**Title:** The application of quantitative petrography and macroscopic colour change in a comparative analysis of Roman and Anglo-Saxon cremation practices

**First Author:** Emily L. Carroll

University of Reading, Whiteknights Campus, Shinfield Road, Reading, RG6 6UR, UK; e.l.carroll@hotmail.co.uk

**Second Author:** Kirsty E. Squires

Staffordshire University, Science Centre, Leek Road, Stoke-On-Trent, ST4 2DF, UK; Kirsty.Squires@staffs.ac.uk

**Corresponding Author:**Emily L. Carroll; University of Reading, Whiteknights Campus, Shinfield Road, Reading, RG6 6UR, UK; e.l.carroll@hotmail.co.uk

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# **Abstract**

The microscopic examination of burned bone has allowed cremation research to infer a wealth of information concerning burning practices and pyre technology from archaeological contexts. Recently, a new approach for quantifying the microscopic heat-induced alterations in burned bone to categorise burning intensity using petrography has been developed within histomorphological research. The following study is the first application of quantitative petrography to examine cremated remains from two archaeological contexts, with the aim of comparing funerary practices from Roman Britain and Anglo-Saxon England. Fifteen burials, including 12 adults (four males and one female), two juveniles/adults, and one individual of unknown age, from the Roman cemetery of Folly Lane, Hertfordshire, and sixteen burials, comprised of 12 adults (four males and one female), two adolescents and two children, from the Anglo-Saxon cemetery of Elsham, North Lincolnshire, were studied in this research. Analysis revealed a mix of burning intensities, with the majority of the Roman samples from Folly Lane (n = 10, 66.7%) achieving temperatures over 1000˚C. In contrast, the Anglo-Saxon samples from Elsham showed greater diversity in burning intensity, with only six (37.5%) reaching temperatures in excess of 1000˚C. The discussion suggests this differentiation could be due to the use of *ustores,* or professional cremators at the Roman town of Verulamium; a custom that has been referenced amongst the Roman elite in literary sources. The results also suggest that the cremation process from Anglo-Saxon Elsham could be linked to the lack of pyre maintenance, environmental factors (such as weather and lack of resources, including fuel for the pyre), and a difference in cremation technology, such as pyre structure. This assessment demonstrates how quantitative petrography combined with macroscopic colour change is an effective assessment of burning intensities from archaeological burned bone, and should be applied on a larger scale, with a greater sample size across more sites.

# **Introduction**

Despite cremation being a predominant rite in the archaeological burial record, it has been largely understudied compared to other burial practices (McKinley, 1994; Williams, 2008; Thompson, 2015). This neglect is a result of the misconception that burned human bone renders little interpretative data, which has deterred many from conducting more in-depth analyses (Wells, 1960). However, the last few decades have seen a surge in cremation research, with significant advances in the scientific, theoretical and experimental examination of these burial contexts (Jonuks and Konsa, 2007; Schmidt and Symes, 2008; 2015; McKinley, 2015; Thompson, 2015).

This study is the first attempt to combine quantitative petrography with macroscopic colour change to assess the taphonomic transformation of burned bone from two archaeological funerary contexts. Human remains from the Anglo-Saxon cemetery, Elsham, North Lincolnshire and the Roman burial ground of Folly Lane, Hertfordshire, are analysed with the intention of examining whether this new approach can help compare cremation practices from two historical contexts.

## 1.1 Bone Reponses to Heat Exposure

Bone is composed of an organic (mostly collagen) component, an inorganic (mainly calcium phosphate) component, and water (Thompson et al., 2013; Snoeck et al., 2014). Its structure is made of an outer periosteal layer, and inner cortical bone layer, and an endosteal core comprised of compact bone and spongey bone (Thompson et al., 2013). The mineral phase is an impure, non-stoichiometric and poorly crystalline form of hydroxyapatite (also known as bioapatite) (Mkukuma, et al., 2004; Wopenka and Pasteris, 2005; Thompson et al., 2013). When subject to extreme heat, bone undergoes four transition phases of change (Mayne Correia, 1997; Thompson, 2004). These include: 1) Dehydration; 2) Decomposition; 3) Inversion; and 4) Fusion. Both macroscopic and microscopic heat-induced (H-I) alterations occur at these phases and are used by researchers to assess burning conditions and infer archaeological cremation practices. It is important to highlight that while microscopic H-I alterations are more accurate in the assessment of burning intensity because they are less vulnerable to external stimuli (staining from the burial environment or fragmentation from the disturbance of the burial context), studies advise the combined examination of macro- and microscopic alterations to obtain a more holistic interpretation of firing conditions (Squires et al., 2011; Thompson et al., 2016).

