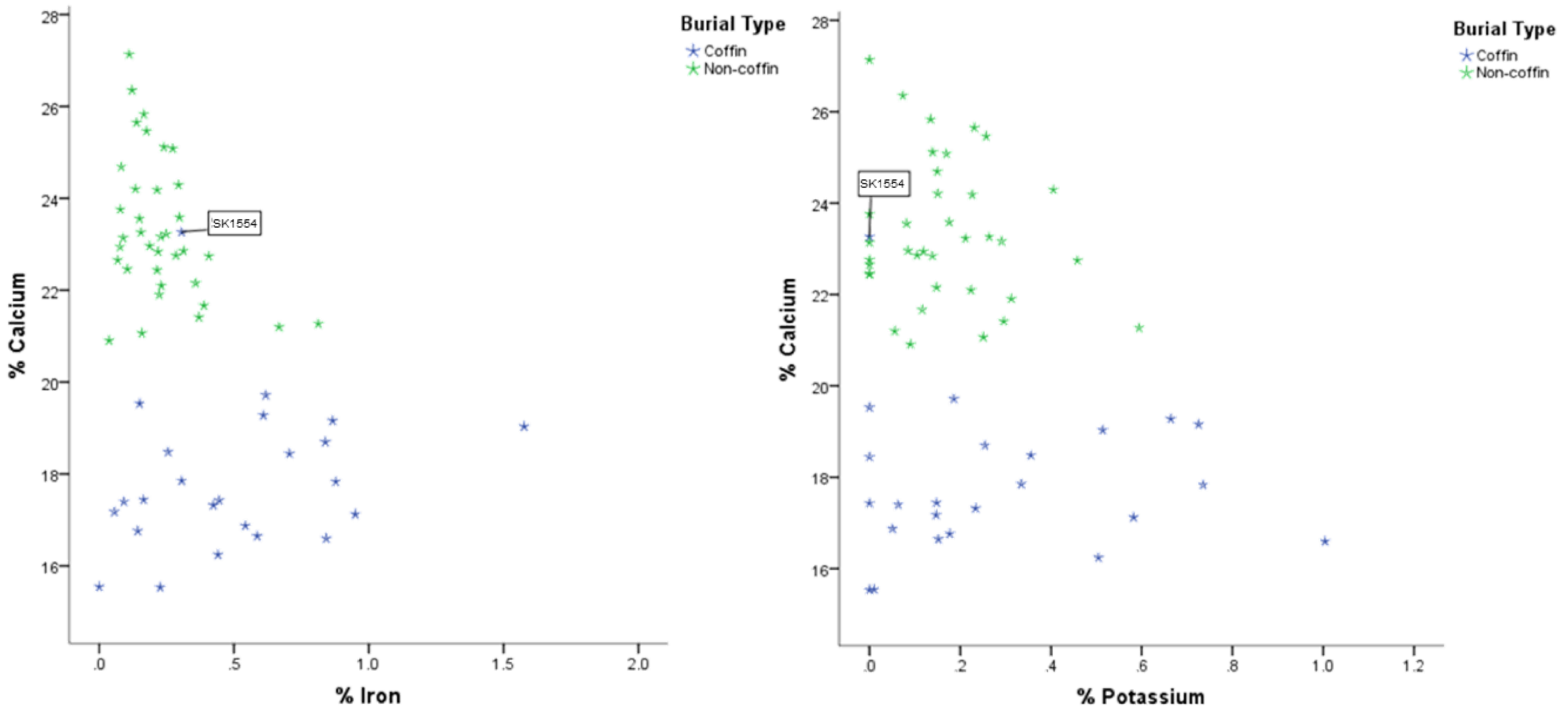

Figure 7.2. Scatterplots showing the distribution of the coffin and non-coffin burials when considering the percentage of calcium, iron and potassium present. Note that SK1554 from Gloucester is a coffin burial that sits in the non-coffin burial cluster.

The more exposure the individual has to the phosphorous, the more severe the build-up of the calcium phosphates can be. Once calcium phosphate salts build-up, there is no way to reverse the impact, with moderate exposure over a long period of time leading to increased mortality for those subjected to high levels of phosphorous (Razzaque, 2011). The increase in phosphorous, in the form of calcium phosphate, would leach into the surrounding environment during decomposition of the soft tissues, leading to much higher levels of calcium observed in the bone than would normally be seen in a coffin burial as the element is readily available. The calcium percentate seen in the bone of skeleton 1554 (23.26%) was much higher than the levels seen normally within fresh human bone (18.96%; Walden *et al*, 2017), providing further evidence for the diagnosis of Phossy Jaw given for this individual.

Figure 7.3. The left mandibular ramus from skeleton 1554 showing the destruction and formation of the bone. ©CAL Davenport.

The presence of pathologies was investigated in the different studied sites to determine whether it would have an impact on the level of taphonomic degradation observed on the skeletons. The skeletons from Chester Greyfriars formed a small sample of individuals to use as a pilot group to determine if there were any early indications of factors that may be influencing their rate of preservation. It had been noted that some of the skeletons excavated from the site had to be stabilised due to the bone becoming soft or friable. Later analysis of the remains in the laboratory revealed that many of these individuals were exhibiting pathologies that interrupted the bone remodelling process leading to a significant increase of bone being formed (for example, Paget’s disease of bone), or decrease, (for example, osteoporosis). Each of the skeletons excavated from Chester Greyfriars were assessed for the presence of skeletal pathology, before comparison to the preservation characteristics and elemental compositions of the bone. Although there was no relationship between abrasion, erosion and fragmentation identified within this small sample, the percentage of calcium was higher in those with a pathological condition, whereas the percentage of potassium present decreased.

Pathologies that alter the bone remodelling process can affect the degradation of the bone by altering the surface area to mass ratio of the bone. Conditions such as osteoporosis have low rates of bone formation, whilst the destruction of the bone to be remodelled continues at normal rates. This leads to a decrease in bone mass, whereas the overall surface area remains the same, which can weaken the bone leading to an increased rate of fractures in living individuals. In buried skeletal remains, assuming no fractures have occurred to weaken the bone further, the decrease in mass will allow the surrounding burial matrix to degrade the bone at a faster rate. Bone forming diseases, such as Paget's disease of bone, have an accelerated rate of bone breakdown and formation, which leads to an increase in bone porosity, bone enlargement, weakening and fractures. Due to the increased porosity, the surface area to volume ratio is adjusted; making the skeleton remains more susceptible to the conditions that favour bone degradation. This was observed in skeletons assessed from Chester Greyfriars, with the high calcium levels occurring due to the burial matrix having a much larger surface area to target. The displacement of the potassium in the bone by the calcium in the surrounding soils accounts for the decrease in this element. It should be noted that the potential availability of calcium in the soil is dependent on the burial practise, with shrouded burials also having increased levels.

To understand the influence post-mortem treatments and process have on the resultant demographic analysis.

As explained in the previous section, differing burial practices can influence the survival of skeletal elements in different ways. A coffin burial may protect the skeleton from the surrounding burial substrate; however, the leachate from decomposition will result in the breakdown of inorganic osseous material. A shrouded burial will protect the inorganic osseous material but the surrounding soils can have an adverse impact on the organic collagen component of the bone. Soils containing coarse sand particles can be more abrasive and lead to the erosion and fragmentation of skeletal elements, preventing the analysis of the age and sex characteristics used when compiling a biological profile. This would lead to a larger number of unaged/unsexed individuals, excluding them from the demographic analysis.

When a cemetery sample is incomplete, it can result in the under-representation of individuals due to the differences in funerary rites leading to different age groups or professions buried in separate locations (Stoodley, 1999; Buckberry and Hadley, 2007). The development phases that took place on Southgate Street resulted in portions of the cemeteries cleared for the development of the docks and building of later churches. As there was no requirement to record the dead prior to 1538 within churches, the burials excavated from a cemetery provide the only record of who was interred at particular location (Chamberlain, 2006). Therefore, rather than investigating the differences between urban and rural demographic profiles, the author of this thesis has shown that there is a difference between complete and incomplete cemetery samples. This is turn has illustrated that for a demographic profile to show a true representation of the sample buried within a cemetery, there needs to be a minimum number of individuals to analyse to prevent the influence of under-representation of age, sex or cultural practice. A thorough understanding of the history of the cemetery under study is required to understand the sample likely to be recovered from the site, any deviations from normal practice, and for the correct interpretation of the demographic profile produced.

Even with the information attained on the potential cemetery sample, the archaeologist must be vigilant as to any deviations from what is expected. The excavation at Chester Greyfriars recovered a highly friable infant burial that would have been missed if inexperienced staff had been carrying out the work. As the cemetery had been identified as serving the lay community the archaeologists expected to find skeletal remains representing all age groups and therefore, the author took time to educate those who were not familiar with non-adult remains. Measures were taken in the field to protect the skeletal remains once located and retrieve as much material and information as possible enable analysis of the biological characteristics. Following the excavation, further issues arise with the post-excavation processing, analysis and storage of the remains (Henderson, 1987; Galloway *et al*, 1997; Lewis and Gowland, 2007). When reviewing the post excavation sheets and photographs for Poulton Chapel and the Gloucester sites, it was clear that skeletal elements retrieved at excavation had gone missing in the years since excavation.

7.2 Future directions

The scope for research on both the intrinsic and extrinsic factors that influence the diagenesis of human (and faunal) skeletal remains is much larger than can be covered by one PhD thesis project. By continuing the investigation by including skeletal remains from other contexts, a more detailed picture of the affect differing burial environments have on human skeletal remains will be uncovered.

The use of rapidly developing imaging techniques, such as photogrammetry and 3D laser scanning, will allow the archaeologist to preserve a three-dimensional representation of the burial *in situ* for further detailed analysis and research (Figure 6.9). As archaeology is, in essence, a destructive process, the use of new and developing tools will allow those working on the site and carrying out subsequent analysis in the laboratory to 'revisit' the burial should questions arise about the context of the burial. The use of 3D laser scanning for four of the skulls from Chester Greyfriars, will allow the work to continue on the skeletal material recovered from this site, further increasing the information retrieved so far. Work planned using this collection includes using the scans to produce 3D models of the skulls for facial reconstruction and DNA testing of SK019 and SK004 to confirm the pathological conditions identified on the remains.

Figure 7.4. Still of a skeleton from Poulton Chapel (SK834) recorded using photogrammetry as part of a project headed up by Dr Isabelle De Groote, which aims to maximise the amount of information retained about a burial site following excavation. ©Poulton Research Project.

The burial practises explored in this thesis broadly covered coffin and non-coffin burials and the impact different environments can have on the preservation of the skeletal remains. Work is currently underway to expand this by taking into account the values given for fresh human bone, anatomical specimens and individuals that have been interred in a variety of environments. As the calcium levels present in the bones are directly affected by the burial substrate material and its access to the skeleton, expanding the technique to other interred using a wider range of burial practises will enable a more thorough understanding of the processes at work during bone diagenesis. It is recommended that studies into the diagenetic changes are supported by the use of histology, which will allow the observation of changes to the bone at a microscopic level. Including the use of micro CT scanning. Combining this further with research on fleshed remains could provide an insight into the timeframe required for skeletal changes to occur, rather than considering the decomposition process as complete once the dry stage is reached.

The presence of pathology also has an influence on the rate at which diagenetic changes occur in human bone due to the increased surface area to volume ratio, which should also be considered when exploring the impact of burial practise on the rate of decomposition. By combining geological and anthropological research to explore further the taphonomic pathways influencing the diagenesis of the human skeleton, it will further increase the potential for developing new techniques for forensic and archaeological investigation

7.3. Conclusions

The research carried out in the PhD thesis aimed to look at how the preservation of the remains affected the resultant demographic analysis; however, it was found that the taphonomy itself was not the underlying factor in the differences between urban and rural populations. The demographers understanding of the completeness of the excavation, and whether this was highlighted in the production of the report for that particular site was the primary reason for the discrepancies in profiles. Once this was understood, the taphonomic influences would play a major impact into the preservation of the skeleton as a whole and the ability to determine age and sex based on the indicators present.

During the research, there were a number of findings that highlight the importance of the work, and offer contributions to the fields of archaeology and anthropology:

1. The analysis of the osteological material from the remains from all five sites (Poulton Chapel, Chester Greyfriars, St Owens Church, Gloucester Congregational Church and Gloucester Infirmary burial ground), allowing publication of the osteological analysis and in some cases the demographic profiles.
2. Soil pH is not the single biggest factor influencing the preservation of skeletal remains; it is the accessibility of the surrounding burial substrate to the skeletal remains that has the greatest impact. The presence of a coffin, or other burial wrapping, will prevent the soil from coming into contact with the remains and therefore minimise the taphonomic damage from the soil (including pH, particle size and chemistry).
3. The taphonomic pathway will vary based on the burial practise, each with its own set of influencing factors, which will require bespoke excavation techniques, analytical testing protocol and analysis to be adapted to the pathway identified to maximise the potential for more accurate demographic analyses.
4. The fragmentation of skeletal remains should be recorded as this also has an impact on the preservation, a method for recording this information is provided in this thesis. This combined with abrasion/erosion scoring and collagen extraction, will lead to a greater understanding of the preservation of human skeletal remains.
5. Arms placed over the torso can protect the underlying skeletal framework, reducing the rate at which the bones are impacted by the surrounding burial substrate. Recording the position of the skeletal elements within a grave will further inform the preservation potential of the remains.

6. There is a relationship between the elements in the surrounding burial substrate and those within the bone, with the interplay between the two having an impact on the preservation of the skeleton
7. The demographics of a rural cemetery sample are more likely to be representative of the local community as the sample will be more complete, whereas those produced from urban cemetery samples should be questioned due to the incomplete nature of the excavations.
8. The level of calcium within the bone can be indicative of burial practice in archaeological human remains. Although the relationship between this and pathology needs to be explored further, the development of this technique could help inform the interpretation of osteological collections from other sites.
9. The inclusion of crania only burials within a palaeodemographic study can alter the results, leading to further bias in the interpretation of the sample.
10. To interpret the demographic results, the researcher must have full knowledge of the completeness of the excavation, the factors that influence the preservation of the skeletal remains to be assessed, and the excavation practices used when retrieving the remains. Knowledge of the historical record for the site is also required, to account for any changes to the use of the site, which may have resulted in the movement of remains and therefore incompleteness of the sample.

The research presented in this thesis has illustrated many issues with the process of compiling demographic reports to compare rural and urban medieval populations. Palaeodemographic studies are valuable in the understanding of past communities, however, it is important for the researcher to understand that the sample being studied is not representative of the population, but of the individuals interred at that cemetery. Furthermore, unless sites are fully excavated, it is not possible to state the differences between rural and urban lifestyles from a demographic study, nor the typical demographic profile of an urban population.

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Appendices

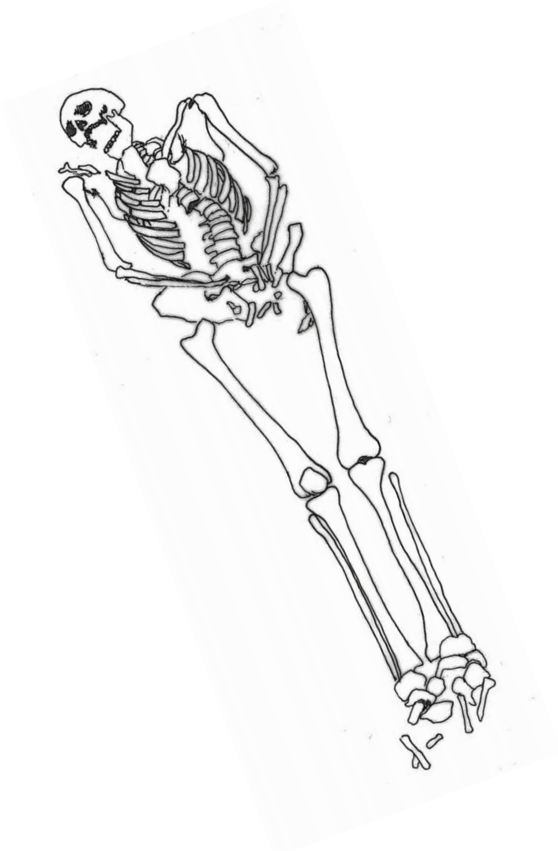


Table of Contents

A1. Data collection forms – Poulton and Gloucester sites

Liverpool John Moores University

School of Natural Sciences and Psychology

Skeleton Summary Form - Adult

Skeleton Number	
Context Number	
Date	
Preservation	
MNI	
Age	
Sex	
Stature	
Non metric traits/ pathology	
Additional notes	

SEX ESTIMATION: *Examine each region present and circle the appropriate description. If the skeletal element is not present, enter "N/A" in the box for Sex.*

Innominate	*Sub-pubic Angle:*	Narrow	Wide	Intermediate	N.E.
	Sub-pubic concavity:	Straight	Concave	Intermediate	N.E
	Ventral Arc:	Absent	Present		N.E.
	Medial aspect of I-R:	Broad	Ridge		N.E.
	Greater Sciatic Notch:	Narrow	Wide	Intermediate	N.E.
	Pre auricular sulcus:	Absent	Present		N.E.
	Obturator foramen:	Oval	Triangular	intermediate	N.E.
Sacrum		Curved	Straight	Intermediate	N.E.

Sex:

Cranium	*Supra-orbital Ridge:*	robust	gracile	intermediate	N.E.
	Supra-orbital Margin:	dull	sharp	intermediate	N.E.
	Mastoid Process:	robust	gracile	intermediate	N.E.
	Nuchal Crest:	robust	gracile	intermediate	N.E.

Sex:

Mandible	*Mental Eminence:*	square	rounded	intermediate	N.E.
	Gonial Angle:	<124°	>125°	intermediate	N.E.
	Mental aversion:	Present	Absent	intermediate	N.E.

Sex:

Metrics	*Humeral head:*	<43mm	43-47mm	>47mm
	Glenoid fossa height:	<34mm	34-36mm	>36mm
	Radial head:	<21mm	22-23mm	>24mm
	Femoral head:	<43.5mm	43.5-46.5mm	>46.5mm
	Bicondylar width:	<74mm	74-76mm	>76mm

Sex:

FINAL SEX ESTIMATION:

AGE ESTIMATION: *If not examined, enter "N.E." for Phase and "unknown" for Age Range.*

Pubic Symphysis (*Suchey-Brooks*)	Left (description):	Phase:	Age Range:
	Right (description):	Phase:	Age Range:
Sternal 4th Rib (*Iscan et al*)	Right or Left (description):	Phase:	Age Range:
Auricular Surface (*Lovejoy et al*)	Left (description):	Phase:	Age Range:
	Right (description):	Phase:	Age Range:

Medial Clavicle (*Webb-Suchey*)	Left (description):	Phase:	Age Range:
	Right (description):	Phase:	Age Range:

Anterior Iliac Crest (*Webb-Suchey*)	Left (description):	Phase:	Age Range:
	Right (description):	Phase:	Age Range:

Dental Attrition (*Lovejoy*)	Maxilla	Phase:	Age Range:
	Mandible	Phase:	Age Range:

Suture Closure (*Meindl & Lovejoy*)	Vault	Lateral-anterior
	1.	6.
	2.	7.
	3.	8.
	4.	9.
	5.	10.
	6.	
	7.	
	Total:	Total:
	Age Range:	Age Range:

FINAL AGE ESTIMATION(RANGE)	

STATURE ESTIMATION: *If a bone cannot be measure, enter a "/" (slash mark) in each box. (Trotter and Gleser)*

	Right or Left?	Measurement (in *cm*)
Maximum Length of Femur		
Maximum Length of Tibia		
Maximum Length of Fibula		
Maximum Length of Humerus		
Maximum Length of Ulna		
Maximum Length of Radius		

Formula computation:

	Minimum	Maximum
FINAL STATURE ESTIMATION (range)*: *If unable to determine stature, enter "?"		

