# Building Roman Britons

## The Use of Novel Construction Materials in the Development of Roman Bath

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Image of the gilded bronze head of Sulis Minerva on the title page modified from the Roman Baths (2022b). © The Roman Baths, Bath and North East Somerset Council.

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# Building Roman Britons:

## The Use of Novel Construction Materials in the Development of Roman Bath

This study investigates the ceramic building materials (CBM) from the UNESCO World Heritage Site of the Roman Baths at Bath, UK. Ceramic building materials from much of Roman Britain are understudied, yet our knowledge of the brick and tile from Bath is not limited solely by a paucity of research, rather than by a lack of synthesis between academic, commercial work, and the study of the Roman Baths itself. This project therefore aimed to create a unified understanding of Roman CBM in the Bath area, bringing together research in Bath and Gloucestershire with novel analyses of the Roman Baths assemblages to develop new understandings of production, procurement and use at the site, local and regional levels.

This has been achieved through two strands of research. A range of previous studies in Bath, Gloucestershire and northwest Wiltshire were collated to investigate diachronic supply of CBM to Roman Bath, particularly through the novel integration of finds of stamped and relief-patterned tiles. A survey of the assemblages at the Roman Baths was conducted, and this material subjected to fabric and chemical analyses with portable energy-dispersive X-Ray fluorescence (pXRF) in order to suggest provenance. These analyses yielded significant results when integrated with regional research. At the site level, two major phases of construction at the Roman Baths have been found to be supplied by the Minety kiln site. This has enabled the redating of the construction of the Spring Reservoir Enclosure to the first century, substantially altering the developmental history of the Roman Baths. At the local and regional levels, it is clear that Minety supplied much of Bath and Cirencester, and was important to distant settlements too. This unified picture therefore indicates that centralised production and routine long-distance transport was key to the supply and procurement of these novel building materials in the area of Bath.

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# Author’s Declaration

I declare that the contents of this thesis are all my own work.

# 1 Introduction

## 1.1 Scope and Context

This study will investigate the ceramic building materials (CBM) preserved from the UNESCO World Heritage Site of the Roman Baths at Bath, UK. CBM includes all forms of bricks and tiles, and these terms are used interchangeably throughout the course of this thesis.

Ceramic building materials from much of Roman Britain are understudied, especially in comparison to the volume of research dedicated to Roman pottery (Warry 2005: 1). The limited scope and lack of integration of many previous studies has hindered the creation of broad understandings of these materials, whether in terms of production, use, or dating. Only in the last decade have coherent regional syntheses emerged for the southeast of England as a result of the collation of academic and commercial research (e.g. Mills 2013, Betts 2016, 2017). These have been significant and demonstrate that the study of Roman brick and tile can produce valuable economic and social insights into past societies at many different scales of analysis.

This project aims to produce a similar unified understanding of production, supply and use at a regional level within the West of England, incorporating areas of Gloucestershire, northeast Somerset, and northwest Wiltshire. It will integrate the results of the novel analysis of the ceramic building materials of the Roman Baths with previous commercial and academic research at other sites in Bath and in its hinterland region, a zone extending 15-20km from the settlement (Davenport 1994: 7).

## 1.2 The Site and Assemblages

The Roman Baths at Bath represent one of the best-preserved Roman sites in the whole of Britain. They are located in the centre of the aptly-named Bath, Somerset, which is nestled in a deep valley ringed by the Jurassic limestone of the southern Cotswolds, upon the banks of the River Avon. The site comprised the heart of the settlement of *Aquae Sulis* in the Roman period, being at the centre of the area enclosed by the Late Roman town walls.

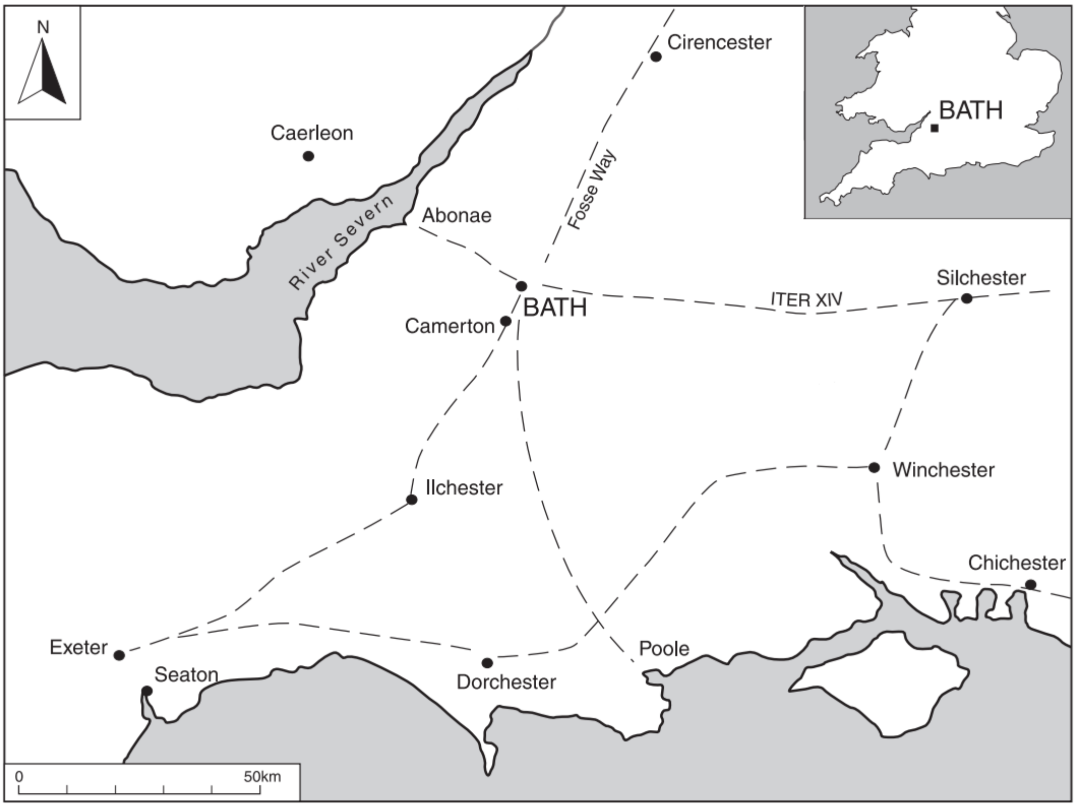


**Figure 1.1: Map showing the location of Bath in Britain, inset, and some of the most important roads and settlements in the Southwest of England during the Roman period. Modified from La Trobe-Bateman and Niblett (2016: figure 2.6). © Historic England. Reuse not permitted.**