Macroscopic colour change is arguably the best-studied H-I alteration that occurs in bone (Shipman et al., 1984; Munro et al., 2007; Alunni et al., 2014; Ullinger and Sheridan, 2015). Examiners have used this feature with the aim of assessing firing temperature, exposure time, body position in relation to the fire and oxygen availability (Ellingham et al., 2015). When subject to extreme heat, bone will pass through a sequential spectrum of colour change, caused by the combustion of bone’s organic and inorganic components, this colouring can also be influenced by the oxygen availability during the process (Ellingham et al., 2015). Initially, bone will change from ivory to brown, black, grey, and finally white (Mayne Correia, 1997). Research has found that this sequence of H-I change is always consistent, but Thompson et al. (2016) has emphasised that several variables can have an effect on burned bone colour and should be viewed as a tentative indication of temperature. In addition, this method is qualitative in nature, meaning that it is based on the examiner’s interpretation of colour and is subject to bias. Macroscopic colour change should therefore be teamed with other methods to infer burning intensities (Squires, 2015).

Other macroscopic changes in bone that occur when heated include warping, fracture patterns, size change and weight loss (Thompson, 2005; Gonçalves et al., 2011; Gonçalves et al., 2015; Vassalo et al., 2016; 2017). While research has considered these H-I alterations in relation to the taphonomic preservation of bone before and after burning, caution is advised when assessing fractures and warpage; experimental research has reported differing results suggesting that the cause of these features is not yet fully understood (Gonçalves et al., 2015).

## Histomorphology in Cremation Research

The microstructure of bone demonstrates increased crystallization when subject to higher temperatures (Thompson et al., 2016); it becomes more disorganised with the degeneration of Haversian systems, Volkmann’s Canals and canaliculi (Squires et al., 2011). Histomorphological studies in cremation research have been examining these microscopic alterations in burned bone since the 1940’s; Forbes’ (1941) was one of the first to observe microstructural changes to bone when exposed to increased temperatures. There have been some discrepancies between experimental studies. For example, examiners have reported both an increase and decrease in osteon size as a result of an increase in temperature (Forbes, 1941; Bradtmiller and Buikstra, 1984; Nelson, 1992; Hummel and Schutkowski, 1993). In addition, the depletion of histological structure has also been described to occur at different temperatures (Brain, 1993; Hanson and Cain, 2007; Squires et al., 2011; Absolonová et al., 2013). These discrepancies have been attributed to a lack of standardisation in experimental design and sampling methods (Gonçalves, 2011).

Another limitation of this field of research is the use of qualitative methods to examine the microstructure of burned bone. In the past, studies have visually assessed H-I alterations at a microscopic level and compared them with burned bone samples of known temperature and duration in order to estimate the burning intensity achieved (Nicholson, 1993; Squires et al., 2011; Castillo et al., 2013). While this approach has been applied successfully in the past, it is hindered by inter-observer biases, and a lack of standardisation. Quantitative petrography aims to tackle these methodological drawbacks by statistically categorising burning intensity based on the quantification of H-I alterations recorded from bone thin-sections (Carroll and Squires, 2020). Currently, this approach has been applied to modern burned animal bone samples in a small pilot study (Carroll and Squires, 2020). This is the first study to apply this new approach to the analysis of archaeological burned bone.