Data Checklist

- ☐ X-ray required
  - o Type of x-ray ____
- ☐ X-ray taken

- ☐ Staining

- ☐ Pre-auricular sulcus
  - ☐ G.P. Groove
  - ☐ G.L. Groove

- ☐ Fragmentary femora
  - ☐ VHD _________________

    Stature Calculation ____

    ____
  - ☐ VHA _________________

    Stature Calculation ____

    ____
  - ☐ LCH _________________

    Stature Calculation ____

    ____

- ☐ Soil Sample

- ☐ Collagen extraction
  - o Weight of sample at start ___________________
  - o Weight of collagen ___________________

- ☐ Carbon dating/stable isotope analysis
  - o Sample taken from ___________________

- ☐ Photographs taken

- ☐ Cranial reconstruction
- ☐ Craniometrics to be taken

Liverpool John Moores University

School of Natural Sciences and Psychology

Skeleton Summary Form - Non-adult

Skeleton Number	
Context Number	
Date	
Preservation	
MNI	
Age	
Non metric traits/ pathology	
Additional notes	

AGE ESTIMATION: *If not examined, enter "N.E." for Phase and "unknown" for Age Range.*

Epiphyseal Closure 1=no union 2=partial union 3=complete union 4=not examined 5=absent

	SCORE		SCORE
Pars lateralis-pars squama		Iliac crest	
Lateralis-squama-basilaris		Proximal Humerus	
Basilar Suture		Distal Humerus	
Cervical Vertebrae Body-Arch		Proximal Ulna	
Cervical Vertebral Rim		Distal Ulna	
Thoracic Vertebrae Body-Arch		Proximal Radius	
Thoracic Vertebral Rim		Distal Radius	
Lumbar Vertebrae Body-Arch		Distal MTC's	
Lumbar Vertebral Rim		Proximal Femur	
Sacral Segments 1-2		Distal Femur	
Sacral Segments 2-3		Proximal Tibia	
Sacral Segments 3-4		Distal Tibia	
Ischium-Pubis		Proximal Fibula	
Ischium-Pubis-Ilium		Distal Fibula	
Ischial Tuberosity		Distal MTT's	

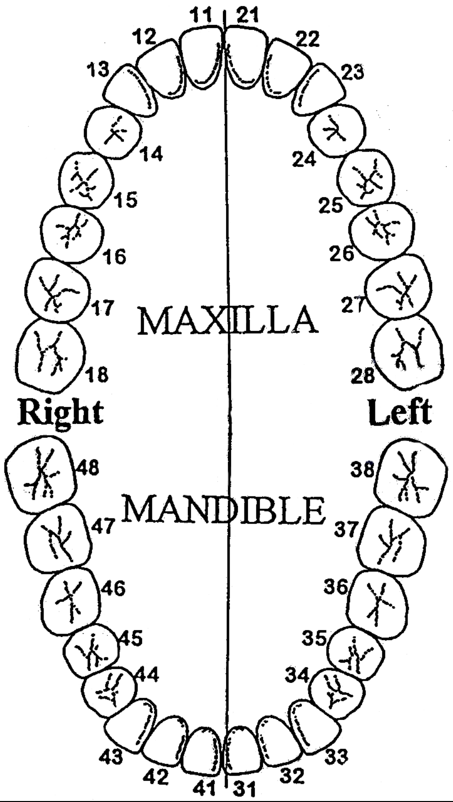
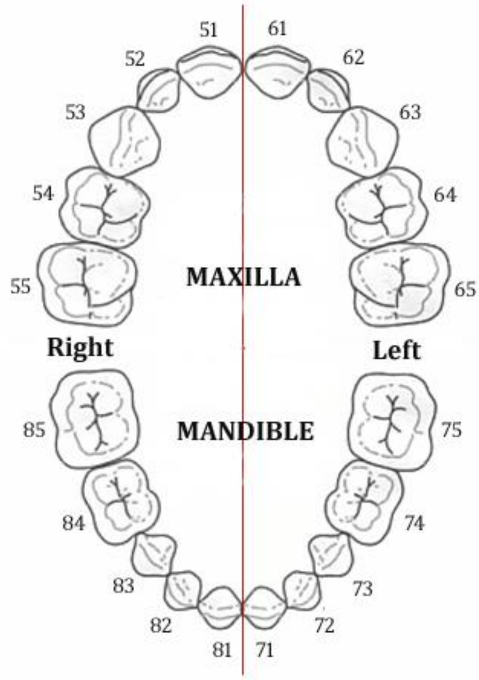
AGE ESTIMATION(RANGE)

Skeletal Measurements

Element Measured	Measurement (mm)	Age Range

AGE ESTIMATION(RANGE)

Dental Inventory

Adult	Non-adult
	

LJMU Skeleton number	
Loose teeth	
Additional notes	

Data Checklist

- ☐ X-ray required
  - Type of x-ray ____
- ☐ X-ray taken

- ☐ Pars basilaris
  - ☐ MWB _____________________
  - ☐ MLB _____________________
  - ☐ SL _____________________

- ☐ Staining

- ☐ Soil Sample

- ☐ Collagen extraction
  - Weight of sample at start ___________________
  - Weight of collagen ___________________

- ☐ Carbon dating/stable isotope analysis
  - Sample taken from ___________________

- ☐ Photographs taken

- ☐ Cranial reconstruction

- ☐ Craniometrics to be taken

A2. Data collection forms – Chester Greyfriars

Liverpool John Moores University

School of Natural Sciences and Psychology

Chester Greyfriars Skeleton Summary Form - Infant

Skeleton Number	
Context Number	
Date	
Preservation	
MNI	
Age	
Non metric traits/ pathology	
Additional notes	

AGE ESTIMATION: *If not examined, enter "N.E." for Phase and "unknown" for Age Range.*

Epiphyseal Closure 1=no union 2=partial union 3=complete union 4=not examined 5=absent

	SCORE		SCORE
Pars lateralis-pars squama		Iliac crest	
Lateralis-squama-basilaris		Proximal Humerus	
Basilar Suture		Distal Humerus	
Cervical Vertebrae Body-Arch		Proximal Ulna	
Cervical Vertebral Rim		Distal Ulna	
Thoracic Vertebrae Body-Arch		Proximal Radius	
Thoracic Vertebral Rim		Distal Radius	
Lumbar Vertebrae Body-Arch		Distal MTC's	
Lumbar Vertebral Rim		Proximal Femur	
Sacral Segments 1-2		Distal Femur	
Sacral Segments 2-3		Proximal Tibia	
Sacral Segments 3-4		Distal Tibia	
Ischium-Pubis		Proximal Fibula	
Ischium-Pubis-Ilium		Distal Fibula	
Ischial Tuberosity		Distal MTT's	

AGE ESTIMATION(RANGE)

Skeletal Measurements

Element Measured	Measurement (mm)	Age Range

AGE ESTIMATION(RANGE)

Skeleton Number _____ **Juvenile Skeletal Inventory**

Bone	Right	Left	Bone	
Parietal			Frontal	
Temporal			Occipital	
Maxilla			Pars Basillaris	
Nasal			Ethmoid	
Zygomatic			Spenoid	
Lacrimal			Fontanelle	
Palatine			Hyoid	
Mandible			Atlas	
Pars Lateralis			Axis	

Bone	No. Bodies	No. right arches	No. left arches
Cervical			
Thoracic			
Lumbar			
Sacrum			
Bone	**Right**	**Left**	
Rib			
Sternum	No. of Sternebrae =		

Right

Bone	Prox. Epiph.	P 1/3	M 1/3	D 1/3	Dist. Epiph.
Humerus					
Radius					
Ulna					
Femur					
Tibia					
Fibula					

Left

Bone	Prox. Epiph.	P 1/3	M 1/3	D 1/3	Dist. Epiph.
Humerus					
Radius					
Ulna					
Femur					
Tibia					
Fibula					

Right

Bone	> 75%	75–50	50–25	<25%
Ilium				
Ischium				
Pubis				
Scapula				
Clavicle				
Patella				

Left

Bone	> 75%	75–50	50–25	<25%
Ilium				
Ischium				
Pubis				
Scapula				
Clavicle				
Patella				

Bones	Number	Bones	Number
Metacarpals		Carpals	
Metatarsals		Tarsals	
Hand phalanges		Foot phalanges	

Other unfused bone elements present

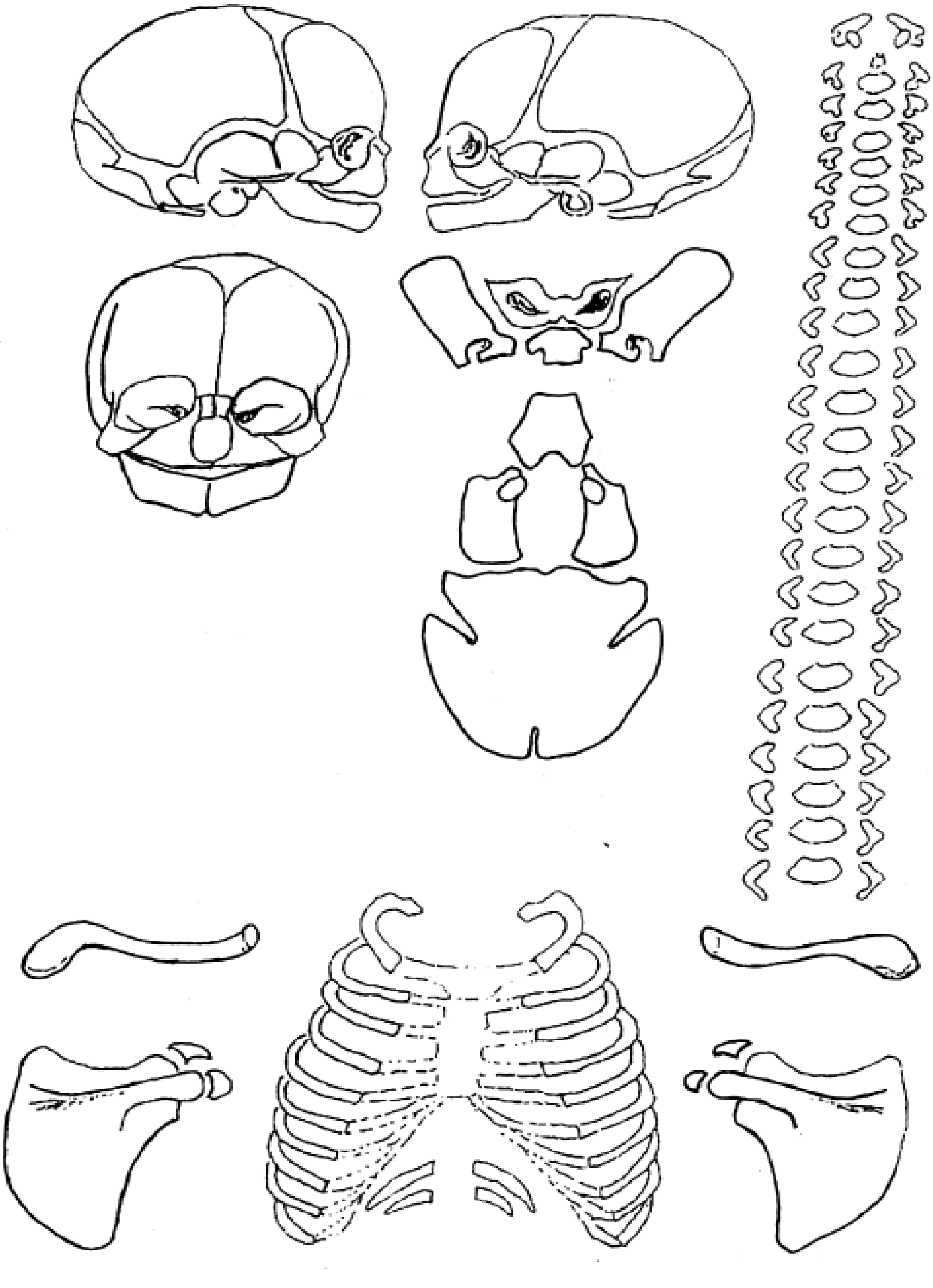
____

____

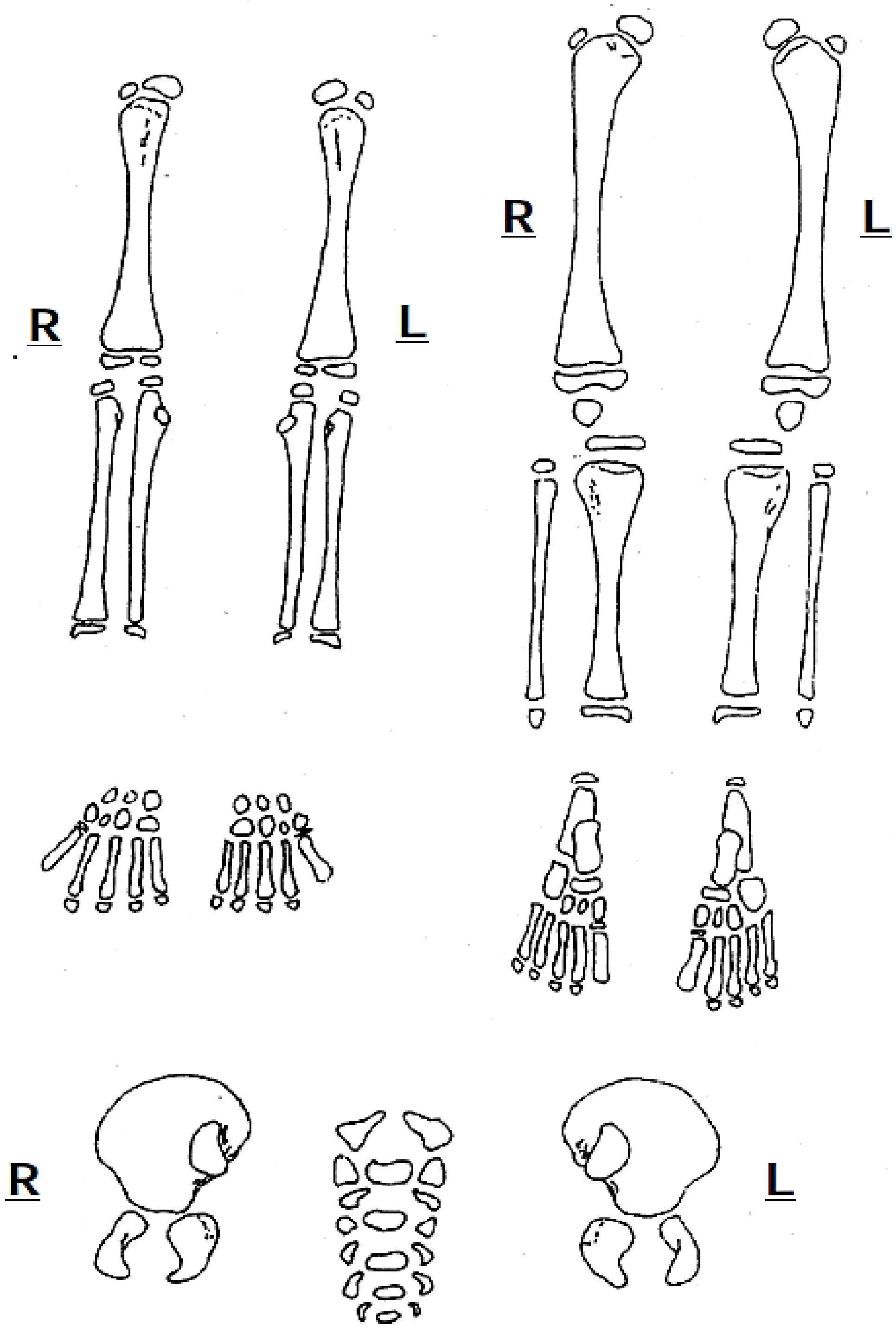
____

____

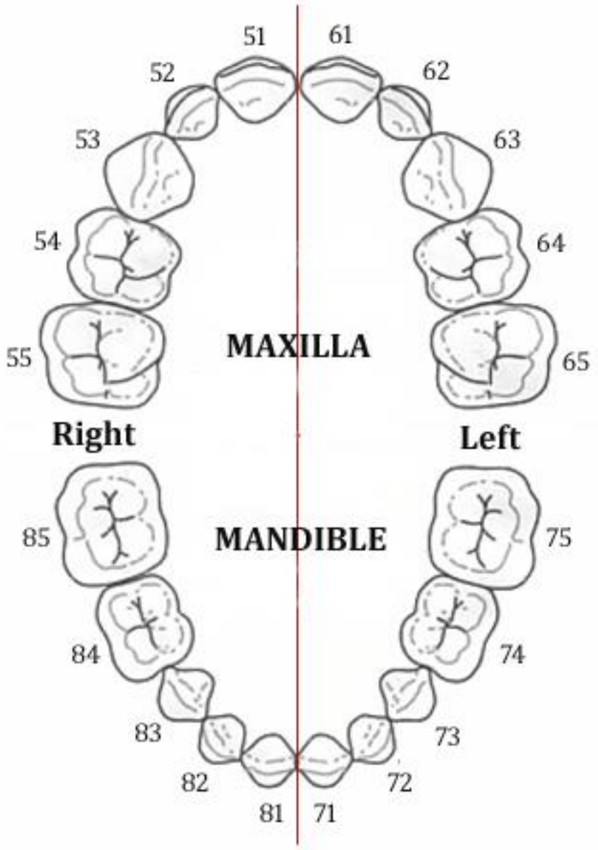
Appendix 1 Infant skeletal record sheet (courtesy: S Black)



Appendix 1 Infant skeletal record sheet (cont)



Dental Inventory

Non-adult


Loose teeth	
Additional notes	

Table 2 Postcranial dimensions: a primary listing

ID code	Brothwell code[1]	Buikstra & Ubelaker number[2]	Brauer/Martin & Saller number[3]	Description
XLF	FeL1	60	1	Maximum femoral length, distance from the most superior point on the femoral head to the most inferior point on the distal condyles
STF	FeD1	64	10	Subtrochanteric antero-posterior (sagittal) diameter of the femur, distance between anterior and posterior surfaces at the proximal end of the diaphysis (avoiding gluteal lines and/or tuberosities)
TTF	FeD2	65	9	Subtrochanteric transverse diameter of the femur, distance between medial and lateral surfaces at the proximal end of the diaphysis (avoiding gluteal lines and/or tuberosities) at the point of its greatest lateral expansion below the lesser trochanter
WBF	FeE1	62	21	Femoral bicondylar breadth, distance between two most laterally projecting points on the epicondyles
LCT			1a	Complete tibial length, from the superior articular facet of lateral condyle to the most distal point of the medial malleolus
XLT	TiL1	69	1	Maximum tibial length, from the most superior point on the intercondylar eminence to the most distal point of the medial malleolus
XLH	HuL1	40	1	Maximum humeral length, direct distance from the most superior point on the humeral head to the most inferior point on the trochlea
SHH		42	10	Sagittal (vertical) diameter of the humeral head, distance between the most superior and inferior points on the border of the articular surface
WDH		41	4	Humeral epicondylar breadth, distance of the most laterally protruding point on the lateral epicondyle from the corresponding projection of the medial epicondyle
XLR	RaL1	45	1	Maximum radius length, distance from the most proximal point on the head to the tip of the styloid process
XLU	UlL1	48	1	Maximum ulna length, distance from the most superior point on the olecranon to the most inferior point on the styloid process
XLG	FiL1	75	1	Maximum fibula length, distance from the most superior point on the fibula head to the most inferior point on the lateral malleolus

[1]Brothwell (1981), [2]Bulkstra and Ubelaker (1994) [3]Brauer (1998) Martin & Saller (1957)

Table 3 Cranial non-metric traits: a primary listing

Trait	Recording Notes
Metopism	Except in young infants, record even when nearly obliterated
Epipteric bones	Left & right
Coronal wormian bones	Left & right
Sagittal wormian bones	
Lambdoid wormian bones	Note numbers (very variable)
Parietal notch bones	Left & right
Bregmatic ossicle	
Asterionic bones	Left & right
Apical bone	
Occipito-mastoid suture ossicles	Left & right
Palatine torus	Note development as none to slight, moderate or extreme (see Figure 10)
Maxillary torus	Note development as none to slight, moderate or extreme (see Figure 10)
Parietal foramen	Left & right, present or absent
Infraorbital forame	Left & right, single or multiple
Mastoid foramen exsutural	Left & right
Fronto-temporal articulation	Left & right
Hypoglossal canals	Left & right, note as single, single with partial bridge or spine, double or multiple
Auditory exostosis	Left & right, present or absent and development (see Figure 11)

Although the presence / absence of auditory exostoses, palatine & maxillary tori are included here, all are generally considered to have a functional (rather than inherited) aetiology.

Table 4 Postcranial non-metric traits: a primary listing

Trait	Recording Notes – record left & right separately
Femoral plaque	Note when bone overgrowth or bony scar can be defined extending from articular surface of femoral head towards anterior portion of femoral neck
Tibial squatting facets	Note medial or lateral expansions of the distal articular surface onto the anterior aspect of the metaphysis. May be congenital rather than activity-related in origin
Distal septal aperture	Note degree of expression as absent, pinhole or true perforation or the humerus. Relatively uncommon in European populations
Suprascapular foramen	Note presence as suprascapular notch (most common), partially bridged or complete bridging to form foramen
Vastus notch present	Note presence as facet or smooth but sharp-edged notch at supero-lateral aspect of patella
Superior atlas facets	Note facet shape as either single (ie long & oval) or double (with two separate facets having either a groove or a ridge of bone between them)
Posterior atlas bridge	Note bridging of posterior aspect of superior articular facet aspect to posterior arch as absent, partial or complete
Accessory transverse foramina in cervical vertebrae	Note as absent, partial or complete in all cervical vertebrae

Chester Greyfriars Data Checklist

- ☐ X-ray required
    - o Type of x-ray ____
- ☐ X-ray taken

- ☐ Staining

- ☐ Pars basilaris
    - ☐ MWB _____________________
    - ☐ MLB _____________________
    - ☐ SL _____________________

- ☐ Soil Sample

- ☐ Collagen extraction
    - o Weight of sample ___________________
    - o Weight of collagen ___________________

- ☐ Carbon dating/stable isotope analysis
    - o Sample taken from ___________________

- ☐ Photographs taken

- ☐ Cranial reconstruction
- ☐ Craniometrics taken

Liverpool John Moores University

School of Natural Sciences and Psychology

Chester Greyfriars Skeleton Summary Form - Non-adult

Skeleton Number	
Context Number	
Date	
Preservation	
MNI	
Age	
Non metric traits/ pathology	
Additional notes	

AGE ESTIMATION: *If not examined, enter "N.E." for Phase and "unknown" for Age Range.*

Epiphyseal Closure 1=no union 2=partial union 3=complete union 4=not examined 5=absent

	SCORE		SCORE
Pars lateralis-pars squama		Iliac crest	
Lateralis-squama-basilaris		Proximal Humerus	
Basilar Suture		Distal Humerus	
Cervical Vertebrae Body-Arch		Proximal Ulna	
Cervical Vertebral Rim		Distal Ulna	
Thoracic Vertebrae Body-Arch		Proximal Radius	
Thoracic Vertebral Rim		Distal Radius	
Lumbar Vertebrae Body-Arch		Distal MTC's	
Lumbar Vertebral Rim		Proximal Femur	
Sacral Segments 1-2		Distal Femur	
Sacral Segments 2-3		Proximal Tibia	
Sacral Segments 3-4		Distal Tibia	
Ischium-Pubis		Proximal Fibula	
Ischium-Pubis-Ilium		Distal Fibula	
Ischial Tuberosity		Distal MTT's	

AGE ESTIMATION(RANGE)

Skeletal Measurements

Element Measured	Measurement (mm)	Age Range

AGE ESTIMATION(RANGE)

Skeleton Number _____ Juvenile Skeletal Inventory

Bone	Right	Left	Bone	
Parietal			Frontal	
Temporal			Occipital	
Maxilla			Pars Basillaris	
Nasal			Ethmoid	
Zygomatic			Spenoid	
Lacrimal			Fontanelle	
Palatine			Hyoid	
Mandible			Atlas	
Pars Lateralis			Axis	

Bone	No. Bodies	No. right arches	No. left arches
Cervical			
Thoracic			
Lumbar			
Sacrum			
Bone	**Right**	**Left**	
Rib			
Sternum	No. of Sternebrae =		

Right

Bone	Prox. Epiph.	P 1/3	M 1/3	D 1/3	Dist. Epiph.
Humerus					
Radius					
Ulna					
Femur					
Tibia					
Fibula					

Left

Bone	Prox. Epiph.	P 1/3	M 1/3	D 1/3	Dist. Epiph.
Humerus					
Radius					
Ulna					
Femur					
Tibia					
Fibula					

Right

Bone	> 75%	75–50	50–25	<25%
Ilium				
Ischium				
Pubis				
Scapula				
Clavicle				
Patella				