The Roman Baths were positioned to exploit a major hot spring that rises to the surface in the area, and which continues to displace around 1.2 million litres of water every day, at a constant temperature of 46ºC (Roman Baths 2022). While this provided ample warm water for bathing, the Spring itself was a focus of extensive religious activity throughout the Roman period (Cousins 2020), a role that probably extended deep into prehistory (Cunliffe and Davenport 1985, Davenport 2021). The structures of the complex therefore comprised two discrete centres of activity. To the south and east, the bathing establishment consisted of a central swimming bath, the Great Bath, with two wings, the East and West Baths, which each included elaborate suites of heated and cold-water baths as well as Turkish-style saunas (Cunliffe 1969, 1976). To the north, the religious area included the Temple, a Temple Precinct, an altar, and the Spring Reservoir itself, over which was constructed a monumental enclosure building (Cunliffe and Davenport 1985). Many of these structures used bricks and tiles extensively in their construction, for example in *hypocausts*, i.e. suspended and heated floors, and in vaulted barrel roofs. The fine preservation and continued importance of the Roman Baths throughout the Roman period, even to regional or Continental visitors (Cunliffe 2000, Cousins 2020), suggests that the ceramic building material assemblages from the site are likely to be of national importance.

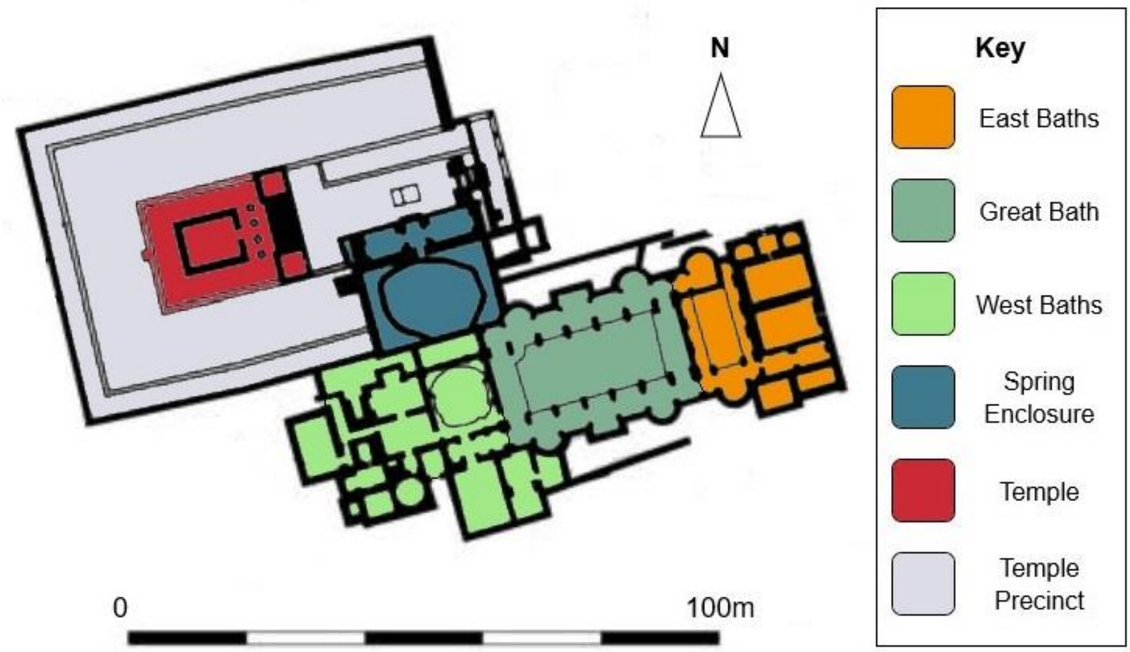


**Figure 1.2: Plan of the Roman Baths site during the late Roman period, showing the complex at its greatest extent. The different areas of the site referred to in the text are colour coded. Modified from Davenport (2007: figure 1.3). © Oxford Archaeology.**

Despite the clear potential of the ceramic building material assemblages at the Roman Baths, previous research has been limited. There are four different assemblages from distinct areas and structures of the complex, yet only that from the Temple Precinct has so far received any substantial investigation (e.g. Foster 1985). Most ceramic building materials recovered from the site have therefore not been studied before or compared to material from the other assemblages. There has also been almost no integration with the analysis of finds from other sites in Bath or the wider region. While the structural development of the Roman Baths has been extensively explored and defined (e.g. Cunliffe 1969, 1976, Cunliffe and Davenport 1985, Davenport 2011a, 2021), the building materials that comprised the site itself are thus relatively poorly understood.

## 1.3 Aim and Objectives

A unified study of all of the ceramic building material assemblages from the Roman Baths has the potential to significantly contribute to the understanding of the site, its development and the provision and use of brick and tile in the local area during the Roman period. Moreover, a range of previous studies have analysed assemblages or single finds of Roman CBM in Bath and parts of Gloucestershire and northwest Wiltshire, but have not yet been synthesised. There is a clear opportunity to bring these strands of research together to produce valuable economic and social conclusions at the site, settlement, and regional level. Therefore, the aim of this study is to:

*Understand the use, procurement and contribution of building materials and construction techniques to the socio-economic development of Roman communities in the region of Bath.*

In order to achieve this, a comprehensive understanding of the range of components and different sources of material from the Roman Baths is needed. It is also necessary to understand to what extent the ceramic building materials from the complex equate to local and regional material and sources. The following objectives were therefore defined in order to allow the aim to be met:

- Complete a unified survey of ceramic building materials from all assemblages at the Roman Baths
- Complete a literature survey of possible source clay deposits and kiln sites within the hinterland area of Bath
- Source CBM to specific geological deposits and kiln sites, where possible
- Integrate results with the commercial analysis of assemblages from other sites in Bath
- Synthesise results with previous research into CBM from the wider region of Bath, northeast Somerset, Gloucestershire, and northwest Wiltshire
- Investigate the production, movement, use and value of Roman ceramic building materials in this region

## 1.4 Methodological Approach

The varied objectives of this study required a range of methods and scales of analysis to be employed together. The character of each assemblage of ceramic building materials from the Roman Baths was assessed through the recording of macroscopic form, marks, and impressions of a large sample of individual sherds. The fabric of each was assessed using a x20 magnification microscope. The resultant fabric series was equated with that established for Roman assemblages from other sites in Bath, and was compared to samples of fired clay and sherds of CBM collected from Roman kiln sites in Gloucestershire, as well as to material from other Roman sites. Chemical analysis was then employed to test relationships observed in the fabrics of the ceramic building materials. Portable energy-dispersive X-ray fluorescence (pXRF) was used for these analyses.

