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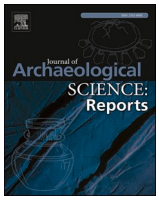

Analysing Roman hobnail footwear in soil-blocks using radiography: Design, dating, and identities

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ABSTRACT

This study presents the radiographic imaging and analysis of eight soil-blocks containing hobnailed footwear from a Romano-British cemetery (5-5a Rhodaus Town, Canterbury, England). The site, dated to the Late Roman period, underwent archaeological excavation prior to commercial development in 2019. Of the 215 inhumations identified, 51 contained evidence of footwear by virtue of hobnails in varying quantities. For a selection of graves, radiography was performed upon soil-blocks with the aim of demonstrating footwear design and dimensions using hobnail distribution, despite the absence of leatherwork. The resultant imaging showed a range of designs in keeping with known examples elsewhere and can assist dating according to changes in fashion. Dimensions of footwear length and width appeared to correlate with descriptions of interred individuals within the osteological report. Limitations for the use of radiography includes taphonomic changes within the grave, damage during excavation, or post-excavation changes within the soil-block which alter the original position of hobnails. Geometric unsharpness is also an inherent limitation within radiography and impacts the accuracy of measurements. Despite this, radiography has been demonstrated as a useful tool, providing a permanent imaging record prior to micro-excavation and aiding identification of footwear type and design. Of particular utility is the imaging of soil-blocks where no skeletal remains have survived, in which case footwear design and dimensions may offer the only clues for age-at-death, biological sex, and social status.

1. Introduction

The recovery of hobnails during excavation of Roman burials provides a tantalising glimpse into the clothing habits of the deceased. The frequent occurrence of hobnails belies their importance within Roman life as an essential component to bind leatherwork together for the creation of footwear. When located at the feet of an individual and in sufficient quantities in discreet proximity, one may surmise they originated from footwear and once permitted traction upon the earth. If recovered with care, the position and quantity of hobnails may suggest construction and therefore type of footwear, ranging from the soldiers' *caligae* (robust and therefore typically considered as boots), closed shoes (*calceii*), nailed sandals (*soleae*) or even wooden pattens (*sculponeae*) (van Driel-Murray, 2007). If discernible, the stylistic hobnail distribution upon the sole may act as independent dating evidence for the quickly changing fashions across the Roman Empire (van Driel-Murray, 2001). Indeed, hobnail use is characteristically Roman, being introduced into the northern provinces only to decline with the collapse of the Empire (Philpott, 1991; Shopland, 2005). As such, the discovery of hobnails or the more perishable leatherwork signifies an opportunity within archaeology to reconstruct military, social or production activities based upon grave finds (Eckardt, 2005; Allison, 2015). And yet, burial reports have been lamented as under-representing the value of hobnails when the associated leatherwork is absent (van Driel-Murray, 1999). Where preservation allows, soil-block lifting is the preferred method, enabling off-site micro-excavation, detailed recording, and analysis in a controlled environment. However, when block lifting is not practical, careful on-site excavation and cleaning of hobnails is recommended, followed by photography or casting to record potential nailing patterns or estimate shoe size (van Driel-Murray, 2007).

This study considers the use of X-ray radiography with soil-blocks containing hobnails which have been lifted from British Roman burials. As a non-invasive, non-destructive investigative tool, radiography has been used to image the internal structure of archaeological specimens, especially within human bioarchaeology for trauma, disease and congenital abnormalities (Conlogue and Beckett, 2020; Elliott,

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2022). Its application with metalwork is also well recognised, with Caple and Garlick (2018) explaining its use for triaging finds for retention (or disposal), conservation or further analysis. Depending upon soil condition and duration of time within the grave, metal objects are typically corroded and/or impregnated with soil and may not be readily identified by eye. In such instances, radiography offers an opportunity to aid identification and possibly construction technique whilst also providing a permanent record which can be submitted as part of the archaeological site report (Fell, Mould and White, 2006; Historic England, 2018). The shape and form of items can be radiographically demonstrated using multiple projections from perpendicular angles, showing the presence of cracks, joins or porosities. In this way, the preservation status can be recorded (see Kraner et al, 2023), with modern digital radiography also allowing measurement of metalwork for quantitative analysis (Matthiesen, Salomonsen and Sørensen, 2004). The distinctive shape of hobnails lends itself to radiographic imaging, with a rounded head and protruding spike which is normally turned at the end as part of the footwear construction process (Fig. 1). A knowledge of hobnail use and footwear construction may allow interpretation of radiographs based upon the arrangement and orientation of nail head, shaft and point. Fig. 2 demonstrates a surviving hobnail shoe alongside common terms for portions of footwear.

The works of Carol van Driel-Murray (1989, 1995a, 1995b, 2001, 1999, 2007) have done much to inform our knowledge and understanding of Roman footwear using the remarkable finds at Vindolanda in England and Waiblingen/Walheim in Germany. Recovery of Roman footwear with surviving leatherwork has been apparent elsewhere too, with examples from Winchester (Booth et al, 2010), Roman Castleford (Cool and Philo, 1998), London (Dyson, 1986) and Carlisle (Zant, 2009). The very wet and anaerobic conditions provide preservation of vegetable-tanned leather (incidentally, another Roman introduction to northern provinces (Shopland, 2005)), with the majority of finds occurring as discarded, worn out shoes in ditches or refuse areas. There are also examples of intentional deposition in wells, theorised as token or substitute sacrifices in place of a somewhat more polluting (living) sacrifice (van Driel-Murray, 1989, 1999). Water-logged burials are rare but could theoretically contain preserved shoes *in situ* with their presumed owner. Buck et al. (2019) illustrates one example of water-logged remains from Vindolanda, albeit not a formal burial and termed as 'deviant body disposal' due to its location within a ditch. Alas, no footwear was recovered, despite the abundance elsewhere on site. As a result of these conditions, the archaeological record has a biased presentation of hobnailed footwear as disposed items rather than interred with the dead. Hobnails offer an underexploited opportunity due to greater durability and therefore survival in comparison to leather. When properly analysed and considered with the osteoarchaeological report, hobnails may offer a unique individual perspective for the deceased.