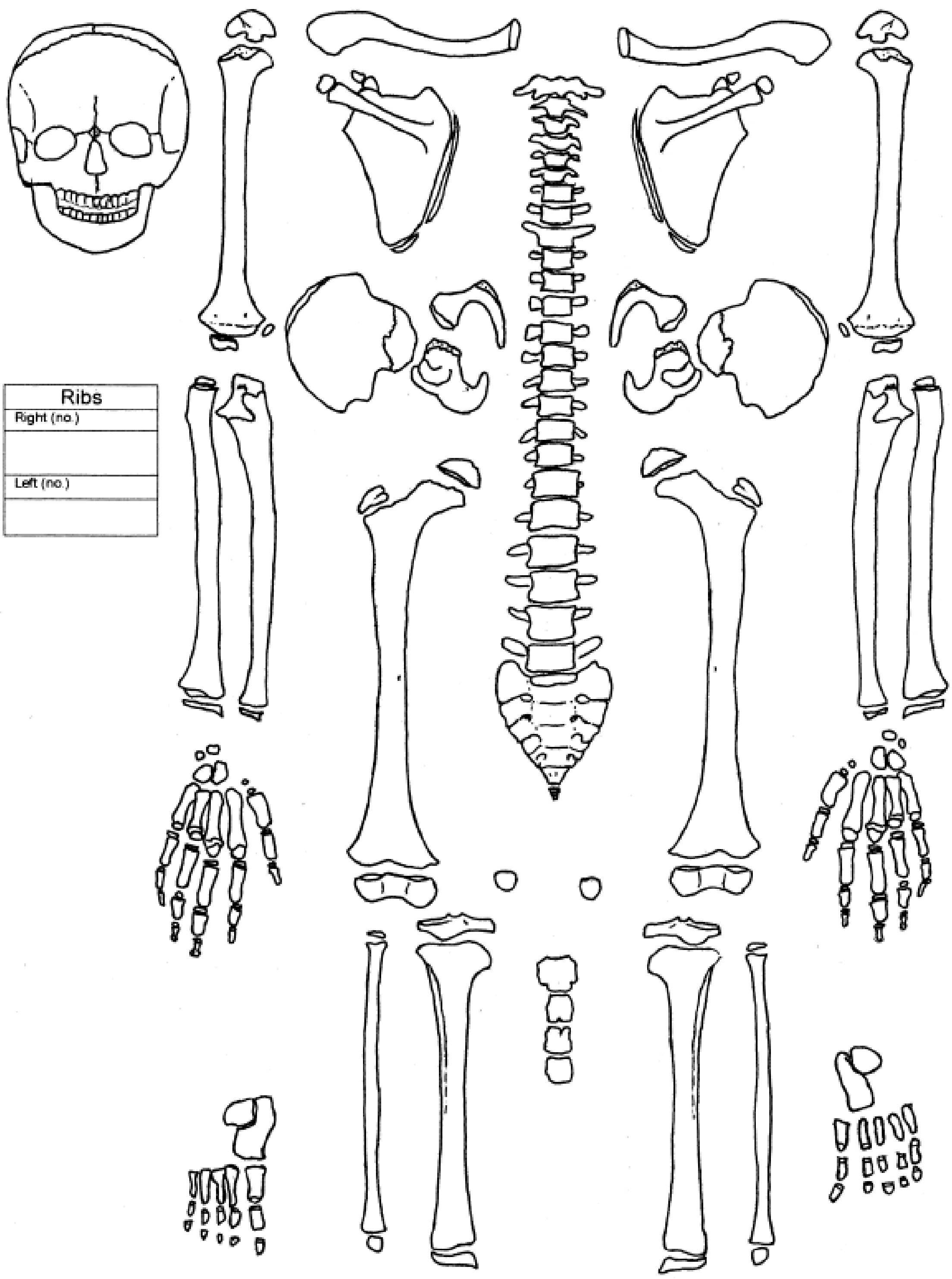
Left

Bone	> 75%	75–50	50–25	<25%
Ilium				
Ischium				
Pubis				
Scapula				
Clavicle				
Patella				

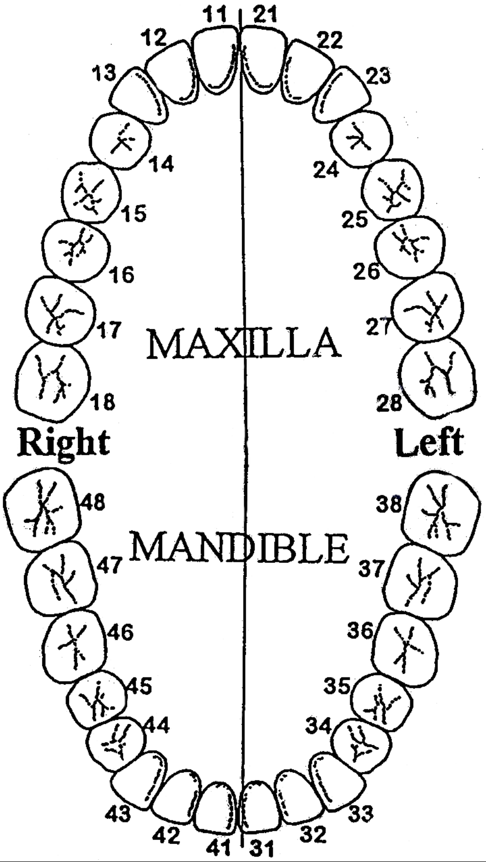
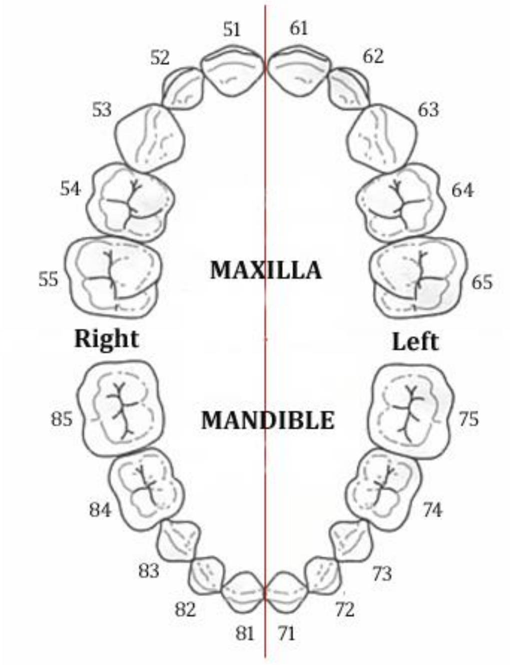
Bones	Number	Bones	Number
Metacarpals		Carpals	
Metatarsals		Tarsals	
Hand phalanges		Foot phalanges	

Other unfused bone elements present

Appendix 2 Juvenile skeletal record sheet



Dental Inventory

Adult	Non-adult
	

Loose teeth	
Additional notes	

Table 2 Postcranial dimensions: a primary listing

ID code	Brothwell code[1]	Buikstra & Ubelaker number[2]	Brauer/Martin & Saller number[3]	Description
XLF	FeL1	60	1	Maximum femoral length, distance from the most superior point on the femoral head to the most inferior point on the distal condyles
STF	FeD1	64	10	Subtrochanteric antero-posterior (sagittal) diameter of the femur, distance between anterior and posterior surfaces at the proximal end of the diaphysis (avoiding gluteal lines and/or tuberosities)
TTF	FeD2	65	9	Subtrochanteric transverse diameter of the femur, distance between medial and lateral surfaces at the proximal end of the diaphysis (avoiding gluteal lines and/or tuberosities) at the point of its greatest lateral expansion below the lesser trochanter
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LCT			1a	Complete tibial length, from the superior articular facet of lateral condyle to the most distal point of the medial malleolus
XLT	TiL1	69	1	Maximum tibial length, from the most superior point on the intercondylar eminence to the most distal point of the medial malleolus
XLH	HuL1	40	1	Maximum humeral length, direct distance from the most superior point on the humeral head to the most inferior point on the trochlea
SHH		42	10	Sagittal (vertical) diameter of the humeral head, distance between the most superior and inferior points on the border of the articular surface
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XLR	RaL1	45	1	Maximum radius length, distance from the most proximal point on the head to the tip of the styloid process
XLU	UlL1	48	1	Maximum ulna length, distance from the most superior point on the olecranon to the most inferior point on the styloid process
XLG	FiL1	75	1	Maximum fibula length, distance from the most superior point on the fibula head to the most inferior point on the lateral malleolus

[1]Brothwell (1981), [2]Buikstra and Ubelaker (1994) [3]Brauer (1998) Martin & Saller (1957)

Table 3 Cranial non-metric traits: a primary listing

Trait	Recording Notes
Metopism	Except in young infants, record even when nearly obliterated
Epipteric bones	Left & right
Coronal wormian bones	Left & right
Sagittal wormian bones	
Lambdoid wormian bones	Note numbers (very variable)
Parietal notch bones	Left & right
Bregmatic ossicle	
Asterionic bones	Left & right
Apical bone	
Occipito-mastoid suture ossicles	Left & right
Palatine torus	Note development as none to slight, moderate or extreme (see Figure 10)
Maxillary torus	Note development as none to slight, moderate or extreme (see Figure 10)
Parietal foramen	Left & right, present or absent
Infraorbital forame	Left & right, single or multiple
Mastoid foramen exsutural	Left & right
Fronto-temporal articulation	Left & right
Hypoglossal canals	Left & right, note as single, single with partial bridge or spine, double or multiple
Auditory exostosis	Left & right, present or absent and development (see Figure 11)

Although the presence / absence of auditory exostoses, palatine & maxillary tori are included here, all are generally considered to have a functional (rather than inherited) aetiology.

Table 4 Postcranial non-metric traits: a primary listing

Trait	Recording Notes – record left & right separately
Femoral plaque	Note when bone overgrowth or bony scar can be defined extending from articular surface of femoral head towards anterior portion of femoral neck
Tibial squatting facets	Note medial or lateral expansions of the distal articular surface onto the anterior aspect of the metaphysis. May be congenital rather than activity-related in origin
Distal septal aperture	Note degree of expression as absent, pinhole or true perforation or the humerus. Relatively uncommon in European populations
Suprascapular foramen	Note presence as suprascapular notch (most common), partially bridged or complete bridging to form foramen
Vastus notch present	Note presence as facet or smooth but sharp-edged notch at supero-lateral aspect of patella
Superior atlas facets	Note facet shape as either single (ie long & oval) or double (with two separate facets having either a groove or a ridge of bone between them)
Posterior atlas bridge	Note bridging of posterior aspect of superior articular facet aspect to posterior arch as absent, partial or complete
Accessory transverse foramina in cervical vertebrae	Note as absent, partial or complete in all cervical vertebrae

Chester Greyfriars Data Checklist

- ☐ X-ray required
    - o Type of x-ray ____
- ☐ X-ray taken

- ☐ Pars basilaris
    - ☐ MWB _____________________
    - ☐ MLB _____________________
    - ☐ SL _____________________

- ☐ Staining

- ☐ Soil Sample

- ☐ Collagen extraction
    - o Weight of sample at start ___________________
    - o Weight of collagen ___________________

- ☐ Carbon dating/stable isotope analysis
    - o Sample taken from ___________________

- ☐ Photographs taken

- ☐ Cranial reconstruction

- ☐ Craniometrics to be taken

Liverpool John Moores University

School of Natural Sciences and Psychology

Chester Greyfriars Skeleton Summary Form - Adult

Skeleton Number	
Context Number	
Preservation	a/e score f score
MNI	
Age	
Sex	
Stature	
Non metric traits/ pathology	
Additional notes	

SEX ESTIMATION: *Examine each region present and circle the appropriate description. If the skeletal element is not present, enter "N/A" in the box for Sex.*

Innominate	*Sub-pubic Angle:*	Narrow	Wide	Intermediate	N.E.
	Sub-pubic concavity:	Straight	Concave	Intermediate	N.E
	Ventral Arc:	Absent	Present		N.E.
	Medial aspect of I-R:	Broad	Ridge		N.E.
	Greater Sciatic Notch:	Narrow	Wide	Intermediate	N.E.
	Pre auricular sulcus:	Absent	Present		N.E.
	Obturator foramen:	Oval	Triangular	intermediate	N.E.
Sacrum		Curved	Straight	Intermediate	N.E.

Sex:

Cranium	*Supra-orbital Ridge:*	robust	gracile	intermediate	N.E.
	Supra-orbital Margin:	dull	sharp	intermediate	N.E.
	Mastoid Process:	robust	gracile	intermediate	N.E.
	Nuchal Crest:	robust	gracile	intermediate	N.E.

Sex:

Mandible	*Mental Eminence:*	square	rounded	intermediate	N.E.
	Gonial Angle:	<124°	>125°	intermediate	N.E.
	Mental aversion:	Present	Absent	intermediate	N.E.

Sex:

Metrics	*Humeral head:*	<43mm	43-47mm	>47mm
	Glenoid fossa height:	<34mm	34-36mm	>36mm
	Radial head:	<21mm	22-23mm	>24mm
	Femoral head:	<43.5mm	43.5-46.5mm	>46.5mm
	Bicondylar width:	<74mm	74-76mm	>76mm

Sex:

FINAL SEX ESTIMATION:

AGE ESTIMATION: *If not examined, enter "N.E." for Phase and "unknown" for Age Range.*

Pubic Symphysis (*Suchey-Brooks*)	Left (description):	Phase:	Age Range:
	Right (description):	Phase:	Age Range:

Sternal 4th Rib (*Iscan et al*)	Right or Left (description):	Phase:	Age Range:

Auricular Surface (*Lovejoy et al*)	Left (description):	Phase:	Age Range:
	Right (description):	Phase:	Age Range:

Medial Clavicle (*Webb-Suchey*)	Left (description):	Phase:	Age Range:
	Right (description):	Phase:	Age Range:

Anterior Iliac Crest (*Webb-Suchey*)	Left (description):	Phase:	Age Range:
	Right (description):	Phase:	Age Range:

Dental Attrition (*Lovejoy*)	Maxilla	Phase:	Age Range:
	Mandible	Phase:	Age Range:

Suture Closure (*Meindl & Lovejoy*)	Vault	Lateral-anterior
	1.	6.
	2.	7.
	3.	8.
	4.	9.
	5.	10.
	6.	
	7.	
	Total:	Total:
	Age Range:	Age Range:

FINAL AGE ESTIMATION(RANGE)	

STATURE ESTIMATION: *If a bone cannot be measure, enter a "/" (slash mark) in each box. (Trotter and Gleser)*

	Right or Left?	Measurement (in *cm*)
Maximum Length of Femur		
Maximum Length of Tibia		
Maximum Length of Fibula		
Maximum Length of Humerus		
Maximum Length of Ulna		
Maximum Length of Radius		

Formula computation:

	Minimum	Maximum
FINAL STATURE ESTIMATION (range)*: *If unable to determine stature, enter "?"		

Skeleton Number _____ **Adult Skeletal Inventory**

Bone	Right	Left	Bone	
Parietal			Frontal	
Temporal			Occipital	
Maxilla			Sphenoid	
Nasal			Vomer	
Zygomatic			Ethmoid	
Lacrimal			Hyoid	
Palatine			Cricoid	
Mandible			Thyroid	
Orbit				

C1		T6	
C2		T7	
C3		T8	
C4		T9	
C5		T10	
C6		T11	
C7		T12	
T1		L1	
T2		L2	
T3		L3	
T4		L4	
T5		L5	

Right ribs ☐ Left ribs ☐

Right

Bone	Prox. J.S	P 1/3	M1/3	D1/3	Dist. J.S
Humerus					
Radius					
Ulna					
Femur					
Tibia					
Fibula					

Left

Bone	Prox. J.S	P 1/3	M1/3	D1/3	Dist. J.S
Humerus					
Radius					
Ulna					
Femur					
Tibia					
Fibula					

Right

Bone	>75%	50–75	50–25	<25%
Ilium				
Ischium				
Pubis				
Scapula				
Clavicle				
Patella				

Left

Bone	>75%	50–75	50–25	<25%
Ilium				
Ischium				
Pubis				
Scapula				
Clavicle				
Patella				

Bone	>75%	50–75	50–25	<25%
Sternum				
Coccyx				
Sacrum				

Right	1	2	3	4	5
Metacarpals					
Metatarsals					

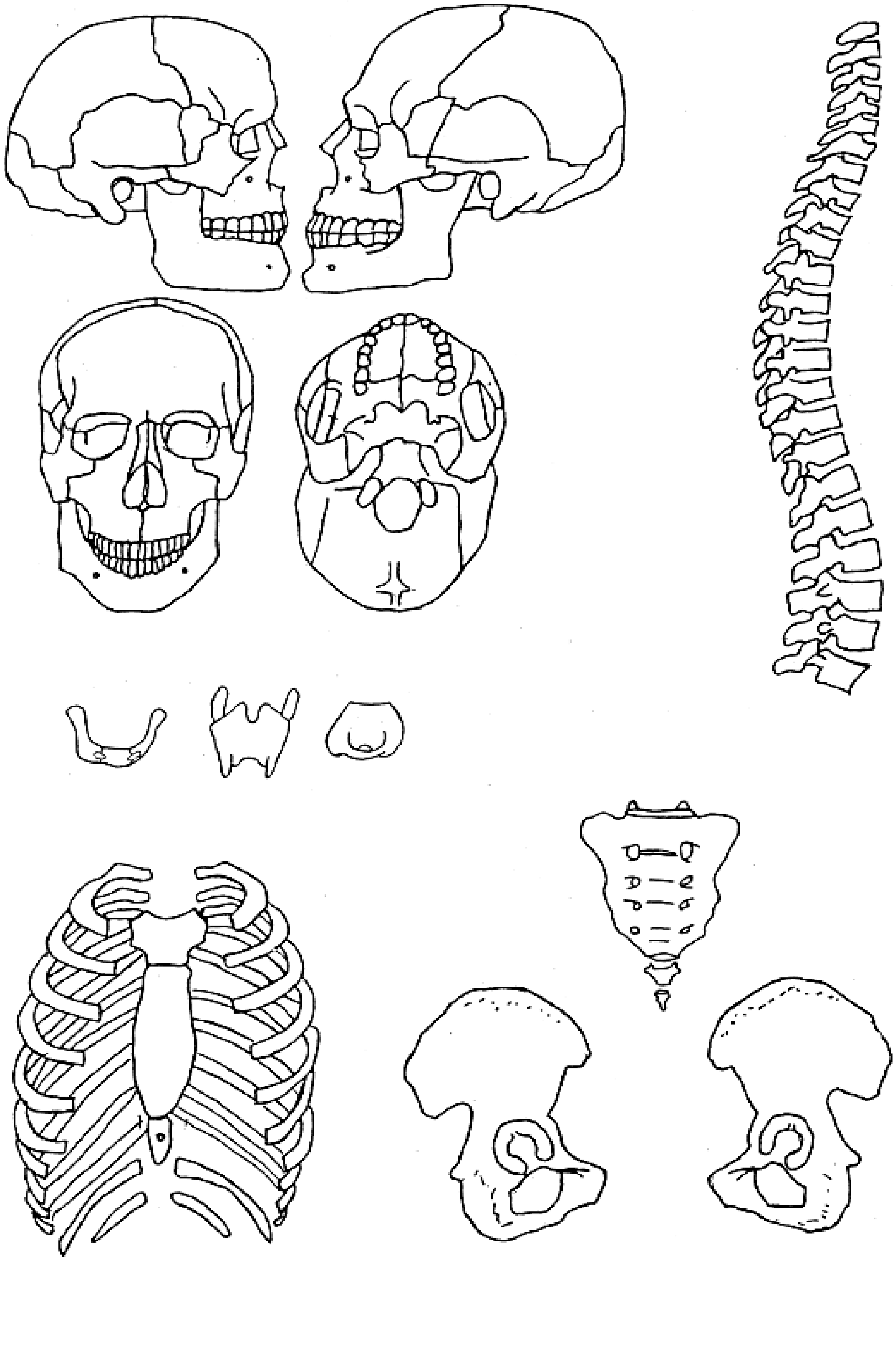
Left	1	2	3	4	5
Metacarpals					
Metatarsals					

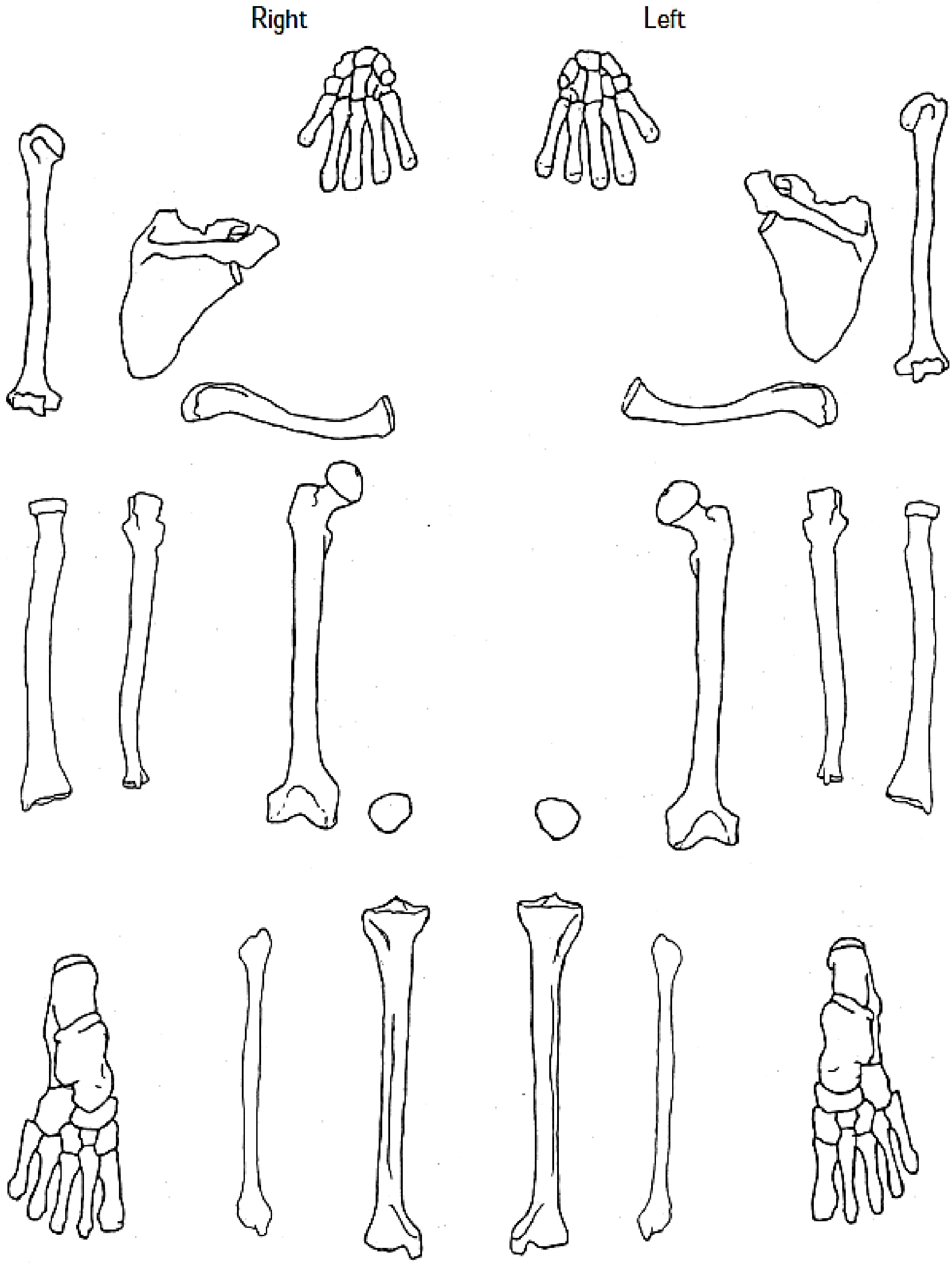
	Scaphoid	Lunate	Triquetral	Pisiform	Trapezium	Trapezoid	Capitate	Hamate	Sesmoid
Right									
Left									
	Talus	Calcaneus	1st Cun	2nd Cun	3rd Cun	Navicular	Cuboid		Sesmoid
Right									
Left									