The combination of these methods proved a powerful tool, particularly in concert with the detailed understanding of the development of the site established by previous researchers (e.g. Cunliffe 1969, 1976, Cunliffe and Davenport 1985, Davenport 1994, 2021), and when integrated with the results of commercial (Betts 1999a, b, 2002, 2007, 2011, 2015) and academic (Darvill 1979, 1980, 1982, 1986, 1998, 2001) analyses of brick and tile from the wider area.

## 1.5 Structure of the Thesis

The thesis begins with a synthetic overview of previous research into Roman ceramic building materials from Roman Britain (section 2.0). This chapter collates the outcomes of past studies and reviews the different theoretical models that have been applied to understand the production and circulation of this material.

The history of excavation of the Roman Baths is then considered (section 3.0), in part to demonstrate what previous research has been conducted into the different assemblages from the complex. It is also important to understand the piecemeal excavation history of the site, as this impacts the interpretation of a range of different material, as investigated in the discussion chapter (section 10.1-10.3).

Two review chapters for the previous applications of different methods are then presented. The first explores the wide range of analytical techniques and scales of analysis that have been applied to ceramic building materials from Roman Britain (section 4.0). The second recaps the underlying theory of X-ray fluorescence analysis, and the development and controversy of the application of portable X-ray fluorescence instruments to archaeological artefacts (section 5.0).

A further review chapter considers the different geological formations present within the Bath hinterland area, and the evidence for the use of these deposits in Roman ceramic manufacture or post-Medieval brick production (section 6.0). A chapter then follows on the state of knowledge of Roman CBM from Bath, prior to any new recording or invasive analyses (section 7.0). While providing a summary of the work of other researchers in Roman Bath, it also integrates and maps the distributions of relief-patterned tiles and stamped tiles together in the wider region for the first time.

The introductory chapters are then followed by a brief chapter (section 8.0) setting out the methodology employed in this study.

The results from the novel analysis of the ceramic building materials from the Roman Baths comprise a chapter in three parts. The first considers the morphologies, marks, impressions, post-depositional concretions, and dateable features alone (section 9.1). The second integrates the results of the fabric analyses of this material (section 9.2). The third, and final, details the results of the pXRF analyses (section 9.3). While the ceramic building materials of the Roman Baths are the focus for these sections, comparison with local or regional samples are conducted in parts 9.2.7 and 9.3.4.

The discussion begins at the scale of the assemblages from the Roman Baths themselves before working upwards to the whole of Bath, and then the regional understanding. At the site level (section 10.2), a range of evidence for the redating of the Spring Reservoir Enclosure to the late first or very early second century is presented. In part, this hinges on the dating of relief-patterned tiles, and this is reconsidered in relation to stamping (section 10.7.2). The kiln site at Minety, its origins, dating and evidence for different workshops are also considered in depth (sections 10.7-10.8). The discussion concludes (section 10.9) by investigating how the demography, Roman road network and past value of CBM contributed to the patterns of production and long-distance transport that have emerged in the study area and in the Roman Southeast, and may yet be revealed elsewhere.

Finally, the conclusion (11.0) identifies the key findings of this study and answers the aim of this research. The impact of these findings upon the current state of knowledge are also considered. Questions raised by this study, and recommended further work to fulfil these, are then proposed.

# 2.0 Ceramic Building Materials in Roman Britain

This chapter will provide an overview of the current understanding of the adoption, production, use and circulation of ceramic building materials in Roman Britain. In doing so, the development of the study and conceptualisation of Roman brick and tile from Britain will be investigated. A range of thematic issues in this research will also be highlighted and discussed. This includes the value and mechanisms of uptake for CBM in the past, as well as the potential for cross-craft ceramic production in Roman Britain. Finally, the international context of brick and tile from the province will be reviewed in order to explore the transmission of ceramic building material innovations between the Continent and Roman Britain.

## 2.1 Overview

Our current understanding of ceramic building materials in Roman Britain is one of production and distribution, although other aspects of these materials have occasionally been explored. This section will summarise these findings, laying the basis for a further exploration of several thematic issues in the next section.

### 2.1.1 Introduction and Earliest Use of Ceramic Building Materials

Brick and tile were produced and used in Roman Britain from an early date. While no kiln sites have been found for the immediate post-Conquest period, the presence of brick and tile at early sites and in Boudiccan destruction layers in the southeast, such as at Colchester (Hawkes and Hull 1947, Warry 2005), London (Betts 2006, 2009, 2017, Pringle 2007) and Verulamium (Frere 1972, McWhirr 1984), indicates that it was likely being produced and used in Britain from the late 40s AD (Betts 2016: 99), and certainly prior to AD 61 (Mills 2013: 454). In London, this early use was predominantly restricted to roof tiles and brick (Betts 2017), although a distinctive form of small, thin-walled box tile has been identified from mid first-century contexts in the city (Pringle 2006, 2007), indicating early bathhouse construction. There was also early production and use by the Legions at bases in the west such as Exeter and Gloucester from the mid-

50s AD onwards (Bidwell 1979: 148, Heighway and Parker 1982: 31). Despite a growing awareness of Roman influence in Britain prior to and immediately after the Conquest (Russell and Laycock 2010, Sharples 2010), including the very early use of Roman CBM at sites like the Fishbourne Proto-palace (Cunliffe 1971) and a possibly Claudian bathhouse at Silchester (Fulford et al. 2019), there is not yet any evidence for pre-Conquest CBM production or importation in Britain (McWhirr 1984, Mills 2013). Given the difficulties of identifying these often-ephemeral pre-Conquest phases, future research may yet significantly alter this picture.

In part due to a poor understanding of the earliest kiln sites, it is not known who was responsible for producing much of the CBM in early Roman Britain. Nor is it clear to what extent this activity integrated local communities. While there is evidence from brick and tile graffiti that individuals with Roman, Gallic and indigenous Celtic names participated in CBM production in Roman Britain (e.g., Lancaster 2012: 434), it is unclear how representative this was of civilian brickmakers more generally, and especially in the first few decades after AD 43. As with early monumental stone carving in Britain (Blagg 1979, Hayward 2009), Gallic specialists may have moved into the Roman province and set up workshops or been commissioned. The use of legionaries and veterans at *Coloniae* has also been suggested (McWhirr 1984: 30). The limited Iron Age exploitation of building stone has long been used to explain the necessity of the movement of trained stonemasons into Roman Britain (e.g. Blagg 1979, 1990). In contrast, the established ceramic traditions of prehistoric southern Britain (Peacock 1968, 1969, Morris 1994) clearly gave potential for a more rapid and active involvement of indigenous communities in CBM manufacture. Given the long continuity of building materials and architectural traditions evident in many rural communities in the southwest of Roman Britain (Williams 1971, Davenport 1994), it nevertheless appears that uptake may have been slow or largely restricted to the south-east.