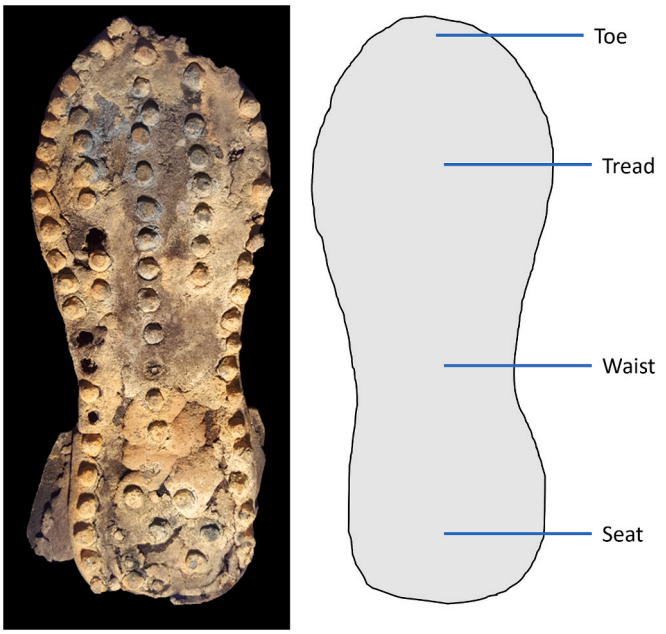

Fig. 2. Left: Example preserved hobnail shoe from Lincoln Roman waterfront (Photo: Copyright Lincoln Museum). Right: Shoe sole design terminologies (recreated from van Driel-Murray, 2007).

There is a lack of published research concerning radiography of hobnails within soil-block lifts, aside from brief accounts such as Wilson (2023, p. 7). The aim of this study was to explore the use of digital radiography with soil-blocks as a method of recording and analysis. For clarity, digital radiography refers to the use of computed radiography (CR) and direct digital radiography (DDR) technologies for imaging, both of which differ from screen-film radiography (with chemical processing) through the generation of digital images, by either latent (CR) or direct (DDR) detection. Benefits for digital radiography include speed of acquisition, a dynamic range (improving image quality), comparable spatial resolution, and lower radiation requirements for image generation (Körner et al., 2007). Importantly, digital files allow for manipulation and measurement of images, with the ability to adjust contrast and brightness without loss of data. With these advantages and abilities in mind, the authors sought to undertake DDR imaging of a limited collection of soil-blocks to aid confirmation and subsequent

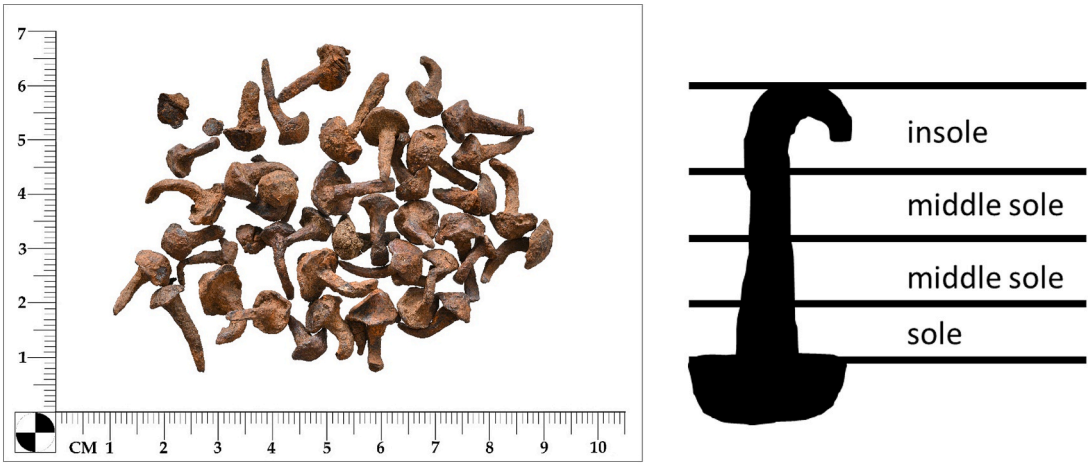

Fig. 1. Left: Roman hobnails found near Kiddington (Oxfordshire, United Kingdom) (Berkshire Archaeology, 2019). Right: Diagram showing use of hobnail to bind layers of soles together, with the end point turned-in (recreated from Shopland, 2005).

characterisation of hobnails. Of interest was whether radiography may demonstrate footwear dimensions, sole shape, or design patterns through the distribution of hobnails. The link between radiographic footwear appearances and identity of the deceased (sex, age, social status, origin) shall be discussed within this paper. Lastly, recommendations for future practice are considered.

2. Materials and methods

The site known as 5-5a Rhodaus Town in Canterbury (Kent, United Kingdom) underwent archaeological investigation in 2019 by Canterbury Archaeological Trust (CAT) prior to commercial development. With a total area spanning 1968 m^2, it was partially situated within the Canterbury Area of Archaeological Importance, and revealed archaeological evidence spanning prehistoric, Roman, post-Roman and post-medieval periods. During the Late Roman period a formal cemetery extended across the development area, and as a result of the investigations 215 inhumation graves were identified, with the remains of 205 individuals being recorded. Assessment of the dateable materials suggests that the cemetery was active no earlier than the late third century AD and continued in use until the mid-fifth century AD. Pertinent to this paper, evidence of footwear was present in 51 graves, with large numbers of hobnails present at the feet, indicating that the deceased had been interred with shoes or boots (Helm et al, 2021). When hobnails arranged in an apparent pattern were uncovered, they were lifted following the guidelines outlined in the First Aid for Finds Manual (Watkinson and Neal, 1998). The lifting strategy employed a combination of block-lifting and encapsulation techniques to ensure the immobilisation of the artefacts. Eight soil blocks from five graves suspected of containing complete hobnail footwear were lifted and form the sample within this study. Please refer to the Supplementary Material file for full grave details and block lifting process.

A direct digital radiography system (Agfa Platinum Detector, Agfa Healthcare United Kingdom Limited) was used with a clinical X-ray table and ceiling-mounted X-ray tube (MULTIX TOP, Siemens Healthcare GmbH) based at Canterbury Christ Church University. Imaging was performed by a diagnostic radiographer/archaeologist, alongside an osteoarchaeologist. Imaging was performed with footwear *in situ*, without removing packaging. A single radiographic view was the norm, with the wooden backing being placed upon the detector with the 'shoe sole' (as indicated by the outline of hobnails) presumed to be parallel. When such an outline could not be deduced, alternative radiographic views were deployed. Imaging parameters were 60 kVp, 5mAs, with a 100 cm source image distance, as determined by prior experience and several preliminary test images. Physical radiographic markers (i.e. lead (Pb) left or right letters) were placed alongside the soil blocks during imaging to assist interpretation of the images, with all other annotations (regarding positioning) being added digitally during post-processing. Radiographic images were exported as Digital Imaging and Communications in Medicine (DICOM) file format. Photography was undertaken as a supplementary method of recording, ensuring visibility of the site code, context, or grave number.