## 1.3 Cremation in Roman and Anglo-Saxon Britain

From the 1st century BC to the 2nd/3rd century AD cremation was the predominant burial right across large parts of Britain (McKinley, 1994; Williams, 2008). Roman accounts of cremation funeral customs describe how the body was washed and dressed before it was placed on a funeral pyre that was built from layers of wooden logs positioned at right angles and packed with tinder (Virgil, Aeneid 6, 218-220; Vitruvius, on architecture, 2.9.15). Offerings of food, animals and pots were placed on the pyre as part of the ceremonial process (Hope, 2009; Cerezo-Román et al., 2017). Davies (1999) has described how the decoration and size of the pyre may have varied according to resources, gender and status. The deceased was left to burn completely before the remains were gathered and buried; several sources have noted that an incomplete cremation would condemn the soul to roam restlessly for eternity (Lindsay, 2000 Cerezo-Román et al., 2017). It is important, however, to consider the validity of these historical sources. Cerezo-Román et al. (2017) emphasises that these accounts are biased towards the social elite in Rome, and therefore are not necessarily representative of Roman Britain. For example, cremated remains recovered from the Romano-British burial record display the full spectrum of macroscopic colour alteration, with white being the predominant colour observed, indicative of both complete and incomplete oxidization (McKinley, 2000; 2004; 2008; Márquez-Grant, 2008). McKinley (1997) has described how this level of diversity is ‘normal’ for cremation deposits from Roman Britain.

In the early Anglo-Saxon period, cremation was mainly practiced from the early 5th century AD to the mid-6th century AD across eastern England, although this funerary rite persisted at some sites into the early 7th century AD (Squires, 2016). Cemeteries where cremation was the predominant mortuary tradition were often large, containing hundreds (e.g. at Sancton, East Riding of Yorkshire, and Elsham, North Lincolnshire) and, in some cases, thousands of cremation burials (e.g. at Cleatham, North Lincolnshire, and Spong Hill, Norfolk), which served several settlements (Squires, 2012). There are strong parallels with the cremation rite at these sites with those found on the continent (Squires, 2016). There are no written records from the period in question, meaning that interpretation of this funerary practice is reliant on the physical evidence. Individuals were typically cremated with a range of animals and (burnt) pyre goods, and often buried with (unburnt) grave goods in cinerary urns. Associations between biological sex, age, social standing, identity and ideological beliefs have been detected through analyses of the biological attributes of the deceased and the animal offerings, pyre and grave goods, cinerary urns in which they were buried, use of the multiple burial rite and burning intensity (McKinley, 1993; 1994; Squires, 2013; 2015; 2016; 2017).

It is clear from this review that there are some similarities between Romano-British and Anglo-Saxon cremation practices, including the provision of pyre goods, as well as grave goods, and faunal offerings. However, it is also important to highlight the key differences in this burial rite between these two historical periods. As previously mentioned, the number of cremation burials is considerably higher at Anglo-Saxon burial grounds as cemeteries often served more than one settlement (Squires, 2012). In contrast, in Roman Britain larger settlements including *municipia* and *Civitas* regularly had multiple satellite burial grounds. At the Late Iron Age and Roman settlement of Baldock, Hertfordshire, for instance, a minimum of 22 formal cemeteries have been identified (Fitzpatrick-Matthews, 2016). There are also differences between Romano-British and early Anglo-Saxon cremation cemetery organisation. During the Romano-British period cemeteries were highly organised, especially at urban centres. Usually placed near the entrance of a town, cemeteries were arranged in neat rows in association with boundary features. The overall lack of intercutting and overlapping burials indicates the use of grave markers to avoid disturbing pre-existing graves (Cleary, 2015). The paucity of certain demographic groups across cremation and inhumation burial grounds, including infants and females, also suggests distinctions according to sex and age (Redfern and DeWitte, 2011). However, in Anglo-Saxon cremation cemeteries, there is little evidence of segregation based on an individual’s age, sex, gender, social standing, or ideological beliefs (Squires, 2013). Instead, it appears that individuals were buried in their household units (Ravn, 1999; Squires, 2013).