Hand Proximal phalanges ☐ Middle phalanges ☐ Distal phalanges ☐

Foot Proximal phalanges ☐ Middle phalanges ☐ Distal phalanges ☐

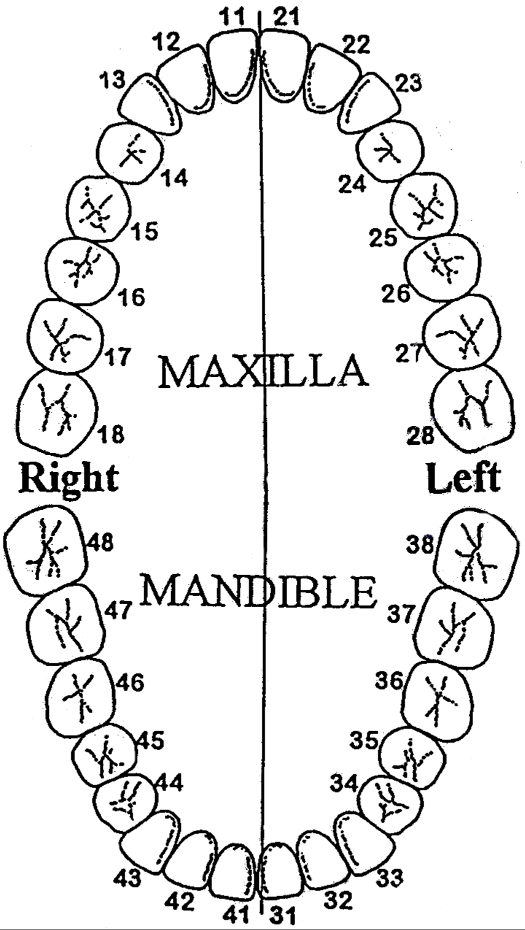
Appendix 3 Adult skeletal record sheet




Right
Left

Dental Inventory

Adult



Loose teeth	
Additional notes	

Table 2 Postcranial dimensions: a primary listing

ID code	Brothwell code[1]	Buikstra & Ubelaker number[2]	Brauer/Martin & Saller number[3]	Description
XLF	FeL1	60	1	Maximum femoral length, distance from the most superior point on the femoral head to the most inferior point on the distal condyles
STF	FeD1	64	10	Subtrochanteric antero-posterior (sagittal) diameter of the femur, distance between anterior and posterior surfaces at the proximal end of the diaphysis (avoiding gluteal lines and/or tuberosities)
TTF	FeD2	65	9	Subtrochanteric transverse diameter of the femur, distance between medial and lateral surfaces at the proximal end of the diaphysis (avoiding gluteal lines and/or tuberosities) at the point of its greatest lateral expansion below the lesser trochanter
WBF	FeE1	62	21	Femoral bicondylar breadth, distance between two most laterally projecting points on the epicondyles
LCT			1a	Complete tibial length, from the superior articular facet of lateral condyle to the most distal point of the medial malleolus
XLT	TiL1	69	1	Maximum tibial length, from the most superior point on the intercondylar eminence to the most distal point of the medial malleolus
XLH	HuL1	40	1	Maximum humeral length, direct distance from the most superior point on the humeral head to the most inferior point on the trochlea
SHH		42	10	Sagittal (vertical) diameter of the humeral head, distance between the most superior and inferior points on the border of the articular surface
WDH		41	4	Humeral epicondylar breadth, distance of the most laterally protruding point on the lateral epicondyle from the corresponding projection of the medial epicondyle
XLR	RaL1	45	1	Maximum radius length, distance from the most proximal point on the head to the tip of the styloid process
XLU	UlL1	48	1	Maximum ulna length, distance from the most superior point on the olecranon to the most inferior point on the styloid process
XLG	FiL1	75	1	Maximum fibula length, distance from the most superior point on the fibula head to the most inferior point on the lateral malleolus

[1]Brothwell (1981), [2]Buikstra and Ubelaker (1994) [3]Brauer (1998) Martin & Saller (1957)

Table 3 Cranial non-metric traits: a primary listing

Trait	Recording Notes
Metopism	Except in young infants, record even when nearly obliterated
Epipteric bones	Left & right
Coronal wormian bones	Left & right
Sagittal wormian bones	
Lambdoid wormian bones	Note numbers (very variable)
Parietal notch bones	Left & right
Bregmatic ossicle	
Asterionic bones	Left & right
Apical bone	
Occipito-mastoid suture ossicles	Left & right
Palatine torus	Note development as none to slight, moderate or extreme (see Figure 10)
Maxillary torus	Note development as none to slight, moderate or extreme (see Figure 10)
Parietal foramen	Left & right, present or absent
Infraorbital forame	Left & right, single or multiple
Mastoid foramen exsutural	Left & right
Fronto-temporal articulation	Left & right
Hypoglossal canals	Left & right, note as single, single with partial bridge or spine, double or multiple
Auditory exostosis	Left & right, present or absent and development (see Figure 11)

Although the presence / absence of auditory exostoses, palatine & maxillary tori are included here, all are generally considered to have a functional (rather than inherited) aetiology.

Table 4 Postcranial non-metric traits: a primary listing

Trait	Recording Notes – record left & right separately
Femoral plaque	Note when bone overgrowth or bony scar can be defined extending from articular surface of femoral head towards anterior portion of femoral neck
Tibial squatting facets	Note medial or lateral expansions of the distal articular surface onto the anterior aspect of the metaphysis. May be congenital rather than activity-related in origin
Distal septal aperture	Note degree of expression as absent, pinhole or true perforation or the humerus. Relatively uncommon in European populations
Suprascapular foramen	Note presence as suprascapular notch (most common), partially bridged or complete bridging to form foramen
Vastus notch present	Note presence as facet or smooth but sharp-edged notch at supero-lateral aspect of patella
Superior atlas facets	Note facet shape as either single (ie long & oval) or double (with two separate facets having either a groove or a ridge of bone between them)
Posterior atlas bridge	Note bridging of posterior aspect of superior articular facet aspect to posterior arch as absent, partial or complete
Accessory transverse foramina in cervical vertebrae	Note as absent, partial or complete in all cervical vertebrae

Chester Greyfriars Data Checklist

- ☐ X-ray required
    - ○ Type of x-ray ____
- ☐ X-ray taken

- ☐ Staining

- ☐ Pre-auricular sulcus
    - ☐ G.P. Groove
    - ☐ G.L. Groove

- ☐ Fragmentary femora
    - ☐ VHD ________________
    - ☐ VHA ________________
    - ☐ LCH ________________

- ☐ Soil Sample

- ☐ Collagen extraction
    - ○ Weight of sample ___________________
    - ○ Weight of collagen ___________________

- ☐ Carbon dating/stable isotope analysis
    - ○ Sample taken from ___________________

- ☐ Photographs taken

- ☐ Cranial reconstruction
- ☐ Craniometrics taken

A3. Poulton Chapel collection

Skeletal collection summary

Key to Poulton excavation years:

Colour	Excavation Year
Mint green	Pre 2000
Dirty Yellow	2001
Purple	2002
Sky Blue	2003
Lilac	2004
Green	2005
Dark Blue	2006
Orange	2007
Pink	2008
Sunny Yellow	2009
Dark Green	2010
Brown	2011
Peach	2012
Red	2013
Aqua	2014
Burgundy	2015

SK #	Context	Age Range	Age Code	Sex	Sex Code	Stature (cm)
41	455	20-24 Y	14	F	3	151.66 ± 3.72
45	470	50-59 Y	20	F	3	159.23 ± 3.57
46	479	40-44 Y	18	M	2	171.61 ± 3.37
47	485	11-12 Y	12	N/A	1	N/A
48	499	25-29 Y	15	M	2	163.04 ± 3.27
49	504	12-18 M	3	N/A	4	N/A
50	513	35-39 Y	17	M	2	173.75 ± 3.27
53	529	50-56 Y	20	M	2	181.60 ± 3.27
54	534	25-29 Y	15	?F	3	160.70 ± 3.57
66	647	12-18 M	3	N/A	1	N/A
67	648	35-39 Y	17	F	3	163.03 ± 3.72
81	706	40-44 Y	18	M	2	168.03 ± 3.27
82	707	45-49 Y	19	M	2	178.25 ± 4.05
83	708	20-24 Y	14	?M	2	172.71 ± 4.05
84	709	45-49 Y	19	?F	3	166.24 ± 3.72
85	718	35-39 Y	17	?M	2	170.65 ± 3.27
86	727	60+ Y	21	F	3	164.37 ± 4.24
87	732	6-12 M	2	N/A	1	N/A
88	745	4-8 M	2	N/A	1	N/A
89	747	3-4 Y	5	N/A	1	N/A
90	790	30-34 Y	16	F	3	163.61 ± 3.66
91	763	30-34 Y	16	M	2	180.89 ± 3.27
92	764	30-34 Y	16	F	3	N.E.
93	765	40-44 Y	18	F	3	160.13 ± 3.66
94	774	50-54 Y	20	M	2	N.E.
95	485	35-39 Y	17	F	3	153.75 ± 3.66
96	808	45-49 Y	19	F	3	164.07 ± 3.27
97	811	40-44 Y	18	F	3	156.89 ± 3.57
98	774	11-12 Y	12	N/A	1	N/A
100	818	45-49 Y	19	?M	2	N.E.
102	822	12-14 Y	12	N/A	1	N/A
103	859	40-44 Y	18	F	3	155.42 ± 3.57
104	861	4-5 Y	6	N/A	1	N/A
105	861	0-1 Y	2	N/A	1	N/A
106	847	1-2 Y	3	N/A	1	N/A
107	860	7-8 Y	9	N/A	1	N/A
108	871	50-59 Y	20	F	3	151.07 ± 5.77
109	872	40-44 Y	18	M	2	N.E.
110	873	35-39 Y	17	F	3	158.10 ± 3.66
112	878	45-49 Y	19	F	3	152.20 ± 3.57
113	928	55-59 Y	20	F	3	156.59 ± 3.57

SK #	Context	Age Range	Age Code	Sex	Sex Code	Stature (cm)
114	901	45-49 Y	19	M	2	N.E.
115	902	10-12 Y	12	N/A	1	N/A
116	920	35-39 Y	17	F	3	151.03 ± 3.57
119	929	45-49 Y	19	M	2	167.32 ± 3.27
120	830	35-39 Y	17	M	2	168.51 ± 3.27
121	933	60+ Y	21	M	2	N.E.
122	934	60+ Y	21	M	2	N.E.
123	935	ADULT	22	M	2	N.E.
124.1	936	1-2 Y	3	N/A	1	N/A
124.2	936	2-3 Y	4	N/A	1	N/A
125	939	40-44 Y	18	M	2	178.25 ± 4.05
126	942	2-3 Y	4	N/A	1	N/A
127	948	3-4 Y	5	N/A	1	N/A
128	945	6-7 Y	8	N/A	1	N/A
129	958	7-8 Y	9	N/A	1	N/A
130	961	3-4 Y	5	N/A	1	N/A
131	693	35-39 Y	17	M	2	170.42 ± 4.05
132	967	30-34 Y	16	F	3	162.75 ± 3.57
133	970	25-29 Y	15	F	3	154.54 ± 3.57
134	977	10-14 Y	12	N/A	1	N/A
135.1	978	38-40 W	1	N/A	1	N/A
135.2	978	2-3 Y	4	N/A	1	N/A
135.3	978	3-4 Y	5	N/A	1	N/A
138	1104	11-14 Y	12	N/A	1	N/A
139	1105	2-3 Y	4	N/A	1	N/A
140	1106	30-34 Y	16	M	1	168.80 ± 3.29
141	1107	1-2 Y	3	N/A	1	N/A
142	991	15-18 Y	13	M	2	N.E.
142	1109	15-19 Y	13	N.E.	4	N.E.
144	1110	4-5 Y	6	N/A	1	N/A
145	1111	5-6 Y	7	N/A	1	N/A
146	1114	2-3 Y	4	N/A	1	N/A
147	1008	6-7 Y	8	N/A	1	N/A
148	1112	7-8 Y	9	N/A	1	N/A
149	1155	2-3 Y	4	N/A	1	N/A
150	1116	7-8 Y	9	N/A	1	N/A
151	1117	8-9 Y	10	N/A	1	N/A
151.1	1117	0-2 M	2	N/A	1	N/A
152	1118	15-19 Y	13	F	3	N/A
153	1187	15-19 Y	13	F	3	N/A
154	1188	15-19 Y	13	N.E.	4	N/A
155	1012	45-49 Y	19	M	2	175.17 ± 3.27
156	953	17-19 Y	13	M	2	169.93 ± 4.05
157	1121	3-4 Y	5	N/A	1	N/A
158	1002	35-39 Y	17	M	2	166.49 ± 6.24
159	1123	ADULT	22	F?	3	N.E.
160	1024	17+ Y	22	M	2	166.32 ± 3.66
161	1125	30-34 Y	16	F	3	162.45 ± 3.57
162	1029	7-8 Y	9	N/A	1	N/A
163	1028	ADULT	22	N.E.	4	N.E.
164	1015	8-9 Y	10	N/A	1	N/A
165	1030	20-24 Y	14	F	3	151.61 ± 3.57
166	1130	50-59 Y	20	F	3	161.87 ± 3.57
167	1036	0-1 Y	2	N/A	1	N/A
168	1041	2-3 Y	4	N/A	1	N/A
169	1046	25-29 Y	15	M	2	171.17 ± 4.05
170	1123	35-39 Y	17	M?	2	N.E.
171	1042	ADULT	22	N.E.	4	N.E.
172	1042	4-5 Y	6	N/A	1	N/A
173	1135	35-39 Y	17	F	3	155.95 ± 3.57
174	1191	45-49 Y	19	M	2	N.E.
175	1053	7-8 Y	9	N/A	1	N/A
176	1055	40-44 Y	18	F	3	159.21 ± 4.24
177	1138	45-49 Y	19	F	3	148.10 ± 3.57
178	1139	17-19 Y	13	M	2	176.56 ± 3.27
179	1060	6-7 Y	8	N/A	1	N/A
180	977	40-45 Y	18	F	3	156.6 ± 3.72

SK #	Context	Age Range	Age Code	Sex	Sex Code	Stature (cm)
181	1046	9.5 – 10.5 Y	11	N/A	1	N/A
182	1143	ADULT	22	N/A	4	N.E.
183	1063	4-5 Y	6	N/A	1	N/A
184	1063	7-8 Y	9	N/A	1	N/A
185	1146	<15 Y	23	N/A	1	N/A
186	1177	35-39 Y	17	F	3	157.10 ± 3.72
187	1192	ADULT	22	M	2	N.E.
188	1056	15-19 Y	13	F	3	N/A
189	1056	20-24 Y	14	M	2	N.E.
190	1063	5-7 Y	7	N/A	1	N/A
191	1056	NON-ADULT	23	N/A	1	N/A
192	1147	2-3 Y	4	N/A	1	N/A
193	1084	15-19 Y	13	N/A	1	N/A
194	1148	14-16 Y	13	N/A	1	N/A
195	1086	9-10 Y	11	N/A	1	N/A
196	1102	40-44 Y	18	F	3	162.45 ± 3.66
197	1173	6-7 Y	8	N/A	1	N/A
198	1156	7-8 Y	9	N/A	1	N/A
200	1163	35-39 Y	17	M	2	173.75 ± 3.27
201	1020	2-3 Y	4	N/A	1	N/A
202	1331	60+ Y	21	M	2	169.22 ± 3.27
203	1093	50-54 Y	20	M	2	170.65 ± 3.27
204	1092	17-20 Y	13	M	2	176.84 ± 3.27
205	1198	ADULT	22	M?	2	N.E.
206	1199	11-16 Y	12	N/A	1	N/A
207	1205	35-39 Y	17	M	2	171.60 ± 3.27
209	1207	45-49 Y	19	M	2	N.E.
210	1209	4-5 Y	6	N/A	1	N/A
211	1210	25-29 Y	15	F	3	N.E.
212	1213	24-29 Y	15	M	2	161.85 ± 3.27
213	1216	8-9 Y	10	N/A	1	N/A
214	1218	12-18 M	3	N/A	1	N/A
215	1222	40-44 Y	18	M	2	173.98 ± 3.27
216	1225	5-6 Y	7	N/A	1	N/A
217	1228	16-17 Y	13	F	3	150.56 ± 3.66
218	1237	10-14 Y	12	N/A	1	N/A
219	1246	ADULT	22	M	2	N.E.
220	1235	14-18 Y	13	N/A	1	N/A
221	1243	1-2 Y	3	N/A	1	N/A
222	1247	20-24 Y	14	M	2	169.33 ± 3.27
223	1250	45-55 Y	20	F	3	166.29 ± 3.57
224	1253	10-14 Y	12	N/A	1	N/A
225	1256	60+ Y	21	F	3	166.8 ± 3.66
226	1260	45-49 Y	19	F	3	151.91 ± 3.57
227	1262	20-24 Y	14	F	3	155.89 ± 4.24
228	1265	30-34 Y	16	M?	2	167.32 ± 3.27
229	1271	5-6 Y	7	N/A	1	N/A
230	1273	40-44 Y	18	M	2	177.94 ± 4.05
231	1274	6-7 Y	8	N/A	1	N/A
232	1277	ADULT	22	M	2	N.E.
233	1280	7-12 M	2	N/A	1	N/A
234	1283	10-14 Y	12	N/A	1	N/A
235	1289	4-5 Y	6	N/A	1	N/A
236	1290	12-14 M	2	N/A	1	N/A
237	1293	6-7 Y	8	N/A	1	N/A
238	1295	ADULT	22	F	3	N.E.
239	1299	20-24 Y	14	M?	2	N.E.
240	1300	5-6 Y	7	N/A	1	N/A
241	1297	2-3 Y	4	N/A	1	N/A
242	1303	ADULT	22	M	2	169.22 ± 3.27
243	1307	35-39 Y	17	F	3	N.E.
244	1294	45-49 Y	19	?F	3	156.97 ± 5.77
245	1312	8.5-13.5 Y	12	N/A	1	N/A
246	1319	35-39 Y	17	M	2	163.51 ± 3.27
247	1320	9-10 Y	11	N/A	1	N/A
248	1325	16-20 Y	13	F?	3	N.E.
249	1328	40-44 Y	18	F?	3	153.15 ± 3.72

SK #	Context	Age Range	Age Code	Sex	Sex Code	Stature (cm)
250	1330	30-34 Y	16	F?	3	159.59 ± 5.77
251	1334	6-7 Y	8	N/A	1	N/A
252	1340	35-39 Y	17	M	2	161.85 ± 3.27
253	1345	10-14 Y	12	N/A	1	N/A
254	1346	30-34 Y	16	F	3	151.91 ± 3.57
255	1354	8-9 Y	10	N/A	1	N/A
256	1358	45-49 Y	19	F	3	159.81 ± 4.30
257	1360	2-3 Y	4	N/A	1	N/A
258	1361	2.5-3 Y	4	N/A	1	N/A
259	1363	25-29 Y	15	M?	2	169.93 ± 4.05
260	1360	17-19 Y	13	M?	2	164.00 ± 3.27
261	1360	7-8 Y	9	N/A	1	N/A
262	1375	45-49 Y	19	F?	3	155.80 ± 5.77
263	1377	30-34 Y	16	F	3	156.30 ± 3.57
264	1379	2-3 Y	4	N/A	1	N/A
265	1389	16-20 Y	13	M	2	164.25 ± 3.27
266	1391	24-30 Y	15	M?	2	N.E.
267	1393	10-14 Y	12	N/A	1	N/A
268	1394	50-54 Y	20	F	3	152.57 ± 4.24
269	1397	20-24 Y	14	F	3	156.30 ± 3.57
270	1411	60+ Y	21	M	2	170.10 ± 3.27
271	1422	50-59 Y	20	M	2	170.89 ± 3.27
272	1425	6-7 Y	8	N/A	1	N/A
274	1429	55-59 Y	20	F	3	157.10 ± 3.72
275	1431	45-49 Y	19	M	2	166.55 ± 4.05
276	1437	ADULT	22	M	2	N.E.
277	1439	25-29 Y	15	F	3	N.E.
278	1441	16-20 Y	13	F	3	153.75 ± 3.66
279	1443	1-2 Y	3	N/A	1	N/A
280	1450	20-24 Y	14	M	2	166.84 ± 3.27
281	1456	4-5 Y	6	N/A	1	N/A
282	1460	ADULT	22	F	3	N.E.
283	1468	ADULT	22	F	3	N.E.
284	1470	ADULT	22	N.E.	4	N.E.
285	1472	ADULT	22	N.E.	4	N.E.
286	1485	40-44 Y	18	M	2	162.56 ± 3.27
287	1487	5-6 Y	7	N.A	1	N/A
288	1490	40-44 Y	18	M	2	168.51 ± 3.27
289	1492	38-40 W	1	N/A	1	N/A
290	1494	38-40 W	1	N/A	1	N/A
291	1499	ADULT	22	M	2	N.E.
292	1503	50-55 Y	20	M	2	178.27 ± 3.27
293	1506	35-39 Y	17	F	3	156.10 ± 5.77
294	1508	2-3 Y	4	N/A	1	N/A
295	1511	30-34 Y	16	M	2	169.46 ± 3.27
296	1515	40-44 Y	18	F	3	157.43 ± 4.45
297	1517	36.6-54.4 Y	18	M	2	N.E.
298	1523	40-44 Y	18	M	2	170.65 ± 3.27
299	1525	8-9 Y	10	N/A	1	N/A
300	1531	4-5 Y	6	N/A	1	N/A
301	1534	ADULT	22	M	2	171.37 ± 3.27
302	1537	11-12 Y	12	N/A	1	N/A
303	1541	50+ Y	20	M	2	N.E.
304	1543	20-24 Y	14	F	3	
305	1545	30-34 Y	16	M	2	N.E.
306	1547	40-44 Y	18	F	3	143.61 ± 3.66
307	1549	9-10 Y	11	N/A	1	N/A
308	1566	11-12 Y	12	N/A	1	N/A
309	1569	35-39 Y	17	F	3	N.E.
310	1568	45-49 Y	19	M	2	173.27 ± 3.27
311	1572	25-29 Y	15	M	2	
312	1575	ADULT	22	F	3	N.E.
313	1578	50-54 Y	20	F	3	
314	1582	ADULT	22	F	3	N.E.
315	1584	25-29 Y	16	M	2	166.34 ± 3.27
316	1587	ADULT	22	M	2	N.E.
317	1592	1-2 Y	3	N/A	1	N/A