Imaging was analysed using RadiAnt DICOM viewer (RadiAnt Medixant, 2024) upon medical-grade computer monitors. For each soil-block, the position of hobnails on the horizontal (X) and vertical (Y) axis were recorded onto an Excel spreadsheet and presented as a scatter graph. In doing so, the quantity and relative distribution of hobnails could be demonstrated. Measurement of length (seat to toe) and greatest width was made using the measuring tool within RadiAnt DICOM viewer in centimetres. Previously published accounts of sole shape (Fig. 3) and nailing patterns (Table 1) were then used to estimate dating of the burial.

3. Results

Hobnails were identified as being distinct from other metallic

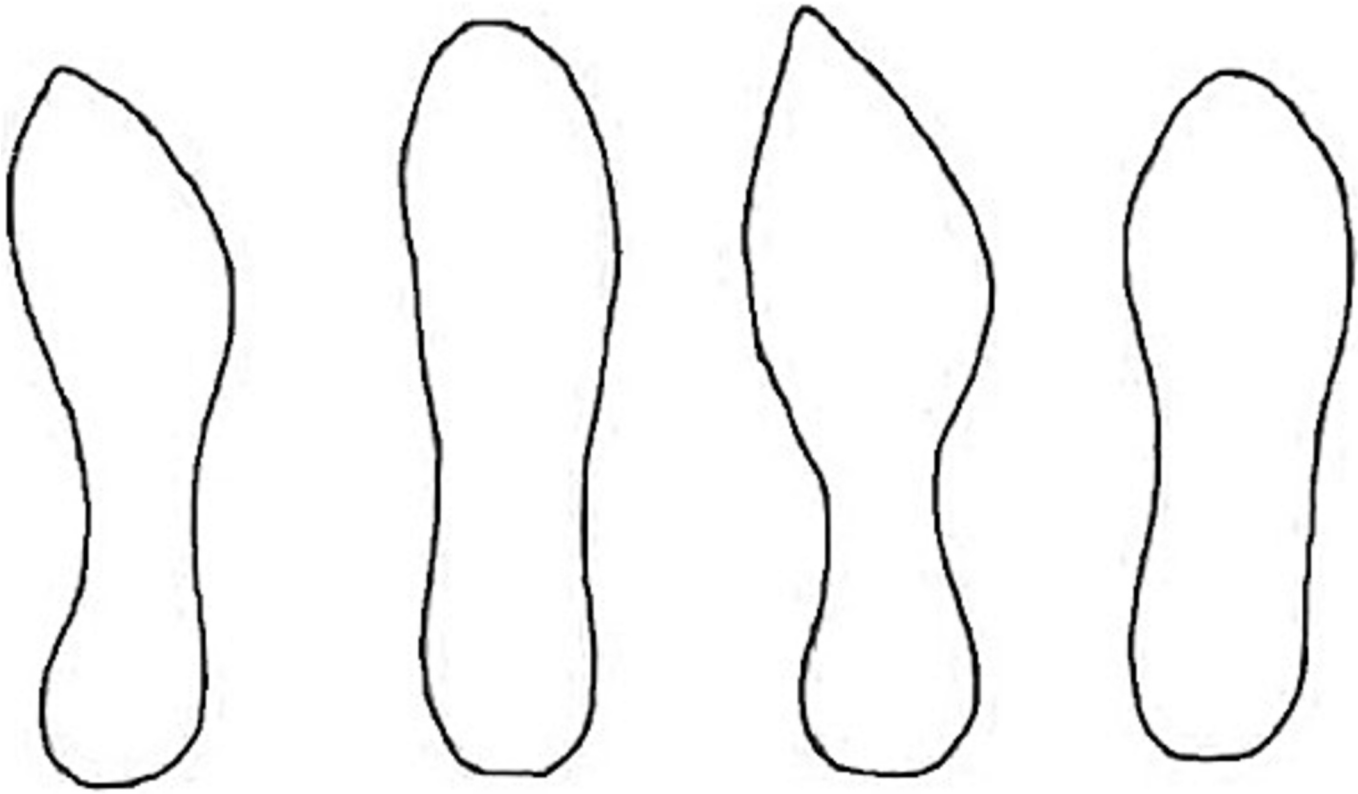

Fig. 3. Sole shape designs, from left to right: Swayed (1st century), straight (later 1st century, first decade of second century), swayed and pointed (second half of 2nd century), wide and blunt (3rd and 4th century). Recreated from van Driel-Murray (2007).

Table 1
Nailing patterns with associated dating (AD) from Vindolanda (van Driel-Murray, 2007).

	Description	Prevalence
Pattern 1	A single line of nails around the edge of the sole	Greater numbers in later periods. Later 2nd century onwards.
Pattern 2	A double line of nails around the edge of the sole.	Throughout all periods in small numbers.
Pattern 3	A single line of nails around the edge of the sole, with a double line at the outside edge.	Greater numbers in early periods. 1st/2nd century
Variants	Straight row of nails down the whole length of the sole A gap left at the waist Widely spaced nails down the length of the sole	
Indicators	P – Patterned (S-shape, lozenges, circles, swastikas, tridents) T – Tendril S – Sparse (fewer than 15 nails used in total)	Early 3rd-4th century

fragments or small stones by their irregular but characteristic outline and frequent lucency within the head, likely due to a combination of corrosion and construction methods (Fig. 4). Radiography was successful in demonstrating hobnails in all soil blocks despite the presence of wooden backing boards and packaging material. Across all eight soil blocks, 545 hobnails were recorded and depicted as scatter graphs (examples shown in Figs. 5 and 6). No lower limb bones were identified within the soil blocks. An overview of results can be seen in Table 2, with descriptions of the soil block condition (fragmented/intact), quantity of hobnails, approximate footwear dimensions, sole shape and nailing pattern. Approximate dimensions, based upon hobnail locations, were possible for five shoes and were in keeping with adult decedents as stated within the archaeological site report. For the majority of the sample, it was not possible to determine a sole shape, although three were deemed to be wide and blunt and one swayed and pointed. Similarly, three were of indeterminant nailing pattern, with four classified as Pattern 1 (single line of nails) and one as possible Pattern 2 (double line of nails). Nailing patterns of the interior sole were highly variable, ranging from sparse (Gr7, SM24) to high density (Grave 101), with generally fewer nails at the waist. One shoe from grave 24 (small find, SF100) suggests a decorative nailing pattern extending from the waist to the tread, however its original form is unclear due to taphonomic changes. Unfortunately, several shoes were either highly fragmented (Grave 136, SM345/SM346) or seemingly compressed during deposition (Grave 24, SM 99) and offered fewer opportunities for interpretation (Fig. 7).