# **2. Materials and Methods**

## 2.1 Materials

Thin-sections from two archaeological sites were examined using the quantitative petrographic method proposed by Carroll and Squires (2020). All human bone was handled in accordance with the British Association for Biological Anthropology and Osteoarchaeology code of ethics (2019a) and code of practice (2019b). Permission to examine the Elsham thin-sections was granted from North Lincolnshire Museum and permission to sample the burned bone from Folly Lane was provided by the curator of the Verulamium Museum (St Albans). Ethical approval to conduct this study was granted by the ethics committees of Staffordshire University and Reading University. A single fragment of burned bone (either a femur, tibia, humerus, radius or ulna) was collected from each cremation burial for sampling. Sections of long bone that represented the main macroscopic colour of each cremation deposit were chosen. While experimental research has found that thermal alteration varies throughout the body as a result of the varied distribution of soft tissue (Schmidt and Symes, 2008; 2015), long bones are better suited for thin-section analysis because of the larger sample area of the cross section.

## 2.1.1 Sites

*Folly Lane, Hertfordshire*

The Romano-British samples came from Folly Lane cemetery in Hertfordshire (Figure 1). Fifteen bone samples were taken from 12 adults and two juveniles/adults from separate cremation burials. Folly Lane is located 1.4 kilometers north-east of the Roman town of Verulamium. The settlement in which the burial ground is situated became a *municipium* following the Roman conquest (Niblett, 1999). The site was first discovered in 1991, but due to time restrictions and limited financial support the full extent of the site could not be investigated; a small cremation cemetery and several inhumations were recovered spanning the mid-1st century AD to the mid-late 3rd century AD. The inclusion of an Iron Age high-status cremation burial of a client king, as well as a funeral shaft that was later replaced by a Roman temple suggests that, at some point, the cemetery was reserved for the social elite. This is reinforced by the addition of several wealthy grave goods, such as bronze and copper alloy objects. The original anthropological assessment by Mays and Steele (1999) did not discuss the heat-induced alterations in the burned bone.

**Figure 1:**Map of Folly Lane (St Albans, Hertfordshire) and Elsham (North Lincolnshire).

*Elsham, North Lincolnshire*

The early Anglo-Saxon samples used in this study came from the cemetery of Elsham, North Lincolnshire (Figure 1). The cemetery lies nineteen kilometers to the north-east of the contemporary cremation-dominant cemetery at Cleatham (Squires, 2012). This site was excavated in 1975 and 1976, resulting in the recovery of 552 cremation burials (excluding animal burials) and eight inhumation burials. Osteological analyses of the cremated skeletal remains revealed a total of 564 individuals as a result of multiple burials (Squires, 2012). Given the large number of individuals buried at Elsham, it appears that the cemetery served several settlements. A total of 16 bone samples were chosen at random and comprised of 12 adults, two adolescent individuals, and two children. The social status of these individuals is unclear, as the pyre good, grave goods, and several of the urns associated with the individuals examined were highly fragmented and damaged (Squires, 2011). Previous anthropological assessment, including a qualitative-based histomorphological examination, concluded that bone at this site was typically subjected to temperatures between 600°C to 900°C under oxidising conditions (Squires et al., 2011).

2.2 Methods

## 2.2.1 Macroscopic Colour

As the burned bone samples used in this study derived from two separate research projects (Squires et al., 2011; Carroll, 2019), two methods were employed to record macroscopic colour. The cremated remains from Folly Lane, Hertfordshire, were assessed using the gradient form used by Munro et al. (2007) and Thompson et al. (2016). While Munsell (2000) colour charts were used to record the burials from Elsham, North Lincolnshire. As each technique refers to the same colour spectrum, the descriptions of macroscopic colour produced can be compared in this study. Every macroscopic colour observed in each cremation deposit was recorded (see section 3.1 Macroscopic Colour Change and Table 2).

## 2.2.2 Quantitative Petrography

The Anglo-Saxon thin-sections from Elsham were produced by Squires et al. (2011) and generously made available for this study. The slides were made using a different methodology to the one applied to the Roman thin-sections (see Carroll and Squires, 2020, for method). These samples were polished to 40μ, while the Anglo-Saxon thin-sections were cut to 60μ, 75μ and 100μ; the differential thin-section thicknesses may influence the microscopic features observed.

All burned bone thin-sections in this research were examined using the quantitative petrographic method introduced by Carroll and Squires (2020). The histomorphology of the burned bone samples were examined using the PETROG motorised stepping stage and 2018 PETROG software provided by Conwy Valley Systems Limited. The 2018 PETROG software was used to identify and count microscopic features in the sample area using the software dictionary, developed from the criteria provided by Squires et al. (2011). The four categories of burning intensity identified by Carroll and Squires (2020) were used here: I: 100-400˚C; II: 500-600˚C; III: 700-900˚C; and IV: 1000-1100˚C (See Table 1).