SK #	Context	Age Range	Age Code	Sex	Sex Code	Stature (cm)
318	1595	45-49 Y	19	M	2	168.27 ± 3.27
319	1606	45-49 Y	19	F	3	N.E.
320	1608	12-14 Y	12	N/A	1	N/A
321	1614	ADULT	22	F	3	162.74 ± 3.66
322	1616	15-19 Y	13	F	3	N/A
323	1618	55-59 Y	20	M	2	
324	1621	50-54 Y	20	F	3	N.E.
325	1625	ADULT	22	F	3	
326	1626	2.5-3 Y	4	N/A	1	N/A
327	1628	4-5 Y	6	N/A	1	N/A
328	1637	40-44 Y	18	M	2	168.75 ± 3.27
329	1642	10-14 Y	12	N/A	1	N/A
330	1644	45-49 Y	19	F	3	N.E.
331	1646	30-34 Y	16	F	3	157.43 ± 4.45
332	1616	10-12.5 Y	12	N/A	1	N/A
333	1652	ADULT	22	F	3	N.E.
333.1	1652	4-5 Y	6	N/A	1	N/A
334	1653	50-59 Y	20	M	2	N.E.
335	1655	9-10 Y	11	N/A	1	N/A
336	1661	45-49 Y	19	M	2	165.18 ± 3.27
337	1668	45-49 Y	19	F	3	155.86 ± 3.72
338	1673	ADULT	22	F	3	N.E.
339	1675	25-29 Y	15	M	2	173.63 ± 4.05
340	1683	40-44 Y	18	F	3	169.70 ± 3.66
341	1687	40-44 Y	18	M	2	168.60 ± 4.32
342	1692	ADULT	22	M	2	N.E.
343	1692	35-39 Y	17	M	2	172.32 ± 3.27
344	1696	35-39 Y	17	F	3	156.65 ± 3.66
345	1699	1-2 Y	3	N/A	1	N/A
346	1700	40-44 Y	18	M	2	165.42 ± 3.27
347	1703	ADULT	22	M	2	N.E.
348	1704	ADULT	22	M	2	N.E.
349	1710	NON-ADULT	23	N/A	1	N/A
350	1710	<12 Y	23	N/A	1	N/A
351	1710	2-2.5 Y	4	N/A	1	N/A
352	1715	39.4-57.8 Y	19	M	2	N.E.
353	1718	6-7 Y	8	N/A	1	N/A
354	1721	45-49 Y	19	M	2	172.71 ± 4.05
355	1723	ADULT	22	F	3	N.E.
356	1724	50-55 Y	20	M	2	N.E.
357	1727	ADULT	22	N.E.	4	N.E.
358	1728	35-39 Y	17	F	3	159.21 ± 4.24
359	1731	ADULT	22	N.E.	4	N.E.
360	1733	ADULT	22	M	2	N.E.
361	1738	NON-ADULT	23	N/A	1	N/A
362	1740	7-8 Y	9	N/A	1	N/A
363	1742	4-5 Y	6	N/A	1	N/A
364	1744	5-6 Y	7	N/A	1	N/A
365	1746	ADULT	22	M	2	N.E.
366	1746	15-19 Y	13	F	3	155.42 ± 3.57
367	1740	NON-ADULT	23	N/A	1	N/A
368	1752	45-49 Y	19	F	3	N.E.
369	1756	30-34 Y	16	F	3	N.E.
370	1758	10-12 Y	12	N/A	1	N/A
371	1760	45-49 Y	19	M	2	N.E.
372	1781	50-59 Y	20	M	2	171.13 ± 3.27
373	1784	4-5 Y	6	N/A	1	N/A
374	1787	20-24 Y	14	F	3	N.E.
375	1789	50-59 Y	21	M	2	169.46 ± 3.27
376	1791	35-39 Y	17	F	3	N.E.
377	1793	30-34 Y	16	F	3	162.13 ± 4.45
378	1798	ADULT	22	F	3	N.E.
379	1801	ADULT	22	M	2	N.E.
380	1802	20-24 Y	14	F	3	160.13 ± 3.66
381	1807	40-45 Y	18	M	2	159.47 ± 3.27
382	1809	35-39 Y	17	F	3	N.E.
383	1812	40-50 Y	19	F	3	N.E.

SK #	Context	Age Range	Age Code	Sex	Sex Code	Stature (cm)
384	1812	ADULT	22	M	2	N.E.
385	1702	ADULT	22	N.E.	4	N.E.
386	1812	30-34 Y	16	M	2	170.65 ± 3.27
387	1816	ADULT	22	N.E.	4	N.E.
388	1819	5-6 Y	7	N/A	1	N/A
389	1821	11-18 Y	22	N/A	1	N/A
390	1823	5-7 Y	8	N/A	1	N/A
390.1	1823	5-18 Y	22	N/A	1	N/A
391	1824	16-20 Y	13	F	3	N.E.
392	1878	45-49 Y	19	F	3	157.23 ± 3.66
393	1827	3-4 Y	5	N/A	1	N/A
394	1833	7-8 Y	9	N/A	1	N/A
395	1835	35-39 Y	17	F	3	152.30 ± 3.66
396	1891	30-34 Y	16	F	3	N.E.
397	1842	35-40 Y	17	N.E.	4	N.E.
398	1844	3-4 Y	5	N/A	1	N/A
399	1847	2-3 Y	4	N/A	1	N/A
400	1850	5-6 Y	7	N/A	1	N/A
401	1855	1-2 Y	3	N.A	1	N/A
402	1856	ADULT	22	F	3	159.26 ± 3.66
403	1858	40-44 Y	18	F	3	165.03 ± 3.66
404	1861	ADULT	22	M	2	169.70 ± 3.27
405	1864	ADULT	22	N.E	4	158.94 ± 3.57
406	1869	35-50 Y	17	F	3	N.E.
407	1870	5-7 Y	7	N/A	1	N/A
408	1872	ADULT	22	M	2	N.E.
409	1890	ADULT	22	M	2	N.E.
410	1875	NON-ADULT	23	N/A	1	N/A
411	1877	24-29 Y	15	F	3	N.E.
412	1883	ADULT	22	F	3	N.E.
413	1875	5-6 Y	7	N/A	1	N/A
414	1883	15-19 Y	13	F	3	N.E.
416	1892	35-39 Y	17	M	2	171.60 ± 3.27
417	1893	50-59 Y	20	F	3	N.E.
418	1896	ADULT	22	M?	2	N.E.
419	1901	60+ Y	21	M	2	165.89 ± 3.27
420	1906	50-59 Y	20	F	3	175.87 ± 3.72
421	1909	ADULT	22	N.E.	4	N.E.
422	1912	50-59 Y	20	M	2	N.E.
423	1916	ADULT	22	M	2	N.E.
424	1915	ADULT	22	M	2	N.E.
425	1918	60+ Y	21	F	3	163.61 ± 3.66
426	1920	25-29 Y	15	N.E.	4	N.E.
427	1942	ADULT	22	M	2	N.E.
428	1926	40-44 Y	18	F	3	163.32 ± 3.66
429	1928	12-18 M	3	N/A	1	N/A
430	1930	ADULT	22	M?	2	171.13 ± 3.27
431	1933	3-6 M	2	N/A	1	N/A
432	1937	40-50 Y	18	M?	2	N.E.
433	1938	ADULT	22	N.E.	4	N.E.
434	1939	ADULT	22	N.E.	4	N.E.
435	1940	35-39 Y	17	M	2	N.E.
436	1943	40-44 Y	18	M	2	166.13 ± 3.27
437	1945	6-7 Y	8	N/A	1	N/A
438	1947	25-29 Y	15	M	2	172.79 ± 3.27
439	1951	1-2 Y	3	N/A	1	N/A
440	1953	4-5 Y	6	N/A	1	N/A
441	1954	3-4 Y	5	N/A	1	N/A
442	1956	45-49 Y	19	F?	3	162.45 ± 3.57
443	1959	40-44 Y	18	M	2	N.E.
444	1961	17-19 Y	13	F	3	152.03 ± 4.45
445	1962	ADULT	22	F?	3	N.E.
446	1964	8-9 Y	10	N/A	1	N/A
447	1965	35-39 Y	17	M?	2	N.E.
448	1974	20-24 Y	14	F	3	156.07 ± 3.66
449	1976	50-60 Y	20	M	2	173.95 ± 4.32
450	1980	30-34 Y	16	M?	2	174.55 ± 4.05

SK #	Context	Age Range	Age Code	Sex	Sex Code	Stature (cm)
451	1981	6-7 Y	8	N/A	1	N/A
452	1983	<40 WPN	1	N/A	1	N/A
453	1986	ADULT	22	F?	3	N.E.
454	1990	10-14 Y	12	N/A	1	N/A
455	1997	NON-ADULT	23	N/A	1	N/A
456	2000	8-9 Y	10	N/A	1	N/A
457	2003	35-39 Y	17	F?	3	171.54 ± 4.45
458	2005	30-34 Y	16	F?	3	155.20 ± 3.66
459	2012	ADULT	22	N.E.	4	N.E.
460	2014	45-49 Y	19	M	2	173.03 ± 3.27
461	2016	ADULT	22	N.E.	4	Sex dependent
462	2017	9.5-12.5 Y	12	N/A	1	N/A
463	2023	45-49 Y	19	M	2	167.32 ± 3.27
464	2026	6-7 Y	8	N/A	1	N/A
465	2028	6-12 M	2	N/A	1	N/A
466	2030	<3 Y	23	N/A	1	N/A
467	2031	ADULT	22	N.E.	4	N.E.
468	2038	6-7 Y	8	N/A	1	N/A
469	2044	ADULT	22	M?	2	N.E.
470	2046	ADULT	22	F?	3	N.E.
471	2043	<3 Y	23	N/A	1	N/A
472	2048	2-3 Y	4	N/A	1	N/A
473	2052	35-39 Y	17	M	2	160.89 ± 3.27
474	2053	3-4 Y	5	N/A	1	N/A
475	2055	2-3 Y	4	N/A	1	N/A
476	2059	16-20 Y	13	F	3	N/A
477	2062	NON-ADULT	23	N/A	1	N/A
478	2065	6-8 Y	8	N/A	1	N/A
479	2071	20-24 Y	14	M	2	162.56 ± 3.27
480	2073	40-45 Y	18	F	3	N.E.
481	2075	30-34 Y	16	M	2	165.89 ± 3.27
482	2077	60+ Y	21	F	3	153.46 ± 3.66
483	2079	40-44 Y	18	M	2	168.27 ± 3.27
484	2081	35-39 Y	17	M	2	171.11 ± 4.05
485	2086	30-34 Y	16	F	3	158.06 ± 3.57
486	2088	5-6 Y	7	N/A	1	N/A
487	2091	20-24 Y	14	F	3	157.23 ± 3.66
488	2095	12-14 Y	12	N/A	1	N/A
489	2101	2-3 Y	4	N/A	1	N/A
490	2103	50-59 Y	21	F	3	156.30 ± 3.57
491	2107	12-14 Y	12	N/A	1	N/A
492	2109	30-34 Y	16	?F	3	169.12 ± 3.66
493	2114	ADULT	22	N.E.	4	N.E.
494	2119	3-4 Y	5	N/A	1	N/A
495	2120	50-59 Y	20	M?	2	N/A
496	2121	35-39 Y	17	M	2	175.65 ± 3.27
497	2125	50-55 Y	20	M	2	181.60 ± 3.27
498	2126	19-23 Y	14	F	3	159.55 ± 3.66
499	2127	ADULT	22	M	2	frag fem
500	2129	3-4 Y	5	N/A	1	N/A
501	2131	4-5 Y	6	N/A	1	N/A
502	2134	ADULT	22	M?	2	N.E.
503	2136	ADULT	22	M?	2	168.97 ± 4.32
504	2140	1.5-3 M	2	N/A	1	N/A
505	2141	50-59 Y	20	M	2	N.E.
506	2144	30-34 Y	16	F	3	frag fem
507	2146	35-39 Y	17	M	2	164.46 ± 3.27
508	2150	30-34 Y	16	F	3	165.64 ± 3.66
509	2153	12-13 Y	12	N/A	1	N/A
510	2156	40-44 Y	18	M	2	N.E.
511	2158	ADULT	22	N.E.	4	N.E.
512	2168	1.5-2 Y	3	N/A	1	N/A
513	2156	40-44 Y	18	M	2	N.E.
514	2173	4-5 Y	6	N/A	1	N/A
515	2178	35-39 Y	17	M	2	168.70 ± 4.05
516	2182	18-19 Y	13	M	1	178.16 ± 3.37
517	2084	2-3 Y	4	N/A	1	N/A

SK #	Context	Age Range	Age Code	Sex	Sex Code	Stature (cm)
518	2186	6-12 M	2	N/A	1	N/A
519	2189	30-34 Y	16	F	3	153.37 ± 3.57
520	2198	8-9 Y	10	N/A	1	N/A
521	2200	35-40 Y	17	F	3	156.08 ± 4.45
522	2207	40-44 Y	18	M	2	frag fem
523	2204	ADULT	22	F	3	N.E.
524	2206	18-20 Y	13	F	2	156.94 ± 3.66
525	2208	5-6 Y	7	N/A	1	N/A
526	2218	45-49 Y	19	F	3	157.44 ± 3.66
527	2220	0-1 Y	2	N/A	1	N/A
528	2222	2-3 Y	4	N/A	1	N/A
529	2224	4-5 Y	6	N/A	1	N/A
530	2226	9-10 Y	11	N/A	1	N/A
531	2228	40-44 Y	18	M	2	173.75 ± 3.27
532	2230	ADULT	22	?M	2	N.E.
533	2232	3-4 Y	5	N/A	1	N/A
534	2234	2-3 Y	4	N/A	1	N/A
535	2235	35-39 Y	17	M	2	169.94 ± 3.27
536	2238	30-34 Y	16	F	3	151.03 ± 3.57
537	2240	30-34 Y	16	M	2	155.66 ± 3.27
538	2242	25-29 Y	15	M	2	167.08 ± 3.27
539	2244	30-34 Y	16	M	2	169.70 ± 3.27
540	2246	6-12 M	2	N/A	1	N/A
541	2248	2-3 Y	4	N/A	1	N/A
542	2250	5-6 Y	7	N/A	1	N/A
543	2252	ADULT	22	N.E.	4	N.E.
544	2254	7-8 Y	9	N/A	1	N/A
545	2257	20-24 Y	14	?F	3	N.E.
546	2259	16-19 Y	13	F	3	159.52 ± 3.57
547	2261	6-12 M	2	N/A	1	N/A
548	2264	40-44 Y	18	F	3	162.16 ± 3.66
549	2270	2-3 Y	4	N/A	1	N/A
550	2282	36-38 WPN	1	N/A	1	N/A
551	2285	16-20 Y	13	F	3	N.E.
552	2290	ADULT	22	?M	2	N.E.
553	2294	40-44 Y	18	M	2	165.42 ± 3.27
554	2296	6-7 Y	8	N/A	1	N/A
555	2298	25-29 Y	15	F	3	156.59 ± 3.57
556	2300	10-11 Y	12	N/A	1	N/A
557	2302	ADULT	22	N.E.	4	N.E.
558	2306	40-50 Y	18	?M	2	N.E.
559	2310	40-44 Y	18	M	2	157.09 ± 3.27
560	2312	24-30 Y	15	?F	3	N/A
561	2316	5-6 Y	7	N/A	1	N/A
562	2318	ADULT	22	N.E.	4	N.E.
563	2321	35-40 Y	17	?M	2	N.E.
564	2323	40-44 Y	18	M	2	174.70 ± 3.27
565	2325	6-7 Y	8	N/A	1	N/A
566	2342	45-49 Y	19	M	2	169.94 ± 3.27
567	2354	12-13 Y	12	N/A	1	N/A
568	2358	5-6 Y	7	N/A	1	N/A
569	2361	45-49 Y	19	F	3	N.E.
570	2363	45-49 Y	19	?F	3	N.E.
571	2365	35-39 Y	17	F	3	164.51 ± 3.72
572	2372	40-50 Y	22	?F	3	N.E.
573	2376	ADULT	22	?M	2	N.E.
574	2378	ADULT	22	N.E.	4	173.88 ± 3.37
575	2380	0-6 M	2	N/A	1	N/A
576	2381	50-59 Y	20	F	3	151.91 ± 3.72
577	2385	6-7 Y	8	N/A	1	N/A
578	2388	30-34 Y	16	M	2	166.13 ± 3.27
580	2395	50-59 Y	20	?F	3	161.11 ± 4.24
581	2397	10-14 Y	12	N/A	1	N/A
582	2400	6-7 Y	8	N/A	1	N/A
583	2403	7-8 Y	9	N/A	1	N/A
584	2406	7-8 Y	9	N/A	1	N/A
585	2408	30-34 Y	16	M	2	172.56 ± 3.27

SK #	Context	Age Range	Age Code	Sex	Sex Code	Stature (cm)
586	2413	40-44 Y	18	?M	2	168.03 ± 3.27
587	2418	50-59 Y	20	F	3	162.45 ± 3.57
588	2424	5-6 Y	7	N/A	1	N/A
589	2426	30-34 Y	16	M	2	174.46 ± 3.27
590	2437	ADULT	22	N.E.	4	N.E.
591	2441	2-3 Y	4	N/A	1	N/A
592	2443	45-49 Y	19	M	2	N.E.
593	2445	10-12 Y	12	N/A	1	N/A
594	2448	14-16 Y	13	N/A	1	N/A
595	2403	2-3 Y	4	N/A	1	N/A
596	2453	35-39 Y	17	F	3	162.53 ± 4.24
597	2454	35-45 Y	22	?M	2	N.E.
598	2457	ADULT	22	?M	2	N.E.
599	2459	45-49 Y	19	F	3	163.03 ± 3.66
600	2101	NON-ADULT	23	N/A	1	N/A
601	2463	25-29 Y	15	M	2	168.51 ± 3.27
602	2463	3-4 Y	5	N/A	1	N/A
603	2467	35-39 Y	17	M	2	174.88 ± 3.37
604	2469	5-6 Y	7	N/A	1	N/A
605	2471	45-49 Y	19	F	3	N.E.
606	2473	10-14 Y	12	N/A	1	N/A
607	2475	3-4 Y	5	N/A	1	N/A
608	2477	ADULT	22	?F	3	N.E.
609	2481	45-49 Y	19	?F	3	166.51 ± 3.66
610	2456	8.5-13.5 Y	12	N/A	1	N/A
611	2490	20-22 Y	14	F	3	167.67 ± 3.66
612	2492	30-34 Y	16	F	3	N.E.
613	2494	ADULT	22	N.E.	4	N.E.
614	2496	3-4 Y	5	N/A	1	N/A
615	2498	45-49 Y	19	F	3	N.E.
616	2500	50-59 Y	20	M	2	N.E.
617	2502	20-24 Y	14	M	2	170.65 ± 3.27
620	2510	45-49 Y	19	M	2	N.E.
621	2513	30-34 Y	16	M	2	168.75 ± 3.27
622	2515	20-24 Y	14	F	3	160.70 ± 3.57
623	2521	35-39 Y	17	M	2	181.12 ± 3.27
624	2523	20-24 Y	14	F	3	156.59 ± 3.57
625	2526	2-3 Y	4	N/A	1	N/A
626	2532	2-3 Y	4	N/A	1	N/A
627	2534	40-44 Y	18	M	2	180.41 ± 3.27
628	2536	30-34 Y	16	M	2	172.56 ± 3.27
629	2542	4-5 Y	6	N/A	1	N/A
630	2544	30-34 Y	16	M	2	N.E.
631	2547	8-9 Y	10	N/A	1	N/A
632	2546	15-30 Y	22	?F	3	N.E.
633	2546	ADULT	22	?F	3	N.E.
634	2556	30-34 Y	16	N.E.	4	N.E.
635	2557	2.5-3 Y	4	N/A	1	N/A
636	2559	5-6 Y	7	N/A	1	N/A
637	2563	25-29 Y	15	F	3	154.91 ± 3.66
638	2565	4-5 Y	6	N/A	1	N/A
639	2567	35-39 Y	17	M	2	N.E.
640	2571	12-13 Y	12	N/A	1	N/A
641	2544	30-34	16	M	2	171.60 ± 3.27
642	2578	5-6 Y	7	N/A	1	N/A
643	2581	24-29 Y	15	?F	3	N.E.
644	2583	12-16 M	3	N/A	1	N/A
645	2588	3-4 Y	5	N/A	1	N/A
646	2593	5-6 Y	7	N/A	1	N/A
647	2595	0-1 Y	2	N/A	1	N/A
648	2598	60+ Y	21	M	2	166.84 ± 3.27
649	2601	50-59 Y	20	M	2	168.51 ± 3.29
650	2603	10-14 Y	12	N/A	1	N/A
651	2609	30-35 Y	16	M	2	171.47 ± 4.05
652	2611	9-10 Y	11	N/A	1	N/A
653	2616	4-5 Y	6	N/A	1	N/A
654	2618	25-29 Y	15	M	2	165.42 ± 3.27

SK #	Context	Age Range	Age Code	Sex	Sex Code	Stature (cm)
655	2620	1-2 Y	3	N/A	1	N/A
656	2622	5-6 Y	7	N/A	1	N/A
657	2624	12-16 Y	13	?F	1	N/A
658	2629	45-49 Y	19	M	2	167.08 ± 3.27
659	2631	1-2 Y	3	N/A	1	N/A
660	2633	6-7 Y	8	N/A	1	N/A
661	2635	25-29 Y	15	F	3	167.97 ± 3.72
662	2638	0-1 Y	2	N/A	1	N/A
663	2640	ADULT	22	F	3	N.E.
664	2642	ADULT	22	N.E.	4	Sex Det.
665	2644	1-2 Y	3	N/A	1	N/A
666	2646	10-11 Y	12	N/A	1	N/A
667	2648	3-4 Y	5	N/A	1	N/A
668	2649	32-36 WPN	1	N/A	1	N/A
669	2655	8-12 M	2	N/A	1	N/A
670	2660	11-13.5 Y	12	N/A	1	N/A
671	2664	8.5-13.5 Y	12	N/A	1	N/A
672	2666	8.5-13.5 Y	12	N/A	1	N/A
673	2670	5-7 Y	8	N/A	1	N/A
674	2672	8-9 Y	10	N/A	1	N/A
675	2676	35-39 Y	17	F	3	163.03 ± 3.66
676	2678	6-12 M	2	N/A	1	N/A
677	2681	3-6 M	2	N/A	1	N/A
678	2685	35-39 Y	17	F	3	170.28 ± 3.66
679	2886	25-29 Y	15	F	3	156.94 ± 3.66
680	2690	5-6 Y	7	N/A	1	N/A
681	2691	25-29 Y	15	F	3	157.52 ± 3.66
682	2693	6-7 Y	8	N/A	1	N/A
683	2701	45-49 Y	19	M	2	N.E.
684	2705	35-39 Y	17	M	2	N.E.
685	2714	25-29 Y	15	F	3	152.20 ± 3.57
686	2716	30-34 Y	16	?M	2	N.E.
687	2718	8-9 Y	10	N/A	1	N/A
688	2720	30-34 Y	16	M	2	171.13 ± 3.27
689	2724	0-2 M	2	N/A	1	N/A
691	2732	20-23 Y	14	2	2	167.80 ± 3.27
692	2734	14-16 Y	13	M	1	N/A
693	2736	7-8 Y	9	N/A	1	N/A
694	2738	4-5 Y	6	N/A	1	N/A
695	2740	30-34 Y	16	M	2	171.60 ± 3.27
696	2742	30-34 Y	16	M	2	159.70 ± 3.27
697	2747	50-59 Y	20	M	2	165.89 ± 3.27
698	2754	40-44 Y	18	M	2	170.41 ± 3.27
699	2755	ADULT	22	?F	3	N.E.
700	2758	25-29 Y	15	M	2	173.03 ± 3.27
701	2760	16-20 Y	13	F	3	N.E.
702	2764	40-44 Y	18	M	2	176.13 ± 3.27
703	2768	8-9 Y	10	N/A	1	N/A
704	2772	4.5-5 Y	6	N/A	1	N/A
705	2774	17-19 Y	13	?M	2	N/A
706	2778	12-14 Y	12	N/A	1	N/A
707	2738	5-6 Y	7	N/A	1	N/A
708	2785	7-8 Y	9	N/A	1	N/A
709	2787	15-16 Y	13	N/A	1	N/A
710	2789	12-14 Y	12	N/A	1	
711	2792	35-39 Y	17	M	2	175.65 ± 3.27
712	2794	50-59 Y	20	F	3	161.57 ± 3.57
713	2790	ADULT	22	?M	2	N.E.
714	2799	36-38 W	1	N/A	1	N/A
715	2804	35-39 Y	17	F	3	160.71 ± 3.66
716	2806	11-14 Y	12	N/A	1	N/A
717	2808	4-5 Y	6	N/A	1	N/A
718	2810	6-8 Y	9	N/A	1	N/A
719	2813	40-44 Y	18	?M	2	171.47 ± 4.05
720	2815	12-14 Y	12	N/A	1	N/A
721	2818	ADULT	22	F	3	162.16 ± 3.66
722	2820	ADULT	22	F	3	147.68 ± 4.45