4. Discussion

4.1. Correlations in footwear design, changing fashions and site dating

The excavation of 5-5a Rhodaus Town in Canterbury led to an interpretation of a formal cemetery in the Late Roman Period comprising of 215 inhumation graves. Of which, 51 contained evidence of footwear by virtue of hobnails either identified as scattered finds or conglomerations suggestive of entire shoes. Of the eight soil-blocks presumed to contain footwear a range of designs could be radiographically identified despite the variable preservation states and taphonomic changes. Although severely limited by sample size, the dominance of nailing pattern 1 coincides with a greater prevalence in later Roman period seen at other sites (van Driel-Murray, 1995a, 2007), with the dating of associated grave goods of 270–325 CE. Pattern 2, with a double line of nails on the outside edge, was observed in one shoe from Grave 136 (SF346) (Fig. 7b) which was highly fragmented as a result of unsuccessful lifting intervention. The ability to discern the characteristic pattern of double hobnails regardless of fragmentation highlights the value of radiography to demonstrate the overall distribution and any partial (but characteristic) patterns. Interestingly, pattern 2 was also found to be consistently used across all periods in small numbers at Vindolanda, although its prevalence within this study may be mere coincidence. Finally, sole shapes act as a separate dating feature with the changing Roman fashions. The presence of wide and blunt sole shapes supports a dating of later periods (3rd and 4th century) for this site, with one swayed and pointed shoe (Grave 24, SF100) hinting at an earlier dating for the second half of the 2nd century. But as van Driel-Murray (2007) points out, sole shapes are not exclusive to particular time periods and relatively natural forms always predominate.

Approximately a quarter of burials at 5-5a Rhodaus Town had evidence of hobnailed footwear, although only a small proportion were suitable for lifting. The cemetery demonstrated continued use until the mid-fifth century AD (Helm et al, 2021), well after the rapid decline in hobnail usage within the mid-fourth century AD and the end of imperial control (Philpott, 1991; Shopland, 2005; van Driel-Murray, 2007). Within Roman Britain, early examples of hobnailed footwear in burials were associated with middle-ranking status cremations, with the footwear placed either alongside or within the cinerary urn (i.e. burnt whilst being worn) (Philpott, 1991). Inhumations become more common by the 4th century CE in south central England, and so did burial with footwear, although there is considerable variation over time and between urban and rural settlements (Philpott, 1991). The early Anglo-Saxon period saw a transition away from burial with footwear, or at least the archaeological record suggests as much. This does not necessarily imply that the deceased lacked footwear, but that any footwear failed to survive. From a dating perspective, the presence of hobnails provides a useful marker for Roman influence and potential for comparison to other datasets locally or nationally. The decline of hobnailed footwear in the archaeological record from the very Late Roman period may represent a transition towards lighter footwear, to which 5-5a Rhodaus Town can neither support nor refute. For those that have been recovered as soil-blocks, the exact construction of each footwear remains unknown, such as the number of sole layers and design of the upper portion. Indeed, the upper portion would have provided further remit for site dating, as the changing fashions have been well documented from waterlogged sites (see Fig. 10 within van Driel-Murray, 2007). As 5-5a Rhodaus Town appears to be in usage beyond Roman occupation, the presence and characteristic patterns of hobnails helps to delineate between burial periods. As cautioned by Gerrard (2015), simplistic categorisation of sites as Roman/post-Roman needs a more nuanced approach which considers complexity of cultural dynamics and differences in urban versus rural contexts. In short, local fashions and the persistence of footwear use should not be discounted.

4.2. Comparison with osteological assessment

An obvious assumption is that the footwear was owned by the interred, but alternative explanations include accidental deposition, tribute, or preparation of the deceased for their onward journey (van Driel-Murray 1999; Swift et al, 2021). Such matters shall be discussed for social interpretation later and what follows here is an objective comparison with the osteological assessment. As reported by Rusu and Loe (2021), over half of the skeletons at 5-5a Rhodaus Town were either 0–25 % or 26–50 % complete, with a large proportion (>75 %) categorised as highly fragmented through post-mortem breakage. In fact, Grave 7 had no recoverable skeletal material at all, with designation as an adult only inferred by grave and shoe size. Once again Vindolanda may offer useful insight, with Greene (2014) segregating sex according to shoe size with lengths of 10–12 cm for infants, 19–22 cm for females, and 24–25 cm for males. Elsewhere, the Roman and late antique Egyptian collection from the Petrie Museum in London listed examples of infant (11.2–13.8 cm) and male (24.6–27.3 cm) leather shoes (Swift et al, 2021). Van Driel-Murray (1995b) tempered simplistic categorisation with caution though, with juvenile males falling within the range of