### 2.1.2 Later Production and Use of Ceramic Building Materials

The scale of ceramic building material production in Roman Britain appears to have increased significantly during the later first century and into the second century (McWhirr 1984, Mills 2013, Betts 2016), perhaps as a response to Flavian and then Trajanic or Hadrianic investment and building booms (Frere 1978, Black 1985). It must be acknowledged that reuse and destructive recycling practices, such as use in hardcore or crushing and addition to *opus signinum*, could have obscured or removed much early CBM, and might thus have served to exaggerate the abundance of material from later periods in comparison to the earliest phases. The identification of later first-century and early second-century CBM is also facilitated by the visibility of two practices adopted during this period, namely the relief-patterning and stamping of tiles.

Relief-patterned impressions were created through the application of a wooden roller-die to the surface of the tile in order to key it to receive plaster (Lowther 1948). This practice was generally limited to a range of components for use in heated rooms and bathhouses, including a wide range of types of box flue tiles, hollow voussoirs and wall tiles (Betts et al. 1997: 8-12). It appears to have been copied from the use of roller-dies to key daub walls for plaster (Russell 1997), and has traditionally been dated to between AD 80-150 (Lowther 1948, Black 1985, Betts et al. 1997). The excavation of the Neronian Little London kiln site in Hampshire has since yielded a range of relief-patterned tiles (Fulford et al. 2017). These finds indicate that this practice was in use by at least the late AD 60s (Fulford et al. 2017: 8-9), and may perhaps have been first adopted as early as the AD 50s (Fulford and Machin 2021: 221-2). While this new start date appears entirely reasonable, Fulford and Machin (2021: 218-222) have argued that all relief-patterned tile be dated to the same pre-Flavian period. While the dating of CBM is admittedly problematic due to residuality and ancient recycling (Fulford and Machin 2021), we cannot be sure how long these relief-patterning practices lasted, or how quick different workshops in different areas were to adopt them. As an example, tile stamping by civilian manufacturers in mainland Italy began in the early first century (Bloch 1941: 4) and continued until the third century (Bloch 1941: 7, Helen 1975: 11), and even in Roman Britain civic or civilian stamping practices may have lasted for around 40-60 years (Warry 2017: 82). The length of time that relief-patterned tiles could conceivably have been produced for might thus span many decades. Even if relief-patterning practices were widely adopted in AD 60 and continued for just 20 years, i.e. the length of only a single generation, then a substantial number of relief-patterned tiles would therefore date to the Flavian period, which began in AD 69. Given these problems, it seems reasonable to assign a broadly first-century date of production to relief-patterned tiles. Specific die types may date to the Neronian period, including those at Little London (Fulford et al. 2019), while it is possible that others are purely

Flavian in date (e.g. Black 1985), and some may even have continued to be produced into the beginning of the second century (Lowther 1948, Betts et al. 1997).

The identification of second-century brick and tile is aided by the introduction of stamping practices (Warry 2010, 2017). Though first-century circular stamps of the Emperor Nero have been found at the Little London kiln site (e.g. *RIB* II(5): 26-27, Fulford et al. 2017), stamping was not widely adopted in Roman Britain until the first half of the second century (Lowther 1948, McWhirr 1979, Heighway and Parker 1982, Black 1985, Betts 1995, Warry 2010, 2017), although varying by region and authority. In contrast to relief-patterned impressions, stamps are almost solely found on tegulae, flat bricks and imbrices in Britain (e.g. *RIB* II(4-5)). By the late third century, stamping as a practice had probably ceased altogether (Heighway and Parker 1982, Warry 2010, 2017), in a parallel to the evidence from mainland Italy (e.g. Bloch 1941: 7, Helen 1975: 11). Brick and tile production variably continued in Roman Britain into the third and fourth centuries (McWhirr 1984, Mills 2013), although after the middle of the second century a lack of innovation and gradual decline in the range of forms being produced has been identified (Betts 2016: 107).

### 2.1.3 Final Production and Use of Ceramic Building Materials

In the late Roman period, there is evidence for the reuse of CBM across much of southern Britain (McWhirr 1984, Betts 2016). In many regions, for example the Cotswolds (Williams 1971, Darvill and McWhirr 1984), stone was increasingly used in favour of CBM for building, roofing and even for hypocaust pilae (Williams 1971, Cram and Fulford 1979, McComish 2012, Betts 2016, Heke 2017). The disappearance of stamping and the recycling of brick and tile make it difficult to distinguish many later products (Lowther 1948, McWhirr 1984), and thus the scale of final production. Nevertheless, late supply appears diminished compared to that of earlier centuries (Mills 2013, Betts 2016). While Betts (2017: 381) has suggested that the increasing use of stone developed as a response to declining CBM production, the relationship between these materials and industries is probably more complex. Certainly, the regional availability of good building or roofing stone must have been a significant factor (Williams 1971, McWhirr 1984). In any case, ceramic building material production in Roman Britain appears to have largely, but not entirely (Betts 2016: 108), ceased by the beginning of the fifth century AD (Mills 2013).

## 2.1.4 Stamping Practices and Authorities

Comparison of stamps has allowed rapid and non-invasive identification and differentiation of kiln site products. This is equally true of tiles stamped with letters or text and those impressed with relief-patterns from roller dies. The value of these stamps in identifying the distribution of specific workshop products is discussed in section 4.1, especially if supplemented by scientific analyses to resolve questions of source or itinerancy (e.g. Darvill 1979, Hughes 2013, 2015, section 4.4). Analysis of stamps on brick and tile from Roman Britain has also contributed to our understanding of production at a much more fundamental level. In particular, these stamps have illustrated that a variety of authorities were active in CBM manufacture in Roman Britain at different times.