SK #	Context	Age Range	Age Code	Sex	Sex Code	Stature (cm)
723	2822	0-5 M	2	N/A	1	N/A
724	2828	11-12 Y	12	N/A	1	N/A
725	2830	ADULT	22	M	2	171.17 ± 4.05
726	2834	4-5 Y	6	N/A	1	N/A
727	2839	3-4 Y	5	N/A	1	N/A
728	2841	ADULT	22	N.E.	4	Sex Depend.
729	2843	18-24 M	3	N/A	1	N/A
730	2845	1-2 Y	3	N/A	1	N/A
732	2851	1.5-3 M	2	N/A	1	N/A
733	2854	60+ Y	21	F	3	N.E.
734	2857	24-30 Y	15	F	3	N.E.
735	2858	15-17.5 Y	13	N/A	1	N/A
736	2863	17-19 Y	13	M	2	164.78 ± 3.29
737	2866	35-39 Y	17	M	2	167.80 ± 3.27
738	2869	40-44 Y	18	F	3	156.89 ± 3.57
739	2872	20-22 Y	14	M	2	176.13 ± 3.27
740	2875	40-50 Y	19	M	2	N.E.
741	2880	0-1.5 M	2	N/A	1	N/A
742	2883	5-6 Y	7	N/A	1	N/A
743	2886	10-13.5 Y	12	N/A	1	N/A
744	2889	30-34 Y	16	M	2	167.08 ± 3.27
745	2891	ADULT	22	M	2	163.27 ± 3.27
746	2893	9-10 Y	11	N/A	1	N/A
747	2896	8-9 Y	10	N/A	1	N/A
748	2902	45-49 Y	19	F	3	154.10 ± 3.72
749	2904	ADULT	22	F	3	N.E.
750	2906	40-44 Y	18	F	3	154.54 ± 3.57
751	2909	8-9 Y	10	N/A	1	N/A
752	2912	50-59 Y	20	F	3	154.97 ± 3.57
753	2915	8-9 Y	10	N/A	1	N/A
755	2923	50-59 Y	20	F	3	165.79 ± 4.30
756	2928	35-39 Y	17	M	2	166.61 ± 3027
757	2931	ADULT	22	N.E.	4	sex dependent
758	2934	35-39 Y	17	?M	2	153.99 ± 3.27
760	2940	25-29 Y	15	F	3	151.61 ± 3.57
761	2941	ADULT	22	?F	3	158.10 ± 4.45
762	2945	30-34 Y	16	M	2	169.46 ± 3.27
763	2948	20-24 Y	14	F	3	156.30 ±3.57
764	2951	2-3 Y	4	N/A	1	N/A
765	2954	ADULT	22	M	2	N.E.
766	2957	ADULT	22	?F	3	N.E.
767	2960	5-6 Y	7	N/A	1	N/A
768	2963	0-3 M	2	N/A	1	N/A
769	2971	1-2 Y	3	N/A	1	N/A
770	2945	0-6 M	2	N/A	1	N/A
771	2974	~40 W	1	N/A	1	N/A
773	2976	16-18 Y	13	N/A	1	N/A
774	2977	11-12 Y	12	N/A	1	N/A
775	2980	18-20 Y	13	M	2	178.16 ± 3.37
776	2983	ADULT	22	F	3	N.E.
777	2985	18-24 M	3	N/A	1	N/A
778	2987	40-44 Y	18	F	3	158.58 ± 3.72
779	2990	6-7 Y	8	N/A	1	N/A
780	2992	7-8 Y	9	N/A	1	N/A
781	2994	5-6 Y	7	N.A	1	N/A
782	2997	35-39 Y	17	F	3	N.E.
783	2999	14-17 Y	13	?F	3	N.E.
784	3001	ADULT	22	N.E.	4	N.E.
785	3003	7-8 Y	9	N/A	1	N/A
786	3006	0-1 Y	2	N/A	1	N/A
787	3007	0-2 M	2	N/A	1	N/A
788	3014	4-5 Y	6	N/A	1	N/A
790	3021	0-1.5 M	2	N/A	1	N/A
791	3026	9-10 Y	11	N/A	1	N/A
793	3042	12-14 Y	12	N/A	1	N/A
793.1	3042	3-6 M	2	N/A	1	N/A
794	3034	15-16 Y	13	?M	2	171.61 ± 3.37

SK #	Context	Age Range	Age Code	Sex	Sex Code	Stature (cm)
795	3037	18-24 M	3	N/A	1	N/A
796	3040	1-2 Y	3	N/A	1	N/A
797	3044	45-49 Y	19	M	2	N.E.
798	3056	30-34 Y	16	F	3	156.87 ± 3.57
799	3057	18-22 Y	14	?F	3	N.E.
800	3060	4-5 Y	6	N/A	1	N/A
801	3063	2-3 Y	4	N/A	1	N/A
802	3073	35-39 WPN	1	N/A	1	N/A
803	3077	ADULT	22	?M	2	N.E.
804	3080	14-17 Y	13	?F	3	158.97 ± 3.66
805	3092	35-39 Y	17	M	2	175.17 ± 4.05
806	3095	4-5 Y	6	N/A	1	N/A
807	3098	1-2 Y	3	N/A	1	N/A
808	3105	16-18 Y	13	?M	2	N/A
809	3108	2-3 Y	4	N/A	1	N/A
810	3113	25-29 Y	15	M	2	167.80 ± 3.27
811	3117	ADULT	22	M	2	N.E.
812	3124	4-8 M	2	N/A	1	N/A
813	3127	ADULT	22	N.E.	4	N.E.
814	3132	4-8 M	2	N/A	1	N/A
815	3135	30-34 Y	16	?F	3	155.71 ± 3.57
816	3138	38 WPN-2M	2	N/A	1	N/A
817	3143	4-5 Y	6	N/A	1	N/A
818	3146	40-44 Y	18	?M	2	178.27 ± 3.27
819	3149	CHILD	23	N/A	1	N/A
820	3156	5-6 Y	7	N/A	1	N/A
821	3159	2-3 Y	4	N/A	1	N/A
822	3162	40-44 Y	18	M	2	170.18 ± 3.27
823	3165	10-11 Y	12	N/A	1	N/A
824	3168	1-2 Y	3	N/A	1	N/A
825	3171	16-19 Y	13	?M	2	N/A
827	3141	ADULT	22	?M	2	N.E.
828	3141	ADULT	22	?F	3	N.E.
829	3141	35-40 Y	17	F	3	N.E.
830	3141	ADULT	22	?F	3	N.E.
832	3186	ADULT	22	?F	3	frag fem
833	3189	6-12 M	2	N/A	1	N/A
834	3192	2-3 Y	4	N/A	1	N/A
835	3195	45-49 Y	19	F	3	156.89 ± 3.57
836	3198	5-6 Y	7	N/A	3	N/A

Standard life table for Poulton Chapel – articulated burials only.

Age x	Individuals dx	Survivorship lx	% of Deaths	Radix (10,000) l'x	Radix (1) l"x	Mortality Qx	Person Years Lx	Person Years Left Tx	Expectation of Life ex
0	125	534	23.41	33585	1.00	0.23	148270.44	756761.01	22.53
5	87	409	16.29	25723	0.77	0.21	114937.11	608490.57	23.66
10	38	322	7.12	20252	0.60	0.12	95283.02	493553.46	24.37
15	30	284	5.62	17862	0.53	0.11	84591.19	398270.44	22.30
20	20	254	3.75	15975	0.48	0.08	76729.56	313679.25	19.64
25	26	234	4.87	14717	0.44	0.11	69496.86	236949.69	16.10
30	42	208	7.87	13082	0.39	0.20	58805.03	167452.83	12.80
35	49	166	9.18	10440	0.31	0.30	44496.86	108647.80	10.41
40	45	117	8.43	7358	0.22	0.38	29716.98	64150.94	8.72
45	35	72	6.55	4528	0.13	0.49	17138.36	34433.96	7.60
50	28	37	5.24	2327	0.07	0.76	14465.41	17295.60	7.43
60	9	9	1.69	566	0.02	1.00	2830.19	2830.19	5.00
Sum	**534**						**756761.01**		

Expanded life table for Poulton Chapel – articulated burials only.

Age x	Individuals dx	Survivorship lx	% of Deaths	Radix (10,000) l'x	Radix (1) l"x	Mortality Qx	Person Years Lx	Person Years Left Tx	Expectation of Life ex
0	33	534	6.18	10000	1.00	0.06	9691.01	224073.03	22.41
1	22	501	4.12	9382	0.94	0.04	9176.03	214382.02	22.85
2	31	479	5.81	8970	0.90	0.06	8679.78	205205.99	22.88
3	15	448	2.81	8390	0.84	0.03	8249.06	196526.22	23.43
4	24	433	4.49	8109	0.81	0.06	7883.90	188277.15	23.22
5	27	409	5.06	7659	0.77	0.07	7406.37	180393.26	23.55
6	20	382	3.75	7154	0.72	0.05	6966.29	172986.89	24.18
7	17	362	3.18	6779	0.68	0.05	6619.85	166020.60	24.49
8	14	345	2.62	6461	0.65	0.04	6329.59	159400.75	24.67
9	9	331	1.69	6199	0.62	0.03	6114.23	153071.16	24.69
10	38	322	7.12	6030	0.60	0.12	28370.79	146956.93	24.37
15	30	284	5.62	5318	0.53	0.11	25187.27	118586.14	22.30
20	20	254	3.75	4757	0.48	0.08	22846.44	93398.88	19.64
25	26	234	4.87	4382	0.44	0.11	20692.88	70552.43	16.10
30	42	208	7.87	3895	0.39	0.20	17509.36	49859.55	12.80
35	49	166	9.18	3109	0.31	0.30	13249.06	32350.19	10.41
40	45	117	8.43	2191	0.22	0.38	8848.31	19101.12	8.72
45	35	72	6.55	1348	0.13	0.49	5103.00	10252.81	7.60
50	28	37	5.24	693	0.07	0.76	4307.12	5149.81	7.43
60	9	9	1.69	169	0.02	1.00	842.70	842.70	5.00
Sum	**534**						**224073.03**		

Reduced life table for Poulton Chapel – articulated burials only

Age x	Individuals dx	Survivorship lx	% of deaths	Radix (10,000) l'x	Radix (1) l''x	Mortality Qx	Person Years Lx	Person Years Left Tx	Expectation of Life ex
0	125	534	23.33	10000.00	1.00	0.23	44147.94	226029.96	22.60
5	87	409	15.93	7659.18	0.77	0.21	34222.85	181882.02	23.75
10	38	322	6.85	6029.96	0.60	0.12	28370.79	147659.18	24.49
15	50	284	9.44	5318.35	0.53	0.18	48501.87	119288.39	22.43
25	162	234	30.37	4382.02	0.44	0.69	57303.37	70786.52	16.15
45	63	72	12.59	1348.31	0.13	0.88	13483.15	13483.15	10.00
65	9	0	1.48	0.00	0.00	0.00	0.00	0.00	0.00
Sum	**534**						**226029.96**		

A4. Greyfriars Chester

Ministry of Justice Licence for the Removal of Human Remains

LICENCE FOR THE REMOVAL OF HUMAN REMAINS

The Secretary of State, in exercise of the power vested in him by section 25 of the Burial Act 1857 (20 & 21 Vic., cap.81), grants a licence for the removal of the remains of **persons unknown** from or within the place in which they are now interred at **Linenhall Stables, Stanley Street, Chester, Cheshire.**

2. It is a condition of this licence that the following precautions shall be observed:

   (a) Any removal or disturbance of the remains shall be effected with due care and attention to decency;

   (b) The ground in which the remains are interred shall be screened from the public gaze while the work is in progress;

   (c) The remains shall, no later than **31 August 2017**, be reinterred in a burial ground in which interments may legally take place. In the meantime shall be kept safely, privately and decently by Nexus Heritage under the control of a competent member of staff.

3. This licence merely exempts those from the penalties, which would be incurred if the removal took place without a licence. It does not in any way alter civil rights. It does not confer the right to bury the remains in any place where such right does not already exist.

4. This licence expires on **31 August 2017.**

Rekha Gohil
on behalf of the Secretary of State for Justice

Ministry of Justice

Licence Number: **15-0256**
File Number: **OPR/072/133**
Date: **16 September 2015**

Skeletal collection summary

SK #	Context	Age Range	Age Code	Sex	Sex Code	Stature (cm)
001	320	45-49 Y	19	M	2	163.54 ± 3.37
002	321	45-49 Y	19	F	3	149.85 ±3.57
003	367	45-49 Y	19	M	2	171.84 ± 3.27
004	322	30-34 Y	16	M	2	172.08 ± 3.27
005	323	20-22 Y	14	F	3	154.75 ± 6.67
006	370	40-44 Y	18	M	2	163.04 ± 3.27
007	324	0-3 M	2	N/A	1	N/A
008	328	7-8 Y	9	N/A	1	N/A
009	331	3-4 Y	5	N/A	1	N/A
010	332	45-49 Y	19	M	2	173.13 ± 4.32
011	335	50-59 Y	20	F	3	N.E.
012	336	2-3 Y	4	N/A	1	N/A
013	392	7-8 Y	9	N/A	1	N/A
014	373	30-35 Y	16	?M	2	N.E.
015	398	30-34 Y	16	F	3	165.35 ± 3.66
016	375	60+ Y	21	F	3	157.81 ± 3.66
017	378	Young Adult	22	F	3	143.12 ± 3.57
018	382	50-59 Y	20	F	3	150.09 ± 7.16
019	384	35-39 Y	17	F	3	147.96 ± 3.72
020	388	ADULT	22	?M	2	172.96 ± 3.27

Craniometric measurements taken

MS1	maximum length of the neural skull
MS3	glabella-lambda length
MS5	cranial base length
MS7	foramen magnum length
MS8	maximum neurocranial breadth
MS10	maximum frontal breadth
MS11	biauricular breadth
MS12	biasterionic diameter
MS16	formen magnum breadth
MS17	basion-bregma height
MS20	porion-bregma height
MS23a	horizontal cranial circumference above ophyron
MS26	nasion-bregma arch
MS28	lambda-opisthion
MS29	occipital arch
MS30	bregma-lambda chord
MS31	lambda- opisthion chord
MS40	length of the face
MS43	upper facial breadth
MS46	maximum bimaxillary breadth of the face
MS48	height of the upper face
MS44	biorbital breadth
MS50	interorbital breadth
MS52	orbital height
MS54	nasal breadth
MS55	nasal height
MS60	maxillo-alveolar length
MS63	palate breadth
MS66	bigoniac breadth
MS67	bimental breadth
MS68.1	projected length of the mandible
MS69	symphyseal height of the chin
MS69.3	thickness of the corpus mandible
MS70	condylar height of the ramus
MS71	minimum ramus breadth referred to the height
MS79	mandibular angle

A5. St Owen Church collection

Skeletal collection summary

Key to St Owens excavation years:

Blue	1983 excavation
Green	1989 excavation

SK #	Age Range	Age Code	Sex	Sex Code	Stature (cm)
IV568a	ADULT	22	?F	3	N.E.
IV568b	30-35 Y	16	M	2	N.E.
IV576	45-49 Y	19	?M	2	N.E.
1033	40-44 Y	18	F?	3	N.E.
1036	2-3 Y	4	N/A	1	N/A
1040	6-7 Y	8	N/A	1	N/A
1055	30-34 Y	16	F	3	157.59 ± 3.72
1056	40-44 Y	18	F	3	161.29 ± 3.66
1062	35-39 Y	17	M	2	171.37 ± 3.27
1065	50-59 Y	20	f	3	159.08 ± 3.72
1068	40-44 Y	18	F	3	153.89 ± 3.72
1069	40-44 Y	18	M	2	N.E.
1072	40-44 Y	18	F	3	N.E.
1075	4-5 Y	6	N/A	1	N/A
1079	20-24 Y	14	F	3	158.94 ± 3.57
1087	35-39 Y	17	F	3	N.E.
1096	ADULT	22	F	3	N.E.
1102	4-5 Y	6	N/A	1	N/A
1108	4-5 Y	6	N/A	1	N/A
1111	3-4 Y	5	N/A	1	N/A
1118	17-19 Y	13	M	2	177.67 ± 4.32
1118	60+ Y	21	M	2	176.13 ± 3.27
1122	40-44 Y	18	M	2	173.51 ± 3.27
1124	40-44 Y	18	F	3	162.53 ± 4.24
1127	10-14 Y	12	N/A	1	N/A
1133	40-44 Y	18	M	2	163.04 ± 3.27
1136	4-5 Y	6	N/A	1	N/A
1139	35-39 Y	17	F	3	152.57 ± 4.24
1142	35-39 Y	17	F	3	154.94 ± 4.24
1142	40-44 Y	18	M	2	N.E.
1144	35-39 Y	17	M	2	175.89 ± 3.27
1146	4-5 Y	6	N/A	1	N/A
1149	25-29 Y	15	M	2	N.E.
1152	4-5 Y	6	N/A	1	N/A
1155	30-34 Y	16	F	3	N.E.
1156	ADULT	22	M	2	N.E.
1157	30-34 Y	16	F	3	161.11 ± 4.24
1160	35-39 Y	17	M	2	167.80 ± 3.27
1165	2-3 Y	4	N/A	1	N/A
1170	30-34 Y	16	F	3	160.63 ± 4.24
1173	40-44 Y	18	M	2	167.46 ± 4.32
1176	25-29 Y	15	F	3	145.46 ± 3.57
1179	25-29 Y	15	M	2	N.E.
1180	ADULT	22	N.E.	4	N.E.
1185	ADULT	22	F	3	154.94 ± 4.24
1188	7-8 Y	9	N/A	1	N/A
1191	2-3 Y	4	N/A	1	N/A
1194	2-3 Y	4	N/A	1	N/A
1197	12-14 Y	13	N/A	1	N/A
1199	<40 W	1	N/A	1	N/A
1201	5-6 Y	7	N/A	1	N/A
1205	9-10 Y	11	N/A	1	N/A
1208	4-5 Y	6	N/A	1	N/A
1211	6-7 Y	`8	N/A	1	N/A
1214	30-34 Y	16	M	2	171.84 ±3.27

SK #	Age Range	Age Code	Sex	Sex Code	Stature (cm)
1217	4-5 Y	6	N/A	1	N/A
1221	10-11Y	12	N/A	1	N/A
1224	3-4 Y	5	N/A	1	N/A
1228	35-39 Y	17	M	2	170.41 ± 3.27
1230	30-34 Y	16	M	2	N.E.
1232	14-16 Y	13	N/A (M)	1	N/A
1235	30-34 Y	16	M	2	174.22 ± 3.27
1241	45-49 Y	19	M	2	N.E.
1244	0-3 M	2	N/A	1	N/A
1247	5-6 Y	7	N/A	1	N/A
1250	ADULT	22	?F	3	157.43 ± 4.45
1253	50-59 Y	20	M	2	N.E.
1256	18-24 M	3	N/A	1	N/A
1259	20-23 Y	14	M	2	178.98 ± 3.27
1265	40-44Y	18	F	3	N.E.
1268	ADULT	22	M	2	N.E.
1271	3-4 Y	5	N/A	1	N/A
1274	2-2.5 Y	4	N/A	1	N/A
1277	9-10 Y	11	N/A	1	N/A
1279	40-44 Y	18	F	3	148.98 ± 3.57
1282	45-49 Y	19	F	3	154.91 ± 3.66
1285	ADULT	22	N.E.	4	sex dependent
1288	20-24Y	14	F?	3	163.95 ± 4.24
1291	60+ Y	21	M?	2	175.41 ± 3.27
1294	1-2 Y	3	N/A	1	N/A
1297	ADULT	22	F?	3	152.49 ± 3.57
1300	2-3 Y	4	N/A	1	N/A
1303	17-19 Y	13	M	2	179.50 ± 4.32
1306	20-24 Y	14	M	2	173.94 ± 4.05
1309	ADULT	22	F?	2	159.55 ± 3.66
1312	45-49 Y	19	M	2	165.01 ± 4.05
1315	50-59 Y	20	M	2	161.29 ± 3.29
1318	40-44 Y	18	M	2	169.46 ± 3.27
1321	45-49 Y	19	F	3	N.E.
1324	5-6 Y	7	N/A	1	N/A
1327	8-9 Y	10	N/A	1	N/A
1330	60+ Y	21	M	2	174.94 ± 3.27
1333	45-49 Y	19	M	2	175.41 ± 3.27
1336	30-34 Y	16	M	2	N.E.
1339	20-24 Y	14	F?	3	160.63 ± 4.24
1342	ADULT	22	M	2	N.E.
1345	8-9 Y	10	N/A	1	N/A
1353	25-29 Y	15	F	3	N.E.
1354	20-24 Y	14	F	3	157.47 ± 3.57
1357	30-34 Y	16	F	3	168.25 ± 3.66
1360	ADULT	22	M?	2	171.47 ± 4.05
1363	ADULT	22	M	2	166.84 ± 3.27
1366	35-39 Y	17	M	2	N.E.
1369	45-49 Y	19	F	3	160.70 ± 3.57
1375	8-9 Y	10	N/A	1	N/A
1381	2-3 Y	4	N/A	1	N/A
1387	30-34 Y	16	F	3	152.59 ± 3.66
1393	13-14 Y	12	N/A	1	N/A
1396	ADULT	22	M?	2	161.13 ± 3.27
1402	7-8 Y	9	N/A	1	N/A
1405	11-12 Y	12	N/A	1	N/A
1408	5-6 Y	7	N/A	1	N/A
1411	54-64 Y	21	M?	2	174.27 ± 4.32
1416	30-34 Y	16	M	2	170.18 ± 3.27
1419	ADULT	22	F?	3	162.16 ± 3.66
1422	40-44 Y	18	M	2	158.75 ± 3.27
1425	5-6 Y	7	N/A	1	N/A
1428	20-25 Y	14	M	2	167.16 ± 4.05
1431	30-34 Y	16	M	2	177.32 ± 3.27
1437	25-29 Y	15	M	2	frag fem