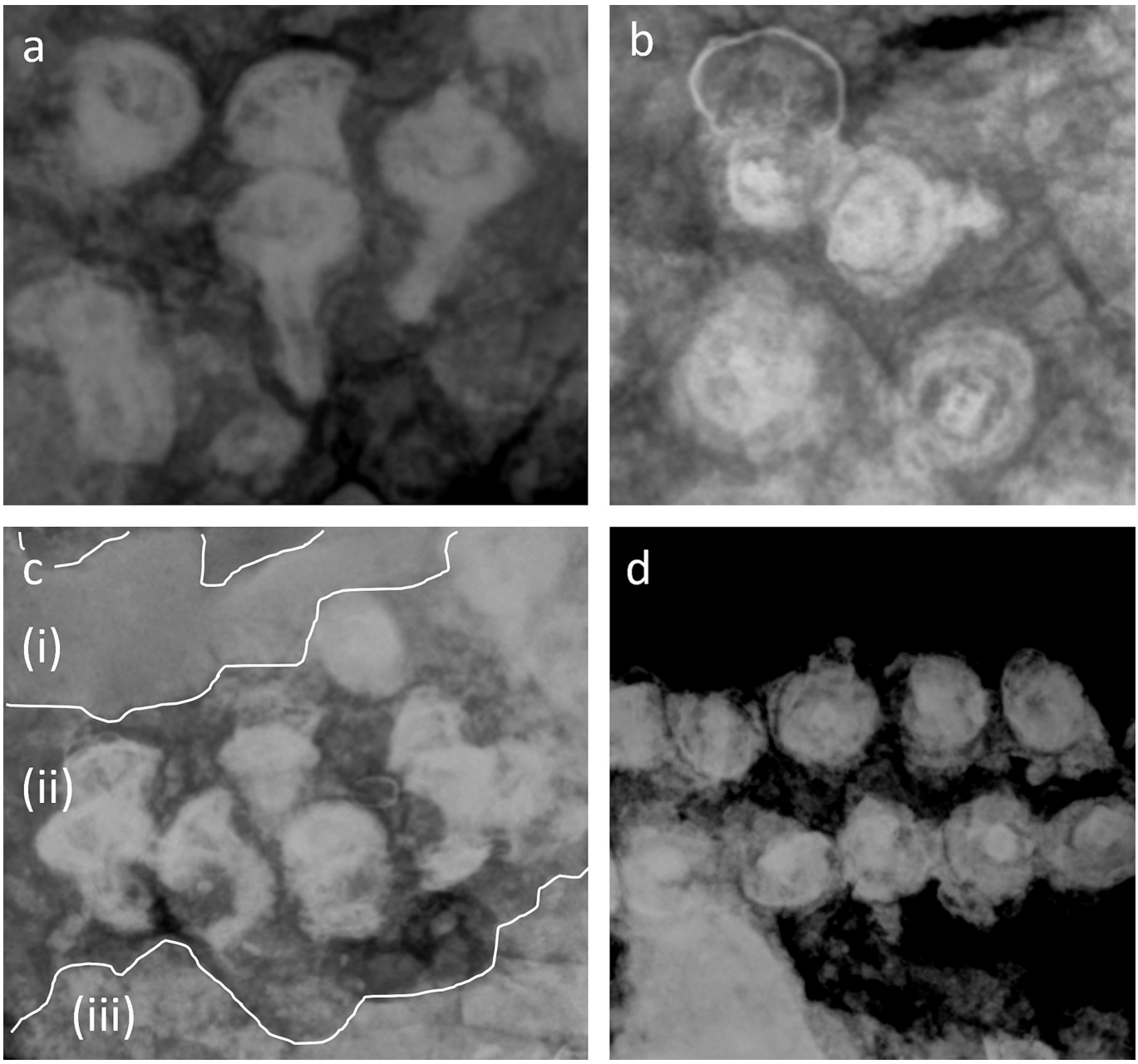

Fig. 4. Radiographic visualisation of hobnails. a) Side profile demonstrating point and head. b) Lucency in head due to corrosion. c) Variable densities due to (i) plaster, (ii) porous soil, and (iii) compacted soil with stones. d) Adjacent to little or no soil during radiography, causing high image contrast due to the difference in relative density.

adult female footwear size. In any case, sex estimation using shoe dimension has been explored with modern populations (Ozden et al, 2005; Atamturk, 2010), with a greater mean shoe length among males and comparable sizes with the abovementioned sources. Ownership and taphonomic changes notwithstanding, the estimated length of the hobnailed shoes appears to match the osteological assessment of adult remains where available (22.7 cm-29.2 cm). All but one grave had an uncertain sex estimation and none underwent aDNA analysis, making any inferences between shoe size and sex difficult. For example, Grave 117 was tentatively female but with a shoe length of ~ 27 cm. Additionally, the shoe waist could also be used to discriminate between sexes, with a smaller width suggestive of female ownership (≤4cm) (Greene, 2014). In this respect, waist sizes varied in this study (5.7–7.7 cm) and did not conform to the expected norm and are therefore perhaps unreliable. It should be noted that the accuracy of radiographic measurements with soil-blocks are not without limitations, and measurements may only be useful for differentiating extremes between infant and adult, or the upper/lower limits of male/female sizes.

Going beyond categorisation of sex and age at death, one may consider the wider osteobiography of the deceased. Specifically related to foot health and/or shoe wear, efforts in osteoarchaeology have suggested links between calcaneal spurs (Vaňatková et al, 2023) and hallux valgus (Dittmar et al, 2021) with historically popular (but detrimental) shoe fashions. Conditions such as flat feet (pes planus) postural defect have also been estimated with archaeological collections (Saldías et al, 2021) and there are rare examples of prosthetic limb usage in antiquity (Brier et al, 2015; Binder et al, 2016). Greene (2019) explored the notion of Roman podiatric knowledge through examples found within the Vindolanda shoe assemblage. She reports instances of metal bars being fitted around the heel to adjust gait and clusters of randomly nailed