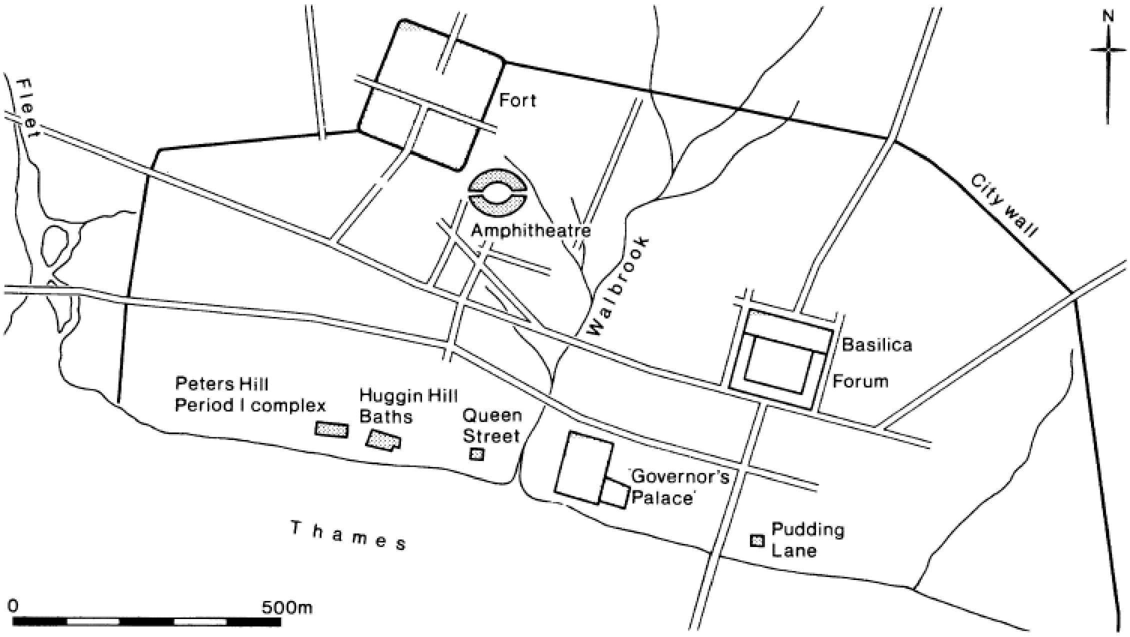


**Figure 2.1: Map indicating the presence of procuratorial stamped tile (P.P.BRILON) at major public buildings in Roman London. From Betts (1995: figure 4). Betts, I. M., 1995. Procuratorial Tile Stamps from London. © Cambridge University Press. Reproduced with permission of The Licensor through PLSclear.**

Procuratorial stamps have been found at sites in London (Betts 1995, 2017), Essex and Hertfordshire (Betts 1995). Imperial stamps have been found at Silchester (Greenaway 1981, Machin 2018), at the Neronian Little London tilery outside Silchester (Greenaway 1981, Fulford et al. 2017) and from a bathhouse site in Carlisle (BBC 2021), perhaps linked to the arrival of Emperor Septimius Severus in Britain (BBC 2021) at the start of the third century AD (Frere 1978: 199). While the procuratorial kiln site for the southeast has not yet been located, finds of stamped waster tile indicate that it was probably situated within the bounds of early Roman London (Betts 2016: 105). These Imperial and procuratorial stamps indicate state interests in brick and tile production in Britain during at least the mid first (Fulford and Machin 2021: 211-212) to early second centuries AD (Betts 1995: 209), though perhaps beyond. This was likely to facilitate large state-sponsored public building projects in the province, for example the Huggin Hill baths in London (Betts 1995: 22, see figure 2.1) or the Neronian public baths at Silchester (Fulford et al. 2019: 3).

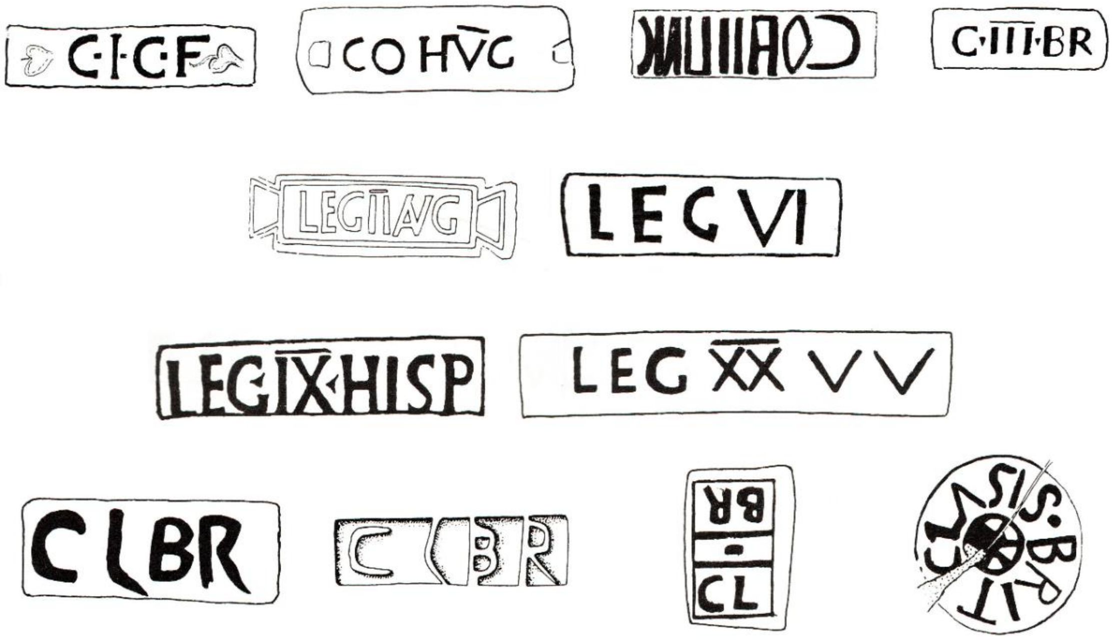


**Figure 2.2: A sample of military stamps found on CBM from Roman Britain including, from top, Auxiliary, Legionary and Classis Britannica stamps. Not to scale. Modified from *RIB* II(4-5). © The History Press.**

Military production was considerable and is often identifiable by systematic and frequent stamping practices (Brodribb 1979, Warry 2010), with the unit responsible listed on the dies used. It became widely adopted, with a significant array of Classis Britannica (Peacock 1977, Brodribb 1979), Legionary (Grimes 1930, Wright 1976, 1978, McWhirr 1979, *RIB* II(4), Warry 2010) and Auxiliary (*RIB* II(4), Warry 2005) stamps all having been identified from Britain (e.g. figure 2.2). As these forces were garrisoned, their stamps have specific local or regional distributions that have often been interpreted with reference to historical or epigraphic records of troop presence at bases (e.g. Wright 1976, 1978, Betts 1985). A good example is the Classis Britannica stamped tile (bottom row of figure 2.2), which has been widely recovered from coastal stations and fortifications on the south coast of Britain and northern France (Peacock 1977, Crowley and Betts 1992, see figure 2.3). This includes a few sherds from London (Crowley and Betts 1992) and an extensive assemblage from Beauport Park, Sussex, a bathhouse on the Weald linked to iron ore extraction by the fleet (Brodribb 1979, Brodribb and Cleere 1988). Unsurprisingly, this distribution is largely consistent with maritime transport of stamped tile between ports and naval bases of the fleet, whether as cargo or ballast (Peacock 1977).