SK #	Age Range	Age Code	Sex	Sex Code	Stature (cm)
1440	2-3 Y	4	N/A	1	N/A
1443	50-59 Y	20	M	2	166.12 ± 3.29
1447	4-5 Y	6	N/A	1	N/A
1450	6-7 Y	8	N/A	1	N/A
1453	20-24 Y	14	F	3	157.35 ± 3.72
1456	40-44 Y	18	F	3	162.16 ± 3.66
1459	50-59 Y	20	M	2	169.46 ± 3.27
1463	20-24 Y	14	M	2	165.92 ± 4.05
1468	20-24 Y	14	M	2	164.94 ± 3.27
1471	25-29 Y	15	F	3	158.83 ± 3.72
1478	2-3 Y	4	N/A	1	N/A
1481	1-2 Y	3	N/A	1	N/A
1484	50-59 Y	20	F	3	159.08 ± 3.72
1487	60 + Y	21	F	3	169.19 ± 3.57
1490	5-6 Y	7	N/A	1	N/A
1493	40-44 Y	18	F	3	156.84 ± 4.24
1496	50-59 Y	20	?M	2	155.90 ± 3.27
1500	40-44 Y	18	F	3	159.82 ± 3.72
1503	1-2 Y	3	N/A	1	N/A
1506	60+ Y	21	F	3	159.26 ± 3.66
1510	7-8 Y	9	N/A	1	N/A
1517	ADULT	22	M	2	N.E.
1520	ADULT	22	F	3	148.68 ± 3.57
1523	45-49 Y	19	M	2	168.99 ± 3.27
1529	60+ Y	21	M	2	172.56 ± 3.27
1530	35-39 Y	17	M	2	164.94 ± 3.27
1532	35-39 Y	17	F	3	157.25 ± 4.30
1535	3-4 Y	5	N/A	1	N/A
1538	45-49 Y	19	F	3	N/E
1541	35-39 Y	17	F	3	157.09 ± 4.45
1547	35-39 Y	17	M	2	161.13 ± 3.27
1551	30-34 Y	16	F	3	161.06 ± 4.24
1554	17-19 Y	13	?M	2	168.75 ± 3.27
1557	35-39 Y	17	F	3	166.55 ± 3.57
1560	35-39 Y	17	F	3	166.79 ± 4.24
1563	7-8 Y	9	N/A	1	N/A
1566	45-49 Y	19	F	3	159.26 ± 3.66
1566	6-7 Y	8	N/A	1	N/A
1569	20-24 Y	14	M	2	163.51 ± 3.27
1572	40-44 Y	18	M	2	N.E.
1575	0-1 Y	2	N/A	1	N/A
1578	ADULT	22	N.E.	4	N.E.
1581	18-24 M	3	N/A	1	N/A
1584	35-39 Y	17	M	2	168.27 ± 3.27
1587	ADULT	22	F	3	153.46 ± 3.66
1590	45-49 Y	19	M	2	170.55 ± 4.05
1593	25-29 Y	15	M	2	166.84 ± 3.27
1598	45-49 Y	19	F	3	160.31 ± 3.72
1602	35-39 Y	17	F	3	154.25 ± 3.57
1605	30-34 Y	16	F	3	165.06 ± 3.66
1608	35-39 Y	17	F	3	162.04 ± 3.66
1611	50-59 Y	20	M	2	164.80 ± 3.27
1614	ADULT	22	N.E.	4	N.E.
1617	60+ Y	21	M	2	168.03 ± 3.27
1620	ADULT	22	N.E.	4	N.E.
1623	25-29 Y	15	M	2	165.89 ± 3.27
1626	40-44 Y	18	F	3	163.04 ± 3.57
1629	45-49 Y	19	F	3	152.16 ± 3.72
1632	45-49 Y	19	M	2	177.02 ± 4.05
1635	ADULT	22	F?	3	163.63 ± 3.57
1638	25-28 Y	15	M	2	169.22 ± 3.27
1641	5-6 Y	7	N/A	1	N/A
1647	2-3 Y	4	N/A	1	N/A
1650	1-2 Y	3	N/A	1	N/A
1653	25 + Y	22	M?	2	164.82 ± 4.32

SK #	Age Range	Age Code	Sex	Sex Code	Stature (cm)
1656	35-39 Y	17	M	2	167.08 ± 3.27
1659	1-2 Y	3	N/A	1	N/A
1662	45-49 Y	19	F	3	158.58 ± 3.72
1663	40-44 Y	18	F	3	155.13 ± 3.57
1668	50-59 Y	20	M	2	170.65 ± 3.27
1671	3-4 Y	5	N/A	1	N/A
1674	40-44 Y	18	M	2	N.E.
1679	8-9 Y	10	N/A	1	N/A
1682	0-1 M	2	N/A	1	N/A
1685	11-13 Y	12	N/A	1	N/A
1688	45-49 Y	19	M	2	169.70 ± 3.27
1691	35-39 Y	17	M	2	173.19 ± 3.27
1694	45-49 Y	19	M	2	167.07 ± 3.37
1701	17-19 Y	13	F	3	150.44 ± 3.57
1704	45-49 Y	19	M	2	163.04 ± 3.27
1708	50-59 Y	20	M	2	172.09 ± 4.05
1711	30-34 Y	16	M	2	171.37 ± 3.27
1714	50-59 Y	20	M	2	167.78 ± 4.05
1714	50-59 Y	20	M	2	167.78 ±4.05
1718	ADULT	22	M	2	171.13 ± 3.27
1721	20-24 Y	14	F	3	177.70 ± 4.24
1724	50-59 Y	20	M	2	169.01 ± 4.05
1727	40-44 Y	18	F	3	158.97 ± 3.66
1728	1.5 – 3 M	2	N/A	1	N/A
1731	35-39 Y	17	M	2	161.37 ± 3.27
1734	40-44 Y	18	M?	2	N.E.
1739	12-14 Y	12	N/A	1	N/A
1742	40-44 Y	18	M	2	163.51 ± 3.27
1745	50-59 Y	20	M	2	N.E.
1751	30-34 Y	16	F	3	N.E.
1755	30-34 Y	16	F	3	159.82 ± 3.57
1761	60+ Y	21	M	2	162.32 ± 3.27
1764	40-44 Y	18	M	2	164.46 ± 3.27

Standard life table for St Owens Church

Age x	Individuals dx	Survivorship lx	% of Deaths	Radix (10,000) l'x	Radix (1) l"x	Mortality Qx	Person Years Lx	Person Years Left Tx	Expectation of Life ex
0	36	192	18.75	10000	1.00	0.19	45312.50	285416.67	28.54
5	21	156	10.94	8125	0.81	0.13	45468.75	240104.17	29.55
10	6	135	3.13	7031	0.70	0.04	20625.00	194635.42	27.68
15	6	129	3.13	6719	0.67	0.05	39375.00	174010.42	25.90
20	12	123	6.25	6406	0.64	0.10	30468.75	134635.42	21.02
25	9	111	4.69	5781	0.58	0.08	27734.38	104166.67	18.02
30	17	102	8.85	5313	0.53	0.17	24348.96	76432.29	14.39
35	20	85	10.42	4427	0.44	0.24	19531.25	52083.33	11.76
40	25	65	13.02	3385	0.34	0.38	13671.88	32552.08	9.62
45	17	40	8.85	2083	0.21	0.43	8203.13	18880.21	9.06
50	14	23	7.29	1198	0.12	0.61	8333.33	10677.08	8.91
60	9	9	4.69	469	0.05	1.00	2343.75	2343.75	5.00
Sum	**192**						**285416.67**		

Expanded life table for St Owens Church

Age x	Individuals dx	Survivorship lx	% of Deaths	Radix (10,000) l'x	Radix (1) l"x	Mortality Qx	Person Years Lx	Person Years Left Tx	Expectation of Life ex
0	5	192	2.60	10000	1.00	0.03	9869.79	284713.54	28.47
1	7	187	3.65	9740	0.97	0.04	9557.29	274843.75	28.22
2	10	180	5.21	9375	0.94	0.06	9114.58	265286.46	28.30
3	5	170	2.60	8854	0.89	0.03	8723.96	256171.88	28.93
4	9	165	4.69	8594	0.86	0.05	8359.38	247447.92	28.79
5	7	156	3.65	8125	0.81	0.04	7942.71	239088.54	29.43
6	4	149	2.08	7760	0.78	0.03	7656.25	231145.83	29.79
7	4	145	2.08	7552	0.76	0.03	7447.92	223489.58	29.59
8	4	141	2.08	7344	0.73	0.03	7239.58	216041.67	29.42
9	2	137	1.04	7135	0.71	0.01	14166.67	208802.08	29.26
10	6	135	3.13	7031	0.70	0.04	20625.00	194635.42	27.68
15	6	129	3.13	6719	0.67	0.05	39375.00	174010.42	25.90
20	12	123	6.25	6406	0.64	0.10	30468.75	134635.42	21.02
25	9	111	4.69	5781	0.58	0.08	27734.38	104166.67	18.02
30	17	102	8.85	5313	0.53	0.17	24348.96	76432.29	14.39
35	20	85	10.42	4427	0.44	0.24	19531.25	52083.33	11.76
40	25	65	13.02	3385	0.34	0.38	13671.88	32552.08	9.62
45	17	40	8.85	2083	0.21	0.43	8203.13	18880.21	9.06
50	14	23	7.29	1198	0.12	0.61	8333.33	10677.08	8.91
60	9	9	4.69	469	0.05	1.00	2343.75	2343.75	5.00
Sum	**192**						**284713.54**		

Reduced life table for St Owens Church

Age x	Individuals dx	Survivorship lx	% of deaths	Radix (10,000) l'x	Radix (1) l''x	Mortality Qx	Person Years Lx	Person Years Left Tx	Expectation of Life ex
0	36	192	18.56	10000.00	1.00	0.19	45312.50	287500.00	28.75
5	21	156	10.82	8125.00	0.81	0.13	37890.63	242187.50	29.81
10	7	135	3.61	7031.25	0.70	0.05	34244.79	204296.88	29.06
15	17	128	8.76	6666.67	0.67	0.13	62239.58	170052.08	25.51
25	69	111	36.60	5781.25	0.58	0.62	79687.50	107812.50	18.65
45	34	42	17.53	2187.50	0.22	0.81	26041.67	28125.00	12.86
65	8	8	4.12	416.67	0.04	1.00	2083.33	2083.33	5.00
Sum	**192**							**287500.00**	

A6. Southgate Congregational Church collection

Skeletal collection summary

Key to Southgate Congregational Church excavation years:

Blue	1983 excavation
Green	1989 excavation

SK #	Age Range	Age Code	Sex	Sex Code	Stature (cm)
I103	30-34 Y	16	F	3	N.E.
II118a	0-1.5 M	2	N/A	1	N/A
II118b	32-34 W	1	N/A	1	N/A
II133	35-39 Y	17	F	3	159.55 ± 3.66
II157	25-29 Y	15	F	3	N.E.
II163	39-43 W	2	N/A	1	N/A
II166	0-2 M	2	N/A	1	N/A
II167	2-3 Y	4	N/A	1	N/A
II176	60+ Y	21	F	3	157.81 ± 3.66
II191	20-23 Y	14	M	2	167.56 ± 3.27
II206	60 + Y	21	F	3	164.80 ± 3.57
II207	50-59 Y	20	M	2	165.42 ± 3.27
II208	50-59 Y	20	M	2	169.46 ± 3.27
II217	25-29 Y	15	F	3	164.78 ± 3.57
II218a	9-12 M	2	N/A	1	N/A
II218b	4-8 M	2	N/A	1	N/A
II218c	0-6 M	2	N/A	1	N/A
II218d	0-6 M	2	N/A	1	N/A
II224	ADULT	22	N.E.	4	Sex dep.
II227	14-20 Y	13	F	3	153.08 ± 3.57
II228	2-3 Y	4	N/A	1	N/A
II229	3-4 Y	5	N/A	1	N/A
II235	12-14 Y	12	N/A	1	N/A
II237	8-9 Y	10	N/A	1	N/A
II243	35-39 Y	17	F	3	N.E.
II244	45-49 Y	19	M	2	169.46 ± 3.27
II246	2-3 Y	4	N/A	1	N/A
II247	6-12 M	2	N/A	1	N/A
II249	50-59 Y	20	M	2	169.22 ± 3.27
II250	25-29 Y	15	?M	2	173.27 ± 3.27
II252	2-3 Y	4	N/A	1	N/A
II253	1-4 Y	23	N/A	1	N/A
II256	2-3 Y	4	N/A	1	N/A
II257	ADULT	22	?M	2	167.07 ± 3.37
II259	40-44 Y	18	F	3	161.00 ± 3.66
II283	40-44 Y	18	?M	2	N.E.
II284	25-29 Y	15	M	2	171.13 ± 3.27
II290	25-29 Y	15	F	3	162.74 ±3.66
II295	45-49 Y	19	F	3	167.38 ± 3.66
III168	17-30 Y	22	?M	2	169.63 ± 4.05
III179	25-28 Y	15	M	2	169.22 ± 3.27
III183	35-39 Y	17	M	2	170.18 ± 3.27
III199	45-49 Y	19	?F	3	159.23 ± 3.57
III200	35-39 Y	17	F	3	171.15 ± 3.66
III201	16-20 Y	13	?M	2	169.34 ± 3.37
III212	40-44 Y	18	M	2	177.63 ± 4.05
III230	20-24 Y	14	F	3	167.09 ± 3.66
III248	45-49 Y	19	M	2	175.17 ± 4.05
III262	13-14 Y	12	N/A	1	N/A
III264	15-16 Y	13	N/A	1	N/A
III282	12-18 M	3	N/A	1	N/A
III311	40-44 Y	18	M	2	172.94 ±3.27
III322	40-44 Y	18	?M	2	N.E.
III334	45-49 Y	19	M	2	169.14 ± 4.32
III346	6-7 Y	8	N/A	1	N/A
V u/s a	30-34 Y	16	?F	3	N.E.

SK #	Age Range	Age Code	Sex	Sex Code	Stature (cm)
V u/s b	30-34 Y	16	M	2	N.E.
V u/s c	30-34 Y	16	M	2	N.E.
V u/s d	10-14 Y	12	N/A	1	N.E.
V u/s e	45-49 Y	19	?M	2	N.E.
BE	12-18 M	3	N/A	1	N/A
BJ	3-9 M	2	N/A	1	N/A
BK	1-2 Y	3	N/A	1	N/A
LC1	35-39 Y	17	F	3	160.16 ± 4.24
LC1a	35-39 Y	17	M	2	163.29 ± 3.37
LC1b	20-23 Y	14	F	3	162.16 ± 3.66
LC1c	Non-adult	23	N/A	1	N/A
LC1d	60 + Y	21	M	2	167.05 ± 6.24
LC1e	ADULT	22	?F	3	158.83 ± 3.72
LC2	60+ Y	21	F	3	159.22 ± 3.72

Standard life table for Southgate Congregational Church

Age x	Individuals dx	Survivorship lx	% of Deaths	Radix (10,000) l'x	Radix (1) l"x	Mortality Qx	Person Years Lx	Person Years Left Tx	Expectation of Life ex
0	20	65	30.77	10000	1.00	0.31	42307.69	256153.85	25.62
5	2	45	3.08	6923	0.69	0.04	33846.15	213846.15	30.89
10	3	43	4.62	6615	0.66	0.07	31923.08	180000.00	27.21
15	3	40	4.62	6154	0.62	0.08	29615.38	148076.92	24.06
20	3	37	4.62	5692	0.57	0.08	27307.69	118461.54	20.81
25	6	34	9.23	5231	0.52	0.18	23846.15	91153.85	17.43
30	4	28	6.15	4308	0.43	0.14	20000.00	67307.69	15.63
35	6	24	9.23	3692	0.37	0.25	16153.85	47307.69	12.81
40	5	18	7.69	2769	0.28	0.28	11923.08	31153.85	11.25
45	6	13	9.23	2000	0.20	0.46	7692.31	19230.77	9.62
50	3	7	4.62	1077	0.11	0.43	8461.54	11538.46	10.71
60	4	4	6.15	615	0.06	1.00	3076.92	3076.92	5.00
	65						256153.85		

Expanded life table for Southgate Congregational Chapel

Age x	Individuals dx	Survivorship lx	% of Deaths	Radix (10,000) l'x	Radix (1) l"x	Mortality Qx	Person Years Lx	Person Years Left Tx	Expectation of Life ex
0	10	64	15.63	10000	1.00	0.16	9218.75	256328.13	25.63
1	3	54	4.69	8438	0.84	0.06	8203.13	247109.38	29.29
2	5	51	7.81	7969	0.80	0.10	7578.13	238906.25	29.98
3	1	46	1.56	7188	0.72	0.02	7109.38	231328.13	32.18
4	0	45	0.00	7031	0.70	0.00	7031.25	224218.75	31.89
5	0	45	0.00	7031	0.70	0.00	7031.25	217187.50	30.89
6	1	45	1.56	7031	0.70	0.02	6953.13	210156.25	29.89
7	0	44	0.00	6875	0.69	0.00	6875.00	203203.13	29.56
8	1	44	1.56	6875	0.69	0.02	6796.88	196328.13	28.56
9	0	43	0.00	6719	0.67	0.00	6718.75	189531.25	28.21
10	3	43	4.69	6719	0.67	0.07	32421.88	182812.50	27.21
15	3	40	4.69	6250	0.63	0.08	30078.13	150390.63	24.06
20	3	37	4.69	5781	0.58	0.08	27734.38	120312.50	20.81
25	6	34	9.38	5313	0.53	0.18	24218.75	92578.13	17.43
30	4	28	6.25	4375	0.44	0.14	20312.50	68359.38	15.63
35	6	24	9.38	3750	0.38	0.25	16406.25	48046.88	12.81
40	5	18	7.81	2813	0.28	0.28	12109.38	31640.63	11.25
45	6	13	9.38	2031	0.20	0.46	7812.50	19531.25	9.62
50	3	7	4.69	1094	0.11	0.43	8593.75	11718.75	10.71
60	4	4	6.25	625	0.06	1.00	3125.00	3125.00	5.00
	64						256328.13		

Reduced life table for Southgate Congregational Church

Age x	Individuals dx	Survivorship lx	% of deaths	Radix (10,000) l'x	Radix (1) l''x	Mortality Qx	Person Years Lx	Person Years Left Tx	Expectation of Life ex
0	20	66	30.30	10000.00	1.00	0.30	42424.24	264393.94	26.44
5	2	46	3.03	6969.70	0.70	0.04	34090.91	221969.70	31.85
10	4	44	6.06	6666.67	0.67	0.09	31818.18	187878.79	28.18
15	6	40	9.09	6060.61	0.61	0.15	56060.61	156060.61	25.75
25	21	34	31.82	5151.52	0.52	0.62	71212.12	100000.00	19.41
45	9	13	13.64	1969.70	0.20	0.69	25757.58	28787.88	14.62
65	4	4	6.06	606.06	0.06	1.00	3030.30	3030.30	5.00
Sum	**66**							**264393.94**	

A7. Southgate Congregational Church burial records

Burial register summary

Surname	Year of Death	Burial location	Age	Sex
Perkins	1786	Unknown	infant	Male
Harrison	1786	Unknown	Unknown	Female
Miller	1786	Unknown	Unknown	Female
Trinder	1786	Unknown	Unknown	Female
Bond	1787	Unknown	Unknown	Female
Perris	1787	Unknown	Unknown	Unknown
Rowland	1788	Unknown	Unknown	Male
Watts	1788	Unknown	Unknown	Female
Loch	1789	Unknown	Unknown	Male
Nichols	1789	Unknown	Unknown	Male
Weaver	1789	Unknown	Unknown	Female
Loid	1789	Unknown	Unknown	Unknown
Thomson	1789	Unknown	Unknown	Unknown
Lasts	1790	Unknown	child	Unknown
Lasts	1790	Unknown	child	Unknown
Bowles	1790	Unknown	Unknown	Male
Cox	1790	Unknown	Unknown	Male
Adley	1790	Unknown	Unknown	Female
Lewes	1791	Unknown	Unknown	Male
Perkins	1791	Unknown	Unknown	Male
Purcer	1791	Unknown	Unknown	Male
Lewes	1791	Unknown	Unknown	Female
Cox	1792	Unknown	Unknown	Male
Gravn	1792	Unknown	Unknown	Male
Smith	1793	Unknown	3yrs 10mths	Male
Perkins	1793	Unknown	4mths	Female
Maycock	1794	Unknown	50yrs	Female
Adey	1794	Unknown	54yrs	Female
Taylor	1794	Unknown	76yrs	Female
Roberts	1795	Unknown	44yrs	Male
Sparrowhawke	1795	Unknown	73yrs	Female
Paytt	1796	Unknown	6days	Male
Perkins	1796	Unknown	7yrs 9mths	Male
Whitehead	1796	Unknown	12yrs	Male
Pytt	1796	Unknown	15yrs	Male
Ashburn	1796	Unknown	49yrs	Male
Butt	1796	Unknown	70yrs	Male
Nale	1796	Unknown	6mths	Female
Perris	1796	Unknown	78yrs	Female
Gill	1796	Unknown	76yrs	Female
Poulson	1796	Unknown	70yrs	Female
Lewis	1797	Unknown	40yrs	Male
Lewis	1797	Unknown	3yrs	Female
Watts	1797	Unknown	67yrs	Female
Cox	1798	Unknown	67yrs	Male
Watts	1798	Unknown	56yrs	Female
Adey Junior	1799	Unknown	27yrs	Male
Watkins	1799	Unknown	15yrs	Female
Perris	1799	Unknown	15yrs	Female
Waite	1800	Unknown	5wks	Male
Coley	1800	Unknown	13mths	Male
Smith	1800	Unknown	2yrs 3mths	Male
Orpin	1800	Unknown	10yrs	Male
Warwick	1800	Unknown	26yrs	Male
Lairet	1800	Unknown	74yrs	Male
Lesley	1800	Unknown	5mths	Female
Harman	1800	Unknown	45yrs	Female
Harmar	1800	Unknown	68yrs	Female
Cornell	1800	Unknown	77yrs	Female
Chandler	1800	Unknown	80yrs	Female