**Table 1:** Burning categories identified by Carroll and Squires (2020) using quantitative petrography.

# 2.2.3. Statistical Analysis

The data from Carroll and Squires (2020) was used in this study to statistically assign the archaeological thin-sections to one of the four burning categories identified in their pilot study using a discriminate function analysis. This test was performed on the archaeological data to group the samples according to burning intensity and was chosen because it is effective in predicting category membership according to a set of variables (Jain, 2010).

# **Results**

## 3.1 Macroscopic Colour Change

The colour of the cremated remains from the Anglo-Saxon cemetery of Elsham, and the Roman burial ground of Folly Lane are recorded in Table 2. Overall, the burned bone from both sites displayed a broad spectrum of colour alteration, from white to black. All of the burials from Folly Lane showed at least two H-I colours. This is common for cremation deposits due to the varying distribution of fatty tissue through the body (DeHaan, 2015). White was the predominant pigmentation recorded for the Folly Lane burials, however black (charring) was identified for Burials 7, 18 and 21 (Table 2). The evidence for charring in these cremation deposits indicates the preservation of bone’s organic material, indicating insufficient firing.

The sixteen cremation burials from the Anglo-Saxon site of Elsham were mostly white in colouration, demonstrative of the mineral component of bone fusing (Table 2). Unlike the burned bone from the Roman burials, only five (31.3%) of the Anglo-Saxon cremation deposits (EL75AO; EL75BK; EL75BQ; EL75CA; EL76MQ) displayed white colouration. This indicates sufficient oxidization and complete cremation. The remaining eleven (68.8%) Anglo-Saxon burials displayed more than one H-I colour. Interestingly, six (37.5%) of the cremation deposits (EL75CR; EL75GA; EL75HL; EL75PF; EL75PM(b); EL76EI) showed signs of charring, suggesting incomplete oxidization.

**Table 2:** Archaeological burned bone thin-sections from Folly Lane and Elsham.

## 3.2 Quantitative Petrography

The assessment of burning intensity using quantitative petrography is recorded in Figure 2. An examination of the archaeological thin-sections has demonstrated a variety of burning intensities, ranging from categories II-IV (500˚C-1100˚C). Of the 31 samples examined in this study, 51.6% (n = 16) reached temperatures in excess of 1000˚C, this is complimented by white being the predominant macroscopic colour identified. Folly Lane Burials 7, 10, 12, 18 and 22 were the only samples that did not demonstrate high burning temperatures. In particular, Burial 18 was assigned to category II (500-600˚C) as it displayed some organic material and defined microstructures within the sample area (Figure 2). This result most accurately correlates with the black and brown macroscopic colouration recorded and is suggestive of incomplete oxidisation.

Six (37.5%) of the thin-sections from Elsham displayed no micro-features including Volkmann’s Canals or organic material, and complete fusion of hydroxyapatite crystals was recorded. These observations fell within category IV indicative of temperatures of 1000˚C and over. Interestingly, similar results were ascertained from the examination of the Roman thin-sections from Folly Lane (Figure 2). In contrast to the Roman thin-sections, more of the Anglo-Saxon burned bone samples (n = 5, 31.3%) showed identifiable micro-features with only a small percentage of hydroxyapatite fusion, suggesting temperatures between 500˚C-600˚C. The petrographic observations recorded here compliment the results from the macroscopic colour change, with these burned bone deposits displaying clear evidence of charring. Overall, it is clear from Figure 2 that the cremated individuals from Anglo-Saxon Elsham displayed greater variability of burning intensities, compared to the Roman samples from Folly Lane.