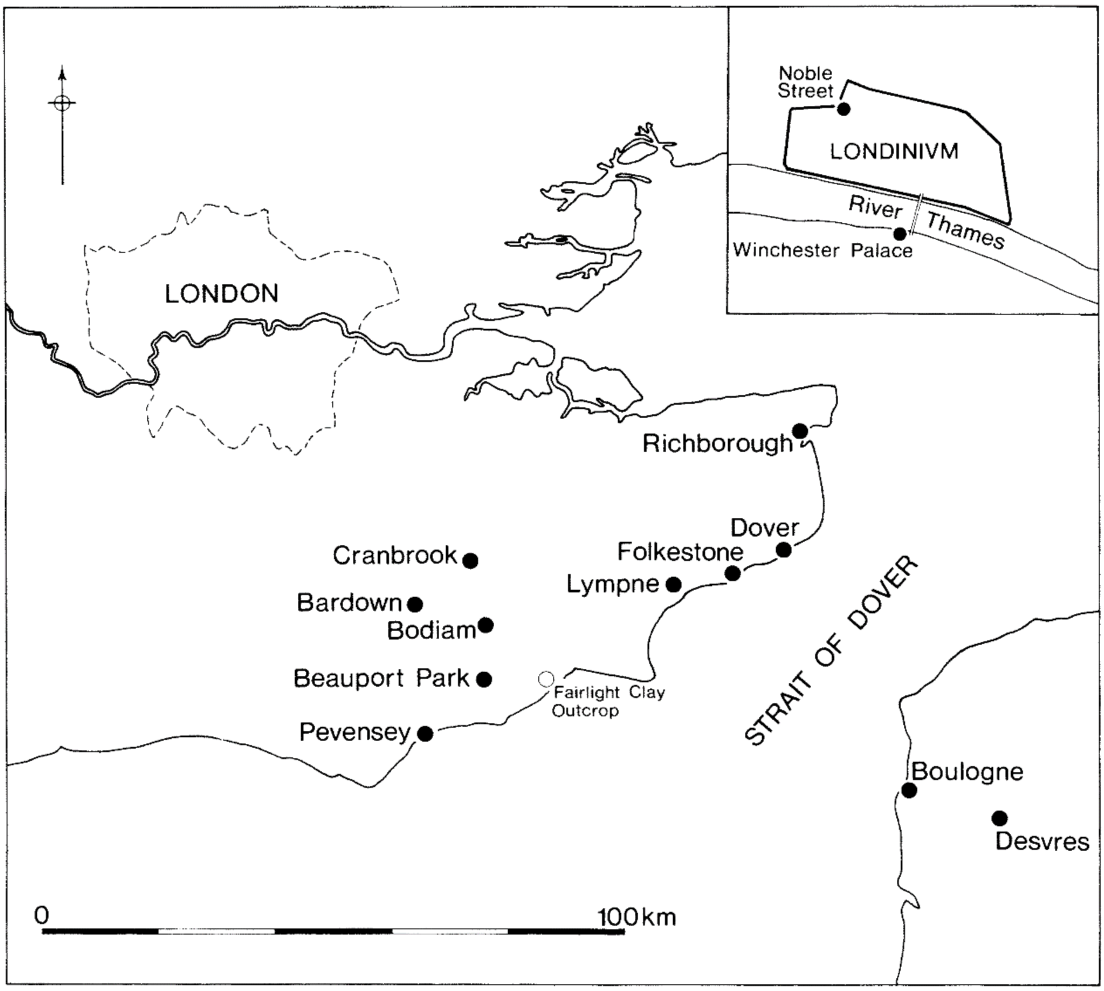


**Figure 2.3: Distribution map of sites yielding Classis Britannica (CL.BR) stamped tile. From Crowley and Betts (1995: figure 2). Crowley, N. and Betts, I. M., 1992. Three Classis Britannica stamps from London. © Cambridge University Press. Reproduced with permission of The Licensor through PLSclear.**

Other forms of stamp have been less confidently interpreted, but where they occur are routinely assigned to civilian production (e.g. Darvill 1980: 50, *RIB* II(5)). Three- or four-letter stamps (see figure 2.4), for example the TPF series from Gloucestershire

(Darvill 1979, Darvill and McWhirr 1984), are often taken to represent the initials of the *tria nomina* of a Romanised or freedman citizen presiding over a brickyard (Bogaers 1977: 277, Betts et al. 1997: 45), presumably as a private enterprise. At certain settlements, such stamps have instead been read as evidence for a production site under municipal control. This includes the RPG stamps from Gloucester (McWhirr and Viner 1978, Heighway and Parker 1982) and LVL stamps from Lincoln (Todd 1966, Bogaers 1977). The kiln site at Minety has also been proposed as having been under the civic control of Cirencester (Warry 2017: 95), although the evidence is ambiguous (section 10.8.3).