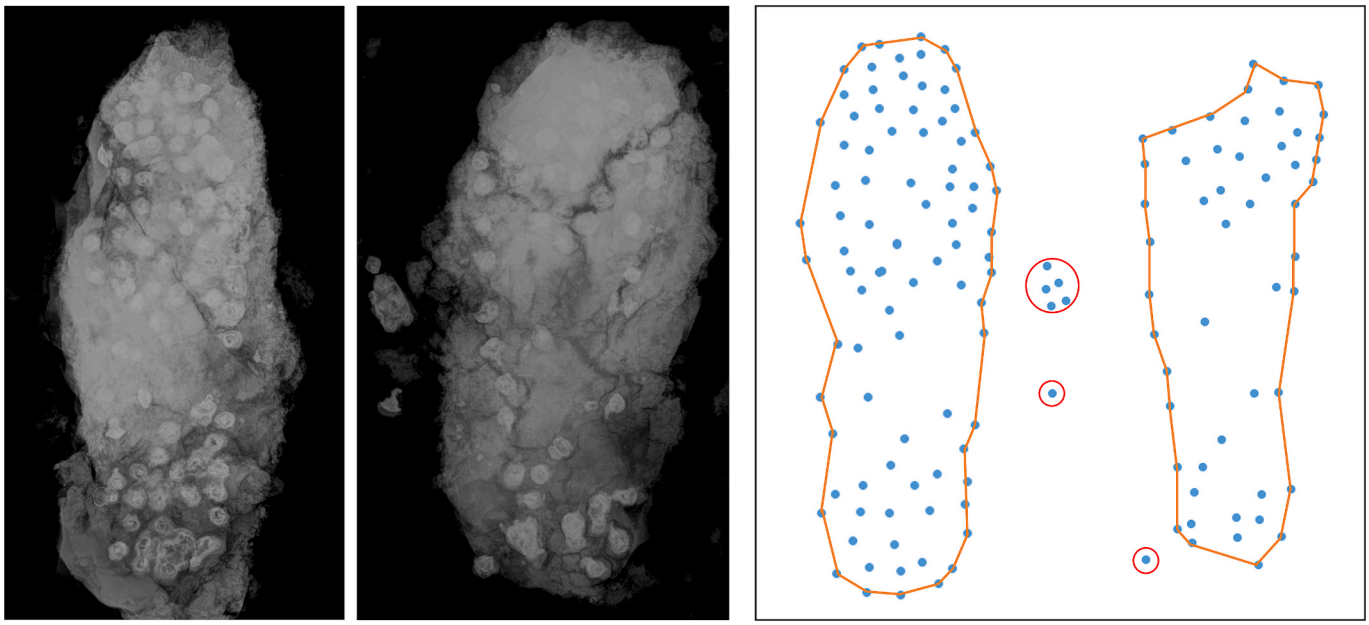

Fig. 5. Left – Radiographs of soil blocks from Grave 101. Right – Location of hobnails (blue dots), outline of the shoe (orange line) and disassociated hobnails (red circles).

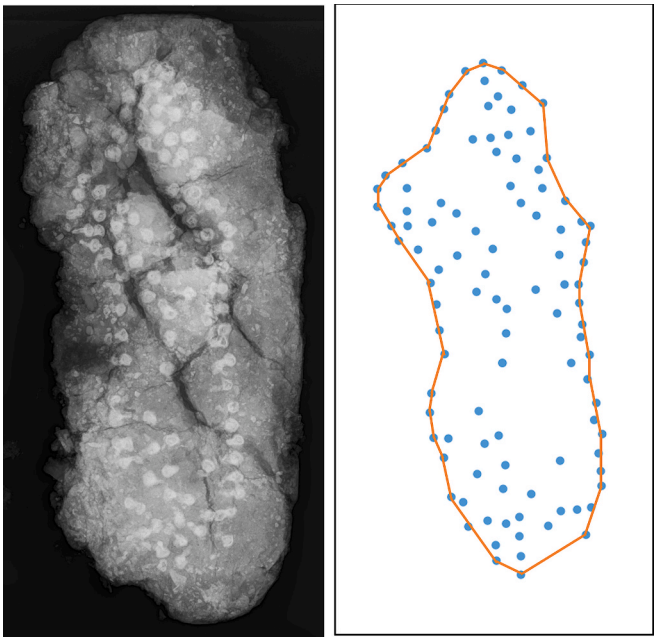

Fig. 6. Left – Radiographs of soil blocks from Grave 24. Right – Location of hobnails (blue dots) and outline of the shoe (orange line) as possible swayed and pointed sole shape.

hobnails to provide additional support. Both of which suggest alterations to shoes to alleviate specific abnormalities. At 5-5a Rhodaus Town a variety of lower-limb skeletal conditions were identified across the assemblage, including trauma, osteoarthritis, and possible Paget's disease (Rusu and Loe, 2021). Within the small sub-sample of graves with hobnail soil blocks, bilateral tibial periostitis was found with one individual (Grave 101). Also known as shin splints, tibial periostitis involves inflammation of the periosteum and new bone growth (periosteal reaction) in chronic conditions (Deshmukh and Phansopkar, 2022). Associated with repetitive strain and excessive physical exertion, the condition is also linked to inappropriate footwear. This diagnosis within Grave 101 is likely incidental and the significance alongside footwear size and design is yet to be determined. Unfortunately, poor skeletal preservation at 5-5a Rhodaus Town precludes further analysis of foot anatomy.

The potential relationship between footwear size and stature warrants investigation. Marado and Ribeiro (2018) present intriguing analysis of Roman footprints and shoeprints preserved on bricks from Bracara Augusta (Braga, Portugal) to estimate sex, height, and age. Using a wide range of published regression formulae, based upon modern and geographically distant populations, the authors use multiple measurements (including hobnail shoeprints) to generate results. Interestingly, weight estimation was also possible but limited to footprints alone. In common with this study, Marado and Ribeiro (2018) admit a small sample size, difficulties obtaining accurate shoe/foot length, and the lack of reference data from a contemporary population. All results were deemed preliminary, illustrative of potential rather than unequivocal biological profiling. Graves which lack skeletal material, but offer undisturbed hobnailed shoes, could build upon the work of Marado and Ribeiro (2018) in the same manner.

A last consideration is the hypothetical ownership of the footwear by a non-local individual or those who otherwise found their unfortunate demise away from home. If so, they may not reflect local trends or traditions in footwear usage or burial goods. A useful example is provided by Pollard et al (2011) who undertook carbon, oxygen, and strontium isotope analysis of Late Roman inhumations (with hobnailed boots) from nearby Gravesend (Kent, England). The results of one individual suggests they originated from northern Italy, with the authors postulating a symbolic provision of hobnailed boots for a long journey home. A selection of remains from 5 to 5a Rhodaus Town underwent isotope analysis with one individual identified as non-local, but unfortunately none of the samples were from those with hobnail soil-blocks. Otherwise, the site demonstrated a relatively homogenous population (Rusu and Loe, 2021) as seen elsewhere in Southern England (Bonsall and Pickard, 2015). Undoubtedly, strontium isotope analysis provides a richer understanding of past populations through dietary evidence, however selection or preservation bias may not offer a representative picture of mobility in Roman Britain. As highlighted by Eckardt, et al (2014) those graves with unusual goods or burial rites may be favoured due to financial limitations for testing. They go on to highlight that the

Table 2
Radiographic interpretation of hobnail shoes. Please note, dimensions are based upon hobnail position after taphonomic changes, not original shoe size. All measurements are illustrative rather than literal shoe dimensions.