Everard	1800	Unknown	85yrs	Female
Surname	**Year of Death**	**Burial location**	**Age**	**Sex**
Bishop	1801	Unknown	2yrs 6mths	Female
Floyd	1801	Unknown	81yrs	Female
Church	1802	Unknown	76yrs	Male
Coley	1802	Unknown	8days	Female
Mason	1802	Unknown	6mths	Female
Vaile	1802	Unknown	18mths	Female
Hitchings	1802	Unknown	19yrs	Female
Cox	1802	Unknown	69yrs	Female
Smith	1803	Unknown	5mths	Unknown
Bourne	1803	Unknown	17mths	Male
Harman	1803	Unknown	70yrs	Male
Butler	1803	Unknown	76yrs	Male
Hughes	1803	Unknown	77yrs	Female
Gill	1804	Unknown	23yrs	Male
Pytt	1804	Unknown	20yrs	Female
Trap…	1804	Unknown	43yrs	Female
Cox	1804	Unknown	45yrs	Female
Wheeler	1804	Unknown	80yrs	Female
Smith	1805	Unknown	14mths	Male
Pytt	1805	Unknown	19yrs	Male
Adey	1805	Unknown	27yrs	Male
Thompson	1805	Unknown	10wks	Female
Smith	1805	Old burying ground	10mths	Female
Price	1805	Unknown	31yrs	Female
Bishop	1806	Unknown	2yrs	Male
Smith	1806	Unknown	3yrs	Male
Keern	1806	Unknown	79yrs	Male
Waite	1806	Unknown	3days	Female
Bourne	1807	Unknown	7wks	Male
Warwick	1807	Unknown	35yrs	Male
Rickets	1807	Unknown	58yrs	Male
Price	1807	Unknown	12yrs	Female
Aviary	1807	Unknown	24yrs	Female
Dowell	1807	Unknown	70yrs	Female
Smith	1808	Unknown	1mths	Male
Orpin	1808	Unknown	48yrs	Male
Winter	1808	Vault - privately owned	65yrs	Male
Watts	1808	Unknown	72yrs	Male
Thompson	1808	Unknown	8mths	Female
Bourne	1808	Unknown	6mths	Female
Mitchel	1808	Unknown	3yrs 9mths	Female
Radnall	1808	Unknown	63yrs	Female
Bishop	1809	Old Ground	7yrs 8mths	Male
Pynock	1809	Old Ground	51yrs	Male
Maycock	1809	Unknown	68yrs	Male
Phillpots	1809	Old Ground	3mths	Female
Waite	1809	New Ground	32yrs	Female
Perris	1809	Old Ground	58yrs	Female
Drew	1809	New Ground	59yrs	Female
Bourne	1810	New Ground	8mths	Female
Ellerhost	1810	New Ground	64yrs	Female
Mason	1811	New Ground	40yrs	Female
Watts	1811	New Ground	68yrs	Female
Tanner	1812	New Ground	5mths	Male
Pervin	1812	New Ground	12yrs	Male
Wheeler	1812	New Ground	20 yrs	Male
Joy	1812	Old Ground	67 yrs	Male
Warwick	1812	New Ground	66yrs	Male
Aviary	1812	New Ground	2yrs 5mths	Female
Barr	1812	New Ground	20yrs	Female
Warwick	1812	New Ground	61yrs	Female
Whittard	1813	New Ground	8mths	Male
Curtis	1813	New Ground	6wks	Male
Church	1813	Unknown	93yrs	Male
Wheeler	1813	Old Ground	2yrs	Female

Surname	Year of Death	Burial location	Age	Sex
Smith	1813	New Ground	19yrs	Female
Jones	1813	New Ground	28yrs	Female
Curtis	1814	Unknown	1mth	Male
Garn	1814	New Ground	80yrs	Female
Washbourne	1815	The ?Difsentiany Meeting burial ground	4mths	Male
Stratford	1815	New Ground	1yr	Male
Roberts	1815	Old Ground	23yrs	Male
Hayward	1815	Old Ground	23yrs	Female
Martin	1816	Old Ground	9mths	Male
Sparrow	1816	New Ground	3yrs	Male
Medhurst	1816	New Ground	23yrs	Male
Allgood	1816	New Ground	46yrs	Male
Jones	1816	New Ground	50yrs	Male
Herbert	1816	New Ground	61yrs	Male
Newby	1816	Old Ground	2yrs	Female
Lancaster	1816	Old Ground	38yrs	Female
Weaver	1816	Old Ground	67yrs	Female
Adey	1816	Old Ground	66yrs	Female
Cue	1817	New Ground	4mths	Male
Cale	1817	Old Ground	65yrs	Male
Thompson	1817	New Ground	43yrs	Female
Clark	1817	New Ground	53yrs	Female
Whitehead	1817	New Ground	79yrs	Female
Wood	1817	New Ground	81yrs	Female
Mills	1818	New Ground	60yrs	Female
Page	1819	Old Ground	2yrs	Male
Drew	1819	New Ground	70yrs	Male
Carol	1819	New Ground	3mths	Female
Lattimer	1819	New Ground	1mth	Female
Cleveland	1819	Old Ground	25yrs	Female
White	1819	New Ground	50-60yrs	Female
Drayton	1820	New Ground	7mths	Male
Adey	1820	Old Ground	76yrs	Male
Cornell	1820	New Ground	83yrs	Male
Barnard	1820	New Ground	18yrs	Female
Lawrence	1820	New Ground	63yrs	Female
Lambard	1820	In [?] Rev. Tallamy's Brick Grave	73yrs	Female
Joy	1820	Old Ground	86yrs	Female
Perkins	1820	New Ground	62yrs	Unknown
Tucker	1821	New Ground	1yr	Female
Watts	1821	New Ground	43yrs	Female
Rickets	1821	New Ground	72yrs	Female
Whitehead	1821	New Ground	82yrs	Unknown
Wheeler	1822	Old Ground	2yrs 3mths	Male
Hampton	1822	Old Ground	29yrs	Male
Warwick	1822	New Ground	29yrs	Male
Smith	1822	Old Ground	43yrs	Male
Pollard	1822	New Ground	69yrs	Male
Perkins	1822	New Ground	63yrs	Male
Smith	1822	New Ground	70yrs	Male
Pytt	1822	New Ground	79yrs	Male
Smith	1822	New Ground	23yrs	Female
Barnard	1822	New Ground	38yrs	Female
Case	1822	New Ground	52yrs	Female
Turk	1823	New Ground	6 dys	Male
Wright	1823	New Ground	19yrs	Female
Williams	1823	Old Ground	43yrs	Female
Green	1823	New Ground	46yrs	Female
Thomas	1823	New Ground	54yrs	Female
Smith	1823	New Ground	64yrs	Female
Smith	1823	New Ground	70yrs	Female
?Orpim	1823	Old Ground	75yrs	Female
Kent	1823	Old Ground	Unknown	Female
Rees	1824	New Ground	2yrs	Male

Surname	Year of Death	Burial location	Age	Sex
Wright	1824	New Ground	27yrs	Male
?vict	1824	New Ground	30yrs	Male
Wheeler	1824	Old Ground	58yrs	Male
Cook	1824	New Ground	61yrs	Male
Weaver	1824	Old Ground	85yrs	Male
Leach	1824	Old Ground	6mths	Female
Gittens	1824	In the Alley	9yrs	Female
Purser	1824	New Ground	22yrs	Female
Purser	1824	New Ground	28yrs	Female
Purser	1824	New Ground	30yrs	Female
Perris	1825	New Ground	73yrs	Male
Thomson	1825	New Ground	17yrs	Female
Page	1825	Old Ground	32yrs	Female
?Ockford	1825	Old Ground	38yrs	Female
Perriman	1825	New Ground	56yrs	Female
Perris	1825	New Ground	78yrs	Female
Grimes	1826	New Ground	26yrs	Male
Haslem	1826	New Ground	59yrs	Male
Jenkins	1826	New Ground	81yrs	Male
Leach	1826	Old Ground	3mths	Female
Cook	1826	New Ground	19yrs	Female
Flowers	1827	New Ground	6mths	Unknown
Richards	1827	New Ground	7mths	Male
Tucker	1827	New Ground	13mths	Male
Green	1827	Unknown	43yrs	Male
Harmer	1827	New Ground	66yrs	Male
Gittens	1827	In the Alley	9mths	Female
Stratford	1827	New Ground	2yrs 10mths	Female
Allgood	1827	New Ground	22yrs	Female
Bowler	1827	Old Ground	56yrs	Female
Gray	1828	Baptist Burial Ground	33yrs	Male
Elliot	1828	New Ground	56yrs	Male
Reeves	1828	New Ground	6mths	Female
Green	1828	New Ground	31yrs	Female
Lennox	1828	New Ground	45yrs	Female
Hall	1828	New Ground	54yrs	Female
Kendall	1828	New Ground	60yrs	Female
Reeves	1829	New Ground	5mths	Male
Shearman	1829	Old Ground	3mths	Male
Grimes	1829	New Ground	16mths	Male
Purser	1829	New Ground	22yrs	Male
Osborne	1829	Old Ground	65yrs	Male
Page	1829	Old Ground	1yr	Female
Corey	1829	Old Ground	10mths	Female
Miur	1829	New Ground	9dys	Female
Stratford	1829	New Ground	24yrs	Female
Allgood	1829	New Ground	28yrs	Female
Stock	1829	New Ground	31yrs	Female
Aviary	1829	New Ground	82yrs	Female
Hendcock	1829	New Ground	85yrs	Female
Green	1830	New Ground	2¾yrs	Male
Purser	1830	New Ground	20yrs	Male
Cox	1830	Old Ground	55yrs	Male
Gibbs	1830	New Ground	64yrs	Male
Cook	1830	Old Ground	33yrs	Female
Pytt	1830	New Ground	74yrs	Female
Ricketts	1831	New Ground	6mths	Unknown
Grimes	1831	New Ground	9mths	Male
Tidmarsh	1831	Old Ground	27mths	Male
Newman Thompson	1831	New Ground	16yrs	Male
Butt	1831	Old Ground	64yrs	Male
Wright	1831	Old Ground	14yrs	Female
Highwood	1831	New Ground	32yrs	Female
Moarne	1831	In the Independent Chapel	56yrs	Female
Perris	1831	New Ground	55yrs	Female

Gardner	1831	New Ground	62yrs	Female
Surname	**Year of Death**	**Burial location**	**Age**	**Sex**
Collinwood	1831	New Ground	71yrs	Female
Pain	1831	New Ground	78yrs	Female
Oakley	1832	New Ground	48yr	Male
Bishop	1832	Unknown	67yrs	Male
Hall	1832	New Ground	3mths 6dys	Female
Peckmore	1832	New Ground	6mths	Female
Tidmarsh	1832	New Ground	3yrs	Female
Morgan	1832	New Ground	10yrs	Female
Hughes	1832	New Ground	23yrs	Female
Cook	1832	New Ground	46yrs	Female
Graves	1832	New Ground	58yrs	Female
Gittens	1833	Unknown	6yrs	Male
Pinder	1833	Unknown	77yrs	Male
Hall	1833	Unknown	7yrs	Female
Eastermeadsea	1833	Unknown	nearly 10? yrs	Female
Stratford	1833	New Ground	78yrs	Female
Hannon Thomspon	1834	Unknown	23yrs	Male
?Kendale	1834	Unknown	30yrs	Male
Eastmead	1834	Unknown	75yrs	Male
Sparrow	1834	Unknown	2yrs	Female
Meadows	1834	Unknown	57yrs	Female
Eastmead	1834	Unknown	75yrs	Female
Cox	1834	Unknown	74yrs	Unknown
Gardner	1835	Unknown	?50yrs	Male
Gain	1835	Unknown	62yrs	Male
Williams	1835	Unknown	62yrs	Male
Joy	1835	Unknown	?55yrs	Female
Cook	1835	Unknown	73yrs	Female
Edwards	1835	Unknown	91yrs	Female
Horne	1836	Unknown	2yrs 3mths	Female
Butt	1836	Unknown	2yrs	Female
Page	1836	Unknown	56yrs	Female
Smith	1836	Unknown	75yrs	Female
Jacob	1836	Unknown	50yrs	Unknown
Hall	1837	Unknown	14mths	Male
Sparrow	1837	Unknown	14mths	Male
Sparrow	1837	Unknown	3yrs	Male
Marsh	1837	Unknown	11wks	Female
Brickerton Gitterant	1837	Unknown	15yrs	Unknown

Expanded life table for Southgate Congregational Church burial records

Age x	Individuals dx	Survivorship lx	% of Deaths	Radix (10,000) l'x	Radix (1) l"x	Mortality Qx	Person Years Lx	Person Years Left Tx	Expectation of Life ex
0	44	271	16.24	10000	1.00	0.16	9188.19	371070.11	37.11
1	11	227	4.06	8376	0.84	0.05	8173.43	361881.92	43.20
2	14	216	5.17	7970	0.80	0.07	7712.18	353708.49	44.37
3	7	202	2.58	7454	0.75	0.04	7324.72	345996.31	46.42
4	0	195	0.00	7196	0.72	0.00	7195.57	338671.59	47.07
5	0	195	0.00	7196	0.72	0.00	7195.57	331476.02	46.07
6	1	195	0.37	7196	0.72	0.01	7177.12	324280.44	45.07
7	3	194	1.11	7159	0.72	0.02	7103.32	317103.32	44.30
8	0	191	0.00	7048	0.71	0.00	7047.97	310000.00	43.98
9	2	191	0.74	7048	0.71	0.01	7011.07	302952.03	42.98
10	6	189	2.21	6974	0.70	0.03	34317.34	295940.96	42.43
15	12	183	4.43	6753	0.68	0.07	32656.83	261623.62	38.74
20	16	171	5.90	6310	0.63	0.09	30073.80	228966.79	36.29
25	11	155	4.06	5720	0.57	0.07	27583.03	198892.99	34.77
30	11	144	4.06	5314	0.53	0.08	25553.51	171309.96	32.24
35	4	133	1.48	4908	0.49	0.03	24169.74	145756.46	29.70
40	9	129	3.32	4760	0.48	0.07	22970.48	121586.72	25.54
45	9	120	3.32	4428	0.44	0.08	21309.96	98616.24	22.27
50	27	111	9.96	4096	0.41	0.24	35977.86	77306.27	18.87
60	32	84	11.81	3100	0.31	0.38	25092.25	41328.41	13.33
70	36	52	13.28	1919	0.19	0.69	12546.13	16236.16	8.46
80	14	16	5.17	590	0.06	0.88	3321.03	3690.04	6.25
90	2	2	0.74	74	0.01	1.00	369.00	369.00	5.00
100	0	0	0.00	0	0.00	1.00	0.000	0.00	0.00
	271						371070.11		

A8. Gloucester Infirmary Burial Ground collection

Skeletal collection summary

Key to Gloucester Infirmary burial ground excavation years:

Blue	1983 excavation
Green	1989 excavation

Sk No	Age	Age Code	Sex	Sex code	Stature (cm)
III150	25-29 Y	15	?M	2	N.E.
III269	35-39 Y	17	?M	2	N.E.
III335	25-29 Y	15	M	2	168.03 ± 3.27
III362a	35-39 Y	17	M	2	172.71 ± 4.05
III362b	20-23 Y	14	F	3	N.E.
III364	40-44 Y	18	F	3	160.42 ± 3.66
III486	ADULT	22	N.E.	4	153.66 ± 3.57
III487	25-29 Y	15	M	2	160.66 ± 3.27
III502	35-39 Y	17	F	3	162.53 ± 3.72
III507	45-49 Y	19	M	2	N.E.
III532	ADULT	22	?M	2	169.34 ± 3.37
III535	30-34 Y	16	M	2	178.98 ±3.27
III560	35-39 Y	17	M	2	163.75 3.27
III612	45-49 Y	19	?M	2	N.E.
III660	18-22 Y	14	M	2	N.E.
III681	20-24 Y	14	?M	2	N.E.
III723	ADULT	22	?M	2	165.01 ± 4.05
III725	45-49 Y	19	?M	2	N.E.
III781	35-39 Y	17	?M	2	171.21 ± 3.29
III789	35-39 Y	17	M	2	172.09 ± 4.05
III799	30-34 Y	16	M	2	170.86 ± 4.05
III814	17-19 Y	13	?M	2	174.55 ± 4.05
L1	60+ Y	21	M	2	163.30 ± 6.10
L2	ADULT	22	?M	2	165.37 ± 6.10
U	ADULT	22	?F	3	N.E.

A9. Presentations and publications associated with the PhD research

Publications

1. Towle I, Davenport CAL, Irish, JD and De Groote, I. 2018. Dietary and behavioural inferences from the dental caries, calculus and non-masticatory wear rates on dentition from medieval Gloucester, UK. International Journal of Palaeopathology. Submitted, under peer review.
2. Davenport CAL, Ohman J, Gonzalez S, Borrini M. 2018. Updating Standard Protocols for Age-at-death Estimations from the unfused Pars basilaris. American Journal of Physical Anthropology. Under peer review.
3. Burrell, CL, Davenport, CAL, Carpenter, RJ and Ohman, JC. 2018. Biological age estimation of non-adult human skeletal remains: Comparison of dental development with the humerus, femur and pars basilaris. Trends in Biological Anthropology. In Press.
4. Davenport CAL. 2017. Osteological Report: Linenhall, Chester, Site Code: LP2045. For Stephenson Developments. Accepted, awaiting publication.
5. Davenport CAL. 2016. Preliminary Osteological Report: Linenhall, Chester, Site Code: LP2045. For Stephenson Developments.
6. Davenport CAL. 2016. Project update: Linenhall, Chester. British Association for Biological Anthropology and Osteoarchaeology Annual Review 2015. BABAO. 17:5.

Conference Presentations

1. Davenport, CAL. 2017. Searching for Clues: How inter-disciplinary communication can breathe new life into investigations. Podium Presentation. 2017 Forensics Europe Expo Conference. London Olympia. Abstract published online: https://www.forensicseuropeexpo.com/2017-fee-conference/searching-for-clues-how-a-combined-approach-comprising-forensic-anthropology-archaeology-and-geology-disciplines-can-breathe-new-life-into-crime-scene-investigations.
2. Davenport, CAL and Ohman, JC and Borrini, M. 2017. Changing Impact Angles: The Mechanics Involved in Blunt Force Cranial Trauma and Their Importance in Investigating Curb-Stomping Cases. Poster Presentation - Anthropology. American Academy of Forensic Sciences (AAFS) 69th Annual Scientific Meeting. New Orleans, LA, USA. Abstract can be accessed online at: http://researchonline.ljmu.ac.uk/5959/.
3. Davenport, CAL and Gonzalez S. 2017. Who Do the Voodoo? A Rapid Field Technique to Identify the Provenance of Unknown Human Skeletal Remains in “Ritual” Cases. Poster Presentation – General Section. American Academy of Forensic Sciences (AAFS) 69th Annual Scientific Meeting. New Orleans, LA, USA. Abstract can be found online at: https://webdata.aafs.org/RefLibrary/REF_Search/Search.aspx
4. Poulson S, Scott GR, Lynnerup N, Burrell C, Davenport CAL. 2016. Isotope Analysis of Dental Calculus to Study Paleodiet: organic-C vs. carbonate-C Fractions. Goldschmidt. Yokohama, Japan. Abstract published, can be accessed online at http://goldschmidt.info/2016/uploads/abstracts/finalPDFs/2535.pdf.

5. Davenport CAL, Reynolds L, Rennie SR, Ohman JC. 2016. Digging Up Dirt: Using ArcGIS Mapping Techniques to Aid Cost Effective Sample Selection for Analytical Testing. BAHID 2016 Summer Conference.
6. Davenport CAL, Ohman J, Gonzalez S, Borrini M. 2016. Updating Standard Protocols for Age-at-death Estimations from the unfused Pars basilaris. BAHID 2016 Summer Conference.
7. Chamberlain EA, Poulson S, Burrell CL, Davenport CAL, Gonzalez S, Scott GR. 2016. Paleodiet of Rural and Urban Medieval English Populations: Further Studies of Extracting Stable Carbon and Nitrogen Isotopes from Dental Calculus. Poster Presentation. The 85th Annual Meeting of the American Association for Physical Anthropology. Atlanta. Abstract published and can be accessed online at: http://meeting.physanth.org/program/2016/session31/chamberlain-2016-paleodiet-of-rural-and-urban-medieval-english-populations-further-studies-of-extracting-stable-carbon-and-nitrogen-isotopes-from-dental-calculus.html.
8. Davenport CAL, Gonzalez S, Scott GR, Poulson SR, Burrell C, Dove E, Towle I. 2015. Good News for Bad Teeth: Paleodiet through the isotopic analysis of dental calculus. Poster Presentation. Paleodiet Meets Paleopathology. Santiago de Compostela, Spain.
9. Davenport CAL. 2015. Digging Up Dirt: using ArcGIS to aid cost effective sample selection. Podium Presentation. 2015 Forensics Europe Expo Seminar Theatre Workshop. London Olympia.
10. Davenport CAL, Reynolds L, Rennie SR and Ohman JC. 2014. Digging up Dirt: Using ArcGIS Mapping Techniques to Aid Cost Effective Sample Selection for Analytical Testing. Poster Presentation. BAHID Winter Conference – DVI: from incident to reconciliation, Manchester.
11. Davenport CAL, Rennie SR and Ohman JC. 2014. Digging Up Dirt: How Using Geological Techniques Can Support Osteological Analyses. Poster Presentation. Day of the Dead Conference. Queens University Belfast.
12. Davenport CAL, Wilmhurst A and Ohman JC. 2014. Life in Medieval Poulton, Cheshire: Revealing a Forgotten Population. Poster Presentation. Day of the Dead. Belfast Queens University.
13. Davenport CAL, Rennie SR and Ohman JC. 2014. Digging Up Dirt: How Using Geological Techniques Can Support Osteological Analyses. Poster Presentation. BABAO – Durham.
14. Davenport CAL, Wilmhurst A and Ohman JC. 2014. Life in Medieval Poulton, Cheshire: Revealing a Forgotten Population. Oral Presentation. LJMU Faculty of Science Research Seminar and Poster Presentation Day.
15. Turner CAL. 2013. Biological age estimation of infant and non-adult human skeletal remains: A comparison of dental development with the pars basilaris of the occipital bone. Oral presentation. Society of Medieval Archaeology Postgraduate Colloquium. University of Aberdeen.
16. Turner CAL, Burrell CL, Carpenter RJ and Ohman JC. 2013. Biological age estimation of non-adult human skeletal remains: Comparison of dental development with humeri, femora and the pars basilaris. Poster Presentation. British Association for Biological Anthropology and Osteoarchaeology Conference – York.
17. Burrell CL, Turner CAL, Carpenter RJ and Ohman JC. 2013. Biological age estimation of infant and non-adult human skeletal remains: A comparison of dental development

with diaphyseal lengths of the humeri and femora. Poster Presentation. Faculty of Science Research Seminar and Poster Presentation Day – Liverpool John Moores University.

18. Turner CAL, Burrell CL, Carpenter RJ and Ohman JC. 2013. Biological age estimation of infant and non-adult human skeletal remains: A comparison of dental development with the Pars basilaris of the occipital bone. Poster presentation. Faculty of Science Research Seminar and Poster Presentation Day – Liverpool John Moores University. First place poster presentation winner (£1000).