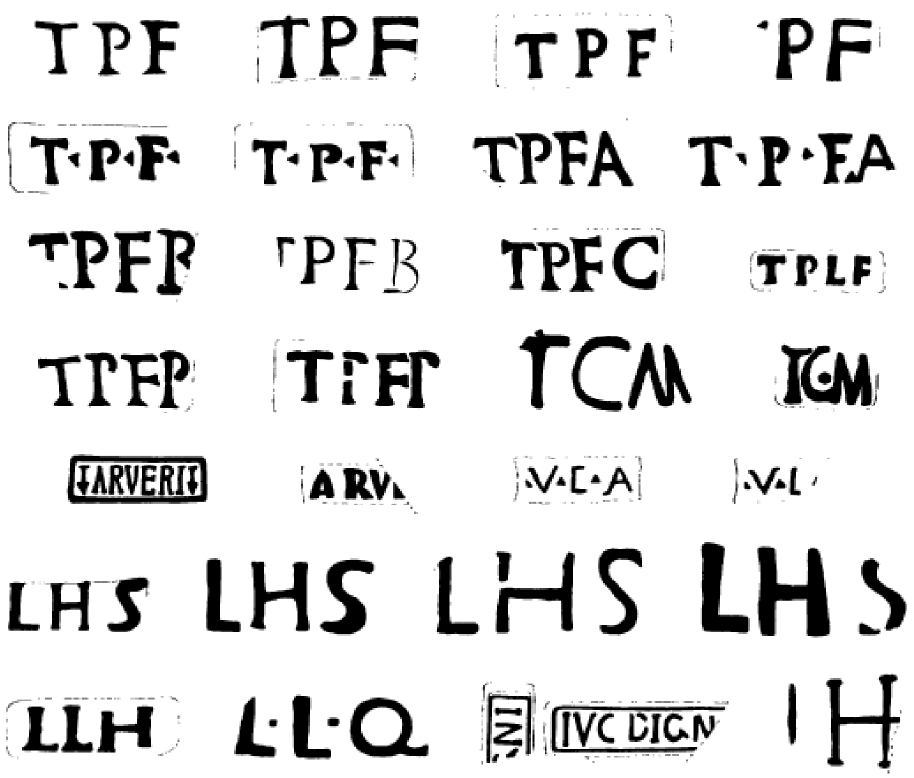

**Figure 2.4: Examples of civilian stamps found in Gloucestershire. From Darvill and McWhirr (1984: figure 5). Darvill, T. C. and McWhirr, A., 1984. Brick and Tile Production in Roman Britain: Models of Economic Organisation. © Informa UK Ltd. Reproduced with permission of The Licensor through PLSclear.**

There is an increasing awareness of potentially complex relationships between civilian and legionary production and stamping in certain regions, although understanding of any changes over time remains limited. Civilian stamping practices in Britain appear to have begun in the early second century (Heighway and Parker 1982, Warry 2017), perhaps a decade after the earliest Legionary stamping in the province (Warry 2010:

127). Civil stamping was not widespread, and the area around Gloucester and Cirencester has yielded two-thirds of the entire corpus of non-military stamped CBM so far known from Roman Britain (*RIB* II(5): 56, Warry 2017: 77). Both of these sites, as well as Lincoln, another civilian stamping centre (Todd 1966, Bogaers 1977), developed from original legionary forts or coloniae (Frere 1978, Heighway and Parker 1982). Warry (2017: 80) has also compared the similarity of forms and evolution of civilian and military stamp dies in this region and identified a range of parallels between them (figure 2.5). The combined implication is that stamping may have been introduced into a civilian context through the involvement of active or retired legionaries in brickmaking (Warry 2017), or through the close contact of civilian firms with military practices.

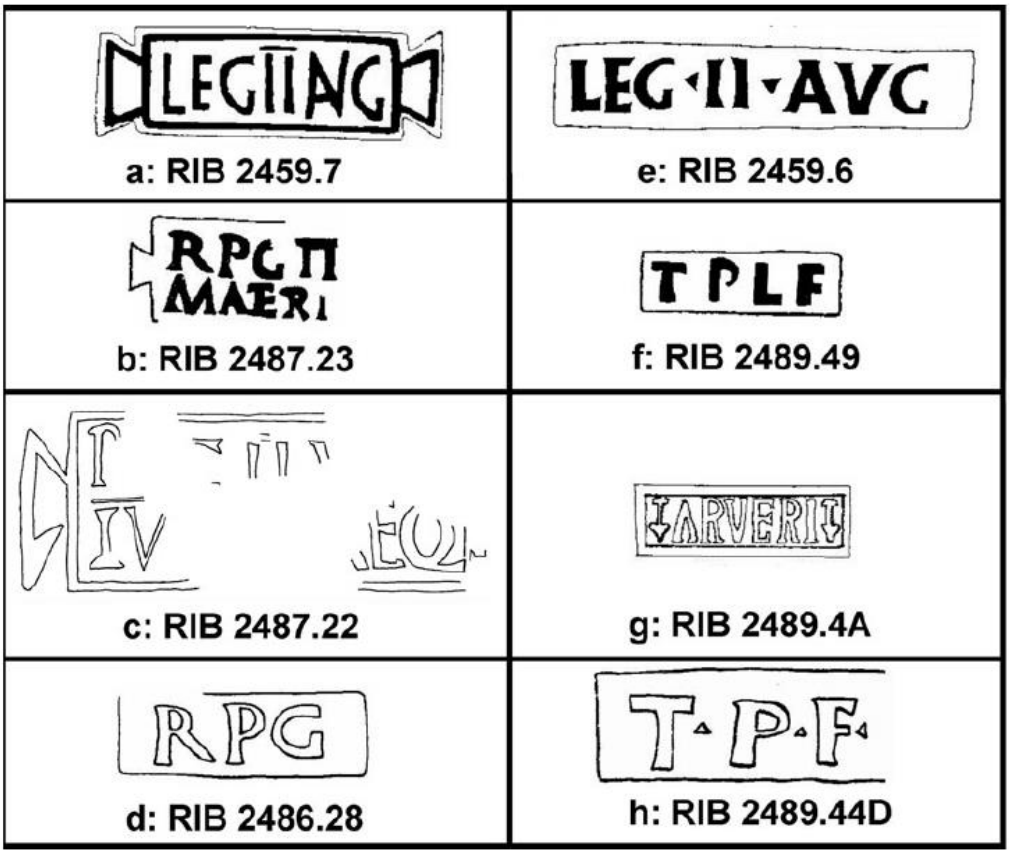


**Figure 2.5: Comparative die illustrations, showing the similar development of Legio II Augusta and civilian stamped tile dies from Gloucestershire. From Warry (2017: figure 1). Warry, P., 2017. Production, Distribution, Use and Curation: A Study of Stamped Tile from Gloucestershire. © Cambridge University Press. Reproduced with permission of The Licensor through PLSclear.**

Stamping could have been transmitted through the integration of certain civilian brickyards into military supply chains, perhaps with stamps being required to be applied to mark batches submitted as part of a contract (Lowther 1948), or as a wider means for accountability or to prevent theft of military property (Brodribb 1979). While civilian CBM stamp types do sometimes appear on military sites, for example in York (Betts 1985, McComish 2012), abbreviated or otherwise untypical military dies have also been used to argue for civilian production on behalf of a Legion. This includes tiles from the production site at Tarbock, Merseyside (Swan and Philpott 2000), which appears to have borne the proclamation "Aulus Viducius made this roofing-tile for Legion XX in the third consulship of Verus" (Swan and Philpott 2000: 56). Swan and Philpott (2000: 62-63) have also suggested that Legionary requirements were increasingly contracted out to civilian manufacturers throughout the course of the second century, including at York (McComish 2012), Merseyside (Grimes 1930, Swan and Philpott 2000) and Caerleon (Burnham et al. 1997). Further analysis is therefore required to determine whether this is more widely true of other military units in Britain, and indeed if any other diachronic trends in these relationships can be identified.