Grave / (find number)	Condition of soil block	Quantity of hobnails identified	Maximum shoe dimensions (cm) length x width (waist width where available in brackets)	Sole shape (footwear laterality)	Nailing pattern
7 (24)	Fragmented	18	Indeterminant	Wide and blunt (indeterminant)	Pattern 1 Sparse?
24 (99)	Intact	72	28.8 x 3.7	Indeterminant (indeterminant)	Indeterminant
24 (100)	Intact	105	29.2 x 5.9 (5.9)	Swayed and pointed (right shoe)	Pattern 1 Patterned waist-tread
101 (289)	Intact	90	24.9 x 8.4 (5.7)	Wide and blunt (indeterminant)	Pattern 1 Gap at waist High concentration
101 (290)	Intact	59	22.7 x 7.5 (6.1)	Wide and blunt (left)	Pattern 1 Gap at waist
117 (313)	Intact	48	27.2 x 12 (7.7)	Indeterminant (Indeterminant)	Indeterminant Sparse
136 (345)	Fragmented	80	Indeterminant	Indeterminant	Indeterminant
136 (346)	Fragmented	73	Indeterminant	Indeterminant	Possible pattern 2

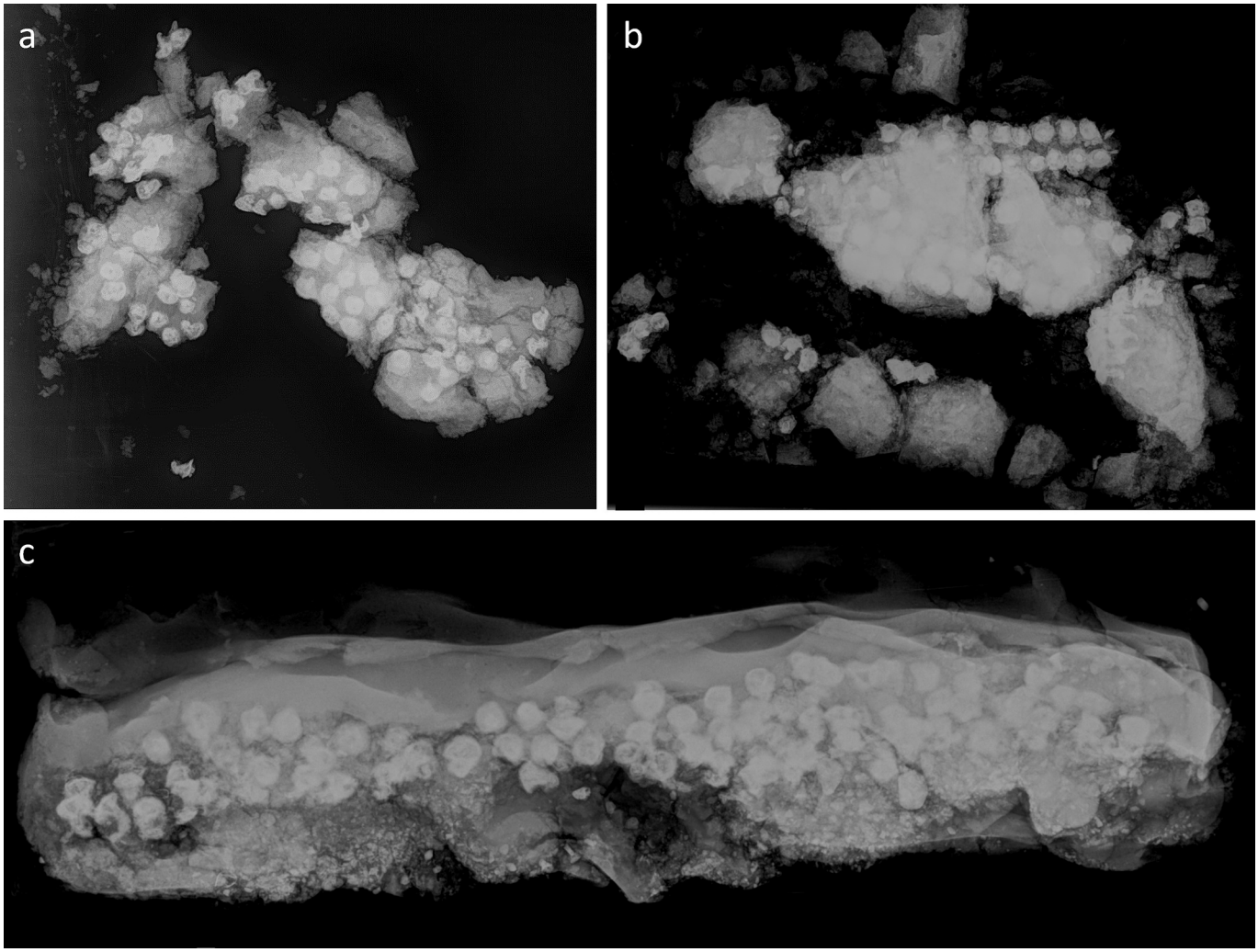

Fig. 7. Examples of fragmented soil blocks and compressed footwear. a) Grave 136 (SF345), b) Grave 136 (SF346) with double nailing consistent with pattern 2. c) Grave 24 (SF99).

absence of grave goods does not necessarily indicate a local burial and vice versa. A clear separation of individuals as either local or immigrant is therefore problematic, especially when considering conflicting evidence with grave goods and isotope results. The desire to mimic local fashion, to naturalise or otherwise assimilate into society introduces a social element which shall now be discussed.

4.3. Social interpretation

A holistic approach to social and cultural identity has been advocated within Roman archaeology, with emphasis upon material culture (Eckardt, 2005) and its synthesis with bioarchaeology rather than in isolation (Gowland, 2017). In the case of 5-5a Rhodaus Town, such synthesis of hobnail and osteological (foot health) data presents limited scope for understanding social interactions due to a small sample size. Furthermore, whilst grave finds were recorded (see Supplementary file), these were unremarkable with common finds including pottery sherds, coffin nails, and animal bones. However, several interpretations may be suggested. Firstly, footwear design varied between graves, but these were in accord with other examples found elsewhere within Britain and the wider Empire. To this extent, it reaffirms a common cultural affinity with the Roman Empire but does not clarify whether the individuals were local or non-local without comparison using isotope analysis. The challenge is therefore an understanding of broader issues of regionality, social status, and ethnicity within a specific locale and time-period, whilst linking to an assessment of biological sex and age-at-death. Rather than being binary, a complex network of interactions may occur between each element.