**Figure 2:** Number of individuals from Folly Lane and Elsham according to burning intensity.

# **Discussion**

This is the first study to apply quantitative petrography in the analysis of archaeologically burned bone. The methodology used in the present study corresponded well with macroscopic colour change, and overall produced complimentary results. The only anomaly observed was burial 21 from Folly Lane, which displayed a range of colour alteration ranging from black to white, as well as severe depletion of the bone’s microstructure indicating high burning temperatures (1000˚C-1100˚C). It is possible that this variation in preservation indicates fluctuating or reducing burning conditions. The thin-sections from the Anglo-Saxon cemetery of Elsham were examined previously by Squires et al. (2011) as part of a separate research project. In this instance, Squires et al. (2011) employed a more traditional approach in the assessment of histomorphology and visually examined each sample under a Leitz LaborLux. This technique also found the Elsham cremation deposits to display a range of burning intensity from 300˚C to 900˚C+ with most reaching temperatures above 900˚C, which indicates that the data presented in this study appears to be reliable.

The macroscopic and microscopic analysis conducted here demonstrated that both the Roman and Anglo-Saxon cremation deposits showed a variety of burning intensities, with complete and incomplete oxidization.

The majority of burials from Folly Lane (n = 10, 66.7%) and Elsham (n = 6, 37.5%) are skewed towards higher burning categories with samples displaying hydroxyapatite fusion, accompanied by white colouration indicative of temperatures above 1000˚C. The remaining cremated bone deposits exhibit a spectrum of macroscopic colour change and variable preservation of the bone’s organic component and microstructure, which correlates with lower burning temperatures. This variation in burning intensities is common amongst archaeological cremation deposits. McKinley (1997, 66) describes this level of diversity as ‘normal’ and reflects issues concerning oxygen supply, duration and the temperature of the fire. For instance, a funeral pyre experiment by Carroll and Smith (2018) examining the H-I alterations in burned bone described how a sufficient oxygen supply on the day of the experiment caused by a strong wind helped with combustion and consequently complete oxidization of the burned bone. It is therefore worth considering that archaeological cremations would have been vulnerable to poor weather conditions, insufficient fuel supply and pyre maintenance (Squires, 2015; 2017). Interestingly, the burials from the Anglo-Saxon cemetery of Elsham demonstrated greater diversity compared to the cremated remains from Folly Lane. It is important to consider that the thin-sections from Elsham were subjected to a different sampling strategy. Here, preservation, completeness, and colour of long bone fragments dictated the bones selected (as also seen in Squires et al., 2011). It is possible that this had an impact on the diversity of burning intensity recorded compared to the Folly Lane burials, however, variation could also represent different cremation practices.

Accounts of Roman funerals indicate that cremations at urban centres were managed by *ustores,* or professional cremators (Virgil, Aeneid 6, 218-220; Thompson et al., 2016; Cerezo-Román et al., 2017) While the validity of these sources are questionable, McKinley (2015) has suggested that based on her examination of oxidization of Romano-British cremation deposits professional cremators may well have operated in Roman Civitas, municipia or coloniae and further that the quality of cremation would have been subject to the amount paid for their services. The results from the macroscopic and microscopic analysis conducted in this study indicate that a larger percentage of the individuals from Folly Lane (n = 10, 66.7%) were subjected to high burning intensities, achieving complete oxidization. Folly Lane was one of the burial grounds associated with the Romano-British town of Verulamium (Mays and Steele, 1999; Niblett, 1999). The few graves uncovered from this small cemetery, which include those examined in this paper, were buried with multiple grave and pyre goods and were associated with an extensive funerary shaft that included the burial of an Iron Age client king which later became the site of a Roman temple (Niblett, 1999). This indicates that the Folly Lane cemetery served social elites from the 1st century AD to the mid-late 3rd Century AD. It is possible, based on the evidence presented here, that the elite Roman families of Folly Lane hired *ustores* tocremate the bodies of their deceased relatives.

With regards to the Anglo-Saxon cemetery of Elsham, evidence of variable degrees of oxidation on the cremation pyre have not only been observed elsewhere from early Anglo-Saxon England, but also from contemporary sites in Germany (Squires, 2016). Here, these Late Roman Iron Age (c. AD 180-400) to Migration Period (c. AD 400-550/600) cremation deposits show similarities in terms of macroscopic colour and large fragment sizes, indicative of minimal intentional disturbance of the pyre (e.g. tending to encourage oxidising conditions) (McKinley, 1994; Squires, 2016). It is possible that the cremations from Anglo-Saxon Elsham were managed less effectively by family members and retainers as opposed to professional cremators. However, it is worth noting that none of these contemporary sites from Germany have been subjected to histomorphological analyses as a means of understanding burning intensity. In contrast to the Roman period (Thompson et al., 2016), the form of pyre constructions from early Anglo-Saxon England is unknown. As such, it is possible that the use of differential pyre structures during this period (e.g. see Wells, 1960; McKinley, 1994) could also account for the greater variability in microscopic H-I alteration recorded here, particularly, if under-pyre scoops or pits were not employed.