A second interpretation uses a pragmatic and utilitarian perspective whereby the greater quantity and density of hobnails seen in Graves 24, 101, and 136 may indicate a design for rigorous (rural) outdoor activities in keeping with robust boots (Philpott, 1991). Conversely, Graves 7 and 117 have substantially fewer hobnails that possibly meant a more delicate design suited to towns and villas. Robust designs may not forgo decorative elements though, with one shoe from Grave 24 suggestive of a pattern at the waist, although the exact design is not clear. Great emphasis has been placed on footwear as an extension of the self (van Driel-Murray, 1999), with individuality exhibited through variable designs of the upper and lower portions of the shoe. The collections analysed by Swift et al (2021) indicate that decoration was not limited to a specific demographic (e.g. children), with leather cutting, tooling, colouring, gilding decorative stitching, and appliqué all being used. Rather symbolically, footwear inspected by Swift et al (2021) tended to be new or at least undamaged when buried with the deceased, perhaps in ritualistic preparation. At 5-5a Rhodaus Town, the condition of the footwear at burial will remain unknown, however radiography may demonstrate completeness and form. If footwear type were to correlate with an individual's employment activities or socio-economic status, radiography may serve as a useful tool for evidence collection. A proviso includes the variable interpretation of identity from funerary context, especially Romano-British (Parker, 2020), dependent upon the individual and the influence of those performing the burial rites. In other words, it is possible that the attire of the deceased reflects an idealised identity from life.

4.4. Practical application and limitations of radiography

Access to digital radiography is increasing within commercial and academic archaeology. This is partly due to their perceived value in identifying and recording of recovered finds (Caple and Garlick, 2018), and partly due to the decreasing availability of traditional chemical-film materials or printed film. Digital radiographs, as a medium of storage, affords several benefits with regards to image manipulation (adjustment of contrast, brightness, zoom), lower burdens of storage, and easier distribution via online sharing (Conlogue and Beckett, 2020). Nonetheless, the use of digital radiography is not ubiquitous and what follows are general points regarding its practical application with hobnail footwear. As shown within this study, radiography can confirm the presence and distribution of hobnails, with the resulting images acting as a permanent record of the soil block prior to micro-excavation. It was often possible to estimate the orientation of individual hobnails by inspecting the direction of the spike and the profile of the head, being either circular, flat or any variant of oval in between. A pattern of hobnails in alignment and orientation may indicate not only the construction of the footwear, but also the shape and form of the shoe remnants within the soil block. The impact of soil upon image quality was minimal within this study, being comprised of mostly silty clay with sparse pebbles. Exposure factors of 60 kV and 5mAs were sufficient to penetrate soil, wooden backing, and plaster used as part of the lifting. Not all soil and radiography systems are alike though, and some degree of experimentation may be necessary to achieve a high signal to noise ratio.

There are limitations with the use of radiography, with the most notable being taphonomic changes *in situ*, accidental damage during grave excavation, or drying out (and cracking) of the soil block. All of which may lead to disassociation of hobnails from their original position and the loss of design or pattern features, ranging from minimal (Fig. 5) to catastrophic (Fig. 7). Grave 24 provides an example of a seemingly compressed shoe, with hobnails in tight proximity despite imaging from several angles. Rather than a limitation of the imaging technique itself, such an occurrence demonstrates the impact of deposition where footwear placed upon their side appear to collapse on themselves. In such instances, radiography can be used to quantify hobnails and thus differentiate between broad design types. Within this sample, the imaging could not determine if the deceased wore the footwear within the grave, with no bones identified within the radiographs and no mention of intermingling of hobnails and bones within the site report. The authors of this paper suggest that hobnail patterns are more likely to be preserved and identifiable when the footwear is placed beside the deceased, for example laid flat with the soles resting on the grave surface. When hobnails are associated with shoes worn at the time of burial, the preservation of original nail patterns becomes less certain. Factors such as the position of the body, whether supine or lateral, post-mortem movement of the feet during decomposition, the burial environment, and any subsequent disturbance, whether natural or anthropogenic, may all contribute to the displacement or distortion of hobnail positions. Further data collection regarding hobnail locations within burials and imaging thereof is required.

A second limitation involves the accuracy of radiographic measurement, where items further from the X-ray detector appear larger due to a phenomenon known as geometric unsharpness. Hobnails may be present at varying levels within the soil-block and therefore have variable degrees of magnification upon the radiograph. An inherent characteristic of radiographs are the two-dimensional depictions of three-dimensional objects, making distinction between overlapping structures challenging. A simple solution would involve computed tomography (CT) of soil-blocks, as with Re et al (2015), allowing volumetric imaging and thus accurate measurements. Alas, CT is prohibitively expensive and relatively inaccessible in comparison to radiography, with greater burden upon data storage. A final limitation relates to the leather from which the shoes are made. In their efforts to quantify shoe dimensions, Swift et al (2021) bemoan the shrinkage of leather due to post-excavation conservation treatments. Elsewhere, an increase in leather size has been noted due to swelling within water (Cronyn, 1990). In which case, measurement of shoes within soil-blocks and their comparison to existing datasets should be interpreted with caution.

5. Conclusions

Radiography of soil blocks suspected of containing hobnail footwear provide a range of complimentary information concerning the deceased, although not without several caveats. Changes in hobnail position pre-

and post-excavation may reduce the accuracy of imaging. Nevertheless, even in instances where degradation have occurred, characteristic hobnail designs can be identified and contribute towards our understanding of the deceased. With the relatively consistent change in shoe design across the Roman Empire, shoes may act as an additional dating benchmark by cross-referencing with well documented collections elsewhere (e.g. Vindolanda). Where no skeletal remains are retrieved, hobnail design or distribution may indicate both biological sex and social status, with typically larger footwear for men and robust designs tentatively linked to rigorous activities. An obvious fallacy is the assumption that the footwear was owned by the interred, and their presence may instead reflect the wishes of those burying the deceased. Looking beyond this study, the use of radiography provides an effective and sensitive means of recording hobnails *in situ*, albeit as a soil-block lift. Where burial conditions are unfavourable for leatherwork preservation, radiography offers an opportunity to collect data and contribute towards a better understanding of hobnail footwear designs.

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James Elliott: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Adelina Teoaca:** Writing – review & editing, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2025.105400.

Data availability

Data will be made available on request.

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