The results presented here from Folly Lane are quite unusual for Romano-British cremation burials. In McKinley’s (1997) examination of Roman cremation deposits she observes diverse microscopic colour change ranging from black to white, and notes that this level of diversity is expected for burials from this historical context. In addition, a study of 1st – 5th century AD military cremation burials from Northern Britain by Thompson et al. (2016) using both macroscopic and microscopic analyses recorded medium burning intensities; this, combined with the large bone fragments, indicated minimal interference with the pyre. By placing the results from Folly Lane in this wider context, it is clear that individuals were subject to unusually high burning intensities with potentially greater pyre intervention due to the use of *ustores*, reinforcing that the burial ground was reserved for the socially elite.

Even though different long bones were selected from the Elsham sample, there is diverse burning intensity when examining at the same type of bones, e.g. femora were assigned to quantitative categories II, III and IV. The variability of burning intensity observed at Elsham is in line with observations made elsewhere from early Anglo-Saxon England and contemporary sites in Germany (Squires 2016). Here, Late Roman Iron Age (c. AD 180-400) to Migration Period (c. AD 400-550/600) cremation deposits show similarities in terms of the macroscopic colour and large fragment sizes, indicative of minimal intentional disturbance of the pyre (e.g. tending to encourage oxidizing conditions) (McKinley, 1994; Squires, 2016). The diversity of burning patterns observed at Elsham perhaps indicates that cremation pyres were managed less effectively by family members and retainers, as opposed to professional cremators. Despite such variability in burning intensity, there is no evidence of failed cremations from early Anglo-Saxon England. Furthermore, in contrast to the Roman period (Thompson et al., 2016), the form of pyre constructions from early Anglo-Saxon England is unknown. As such, it is possible that the use of differential pyre structures during this period (e.g. see Wells, 1960; McKinley, 1994) could also account for the greater variability in microscopic H-I alteration recorded amongst the Anglo-Saxon samples, particularly, if under-pyre scoops or pits were not employed.

It is clear from this research that quantitative petrography, teamed with other modes of macroscopic analysis is an effective method for analysing burning intensity from archaeologically cremated bone. However, the sample sizes examined in this study are relatively small. This was unavoidable due to the limited number of burned bone thin-sections available for examination. This is problematic because many variables can influence H-I alterations in burned bone as pointed out by Thompson et al. (2016); including, sufficient fuel, oxygen supply, size and construction of pyre. It is therefore essential to be cautious when interpreting the differences found between Roman and Anglo-Saxon cremation practices. Larger sample sizes are needed in future research to identify statistically significant trends in cremation analyses.

# **Conclusion**

This study has highlighted the benefits of teaming quantitative petrography with macroscopic colour change to infer burning intensity in archaeologically burned bone. It is the first study to use histomorphometry to analyse Roman and Anglo-Saxon burned human remains, and will hopefully contribute to our continually expanding knowledge of cremation practices in the past. The macroscopic and microscopic observations recorded show a mix of burning intensities, with the majority of individuals falling within category IV indicative of high burning temperatures. Interestingly, a larger percentage of individuals from Folly Lane reached temperatures over 1000˚C, which may represent the use of *ustores* or professional cremators at the Roman town of Verulamium.

Due to the limited availability of burned bone thin-sections the sample sizes used in this study are relatively small, which meant that statistical analysis could not be employed to identify significant trends in Roman and Anglo-Saxon cremation practices. It would therefore be beneficial to apply quantitative petrography to a larger sample of archaeological remains. In addition, future research using this new approach could also focus on comparative analyses between different settlement types, alongside variations over time; this may identify varying responses to resource availability and population size.

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