While the dichotomy between civilian and Legionary stamping was perhaps less absolute than often expected, the joint presence of civil, military and procuratorial stamps nonetheless indicates significant diversity in the authorities once responsible for the manufacture of brick and tile in Roman Britain. Despite this, there is little understanding of changes over time in the organisation of production or the authorities present. In part this is due to the limited duration of stamping practices in Roman Britain, which remains the primary form of evidence for distinguishing procuratorial, civic or military production.

## 2.2 The Study of Production and Circulation

The sheer variety of different stamps, the diversity in the distributions of products and the range of controlling authorities clearly implies that a wide range of different scales and modes of production were once present in Roman Britain. Despite this, early conceptualisations of the manufacture and circulation of Roman brick and tile could be simplistic (e.g. Hodder 1972, 1974). Comparison with the ethnographic and historical record has since provided a more nuanced understanding of the modes of production of these materials, but achieved little synthesis (section 2.2.2). More recent research on large, unstamped assemblages has begun to piece together a national understanding of circulation patterns and changes in supply in Roman Britain. While valuable, it is unclear how representative these patterns are of CBM manufacture and use in regions away from the southeast. Moreover, due to a lack of investigation of many identified or suggested kiln sites, there is often a very limited understanding of the periods of operation of different tileries and the diachronic changes between modes of production, even in well-studied regions.

### 2.2.1 Early Conceptualisations of Ceramic Building Materials

In a brief foray into the subject, Hodder (1972, 1974) advocated CBM as a bulk commodity travelling only short distances, in direct opposition to higher value and more widely circulated pottery. Brick and tile production and distribution was tied into his central place models of town and settlement hierarchies in Roman Britain (Hodder 1972: 901). Ceramic building materials were therefore conceptualised as one of the ‘services’ that major centres provided for smaller settlements and villas in their hinterland, thus limiting the distribution of certain products to a discrete radius of about 20 miles (32km) from the major centre. Despite making generalisations for settlements over a wide swathe of central and southern Britain, Hodder’s (1972) conclusions were drawn only from the early analysis of distributions of stamped tile from Gloucestershire and Wiltshire (e.g. Clifford 1955, shown in figure 2.6). While this remains largely consistent with the evidence for RPG stamped tiles from Gloucester (Heighway and Parker 1982, Warry 2017), research into tiles with the other stamps has since demonstrated wider and more complex circulation patterns (McWhirr and Viner 1978, Darvill 1979, Warry 2017, section 7.2). In particular, Warry (2017: 91-92) has proposed that the LHS stamped tiles (see figure 2.4) were the product of a workshop operating from the kiln site at Minety primarily to supply extra-regional demand. These tiles have so far been found up to 70km from Minety (Darvill and McWhirr 1984: 253), including at and near Old Sarum in Wiltshire (McWhirr and Viner 1978), at Silchester (McWhirr and Viner 1978), at Kenchester in Herefordshire (Darvill 1979), at the North Wraxall villa in the Bath hinterland (Tomlin 2017) and more locally at Wanborough, Wiltshire (McWhirr and Viner 1978, Warry 2017), and in Cirencester (McWhirr and Viner 1978, Warry 2017), although not as common in the city as the TPF-series stamps.

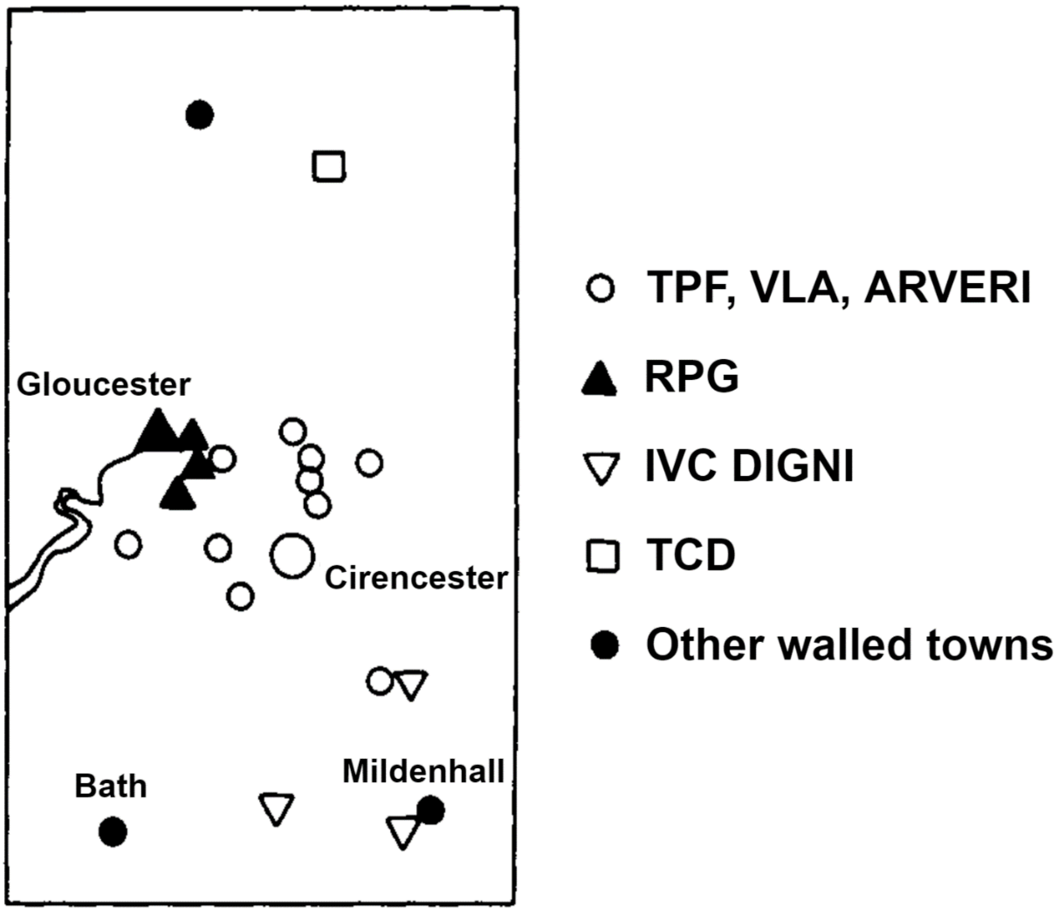


**Figure 2.6: Distribution map of the stamped tiles used by Hodder (1972, 1974) to argue that discrete CBM products were circulated and used within the bounds of major centres. Modified from Hodder (1972: Figure 23.8). Hodder, I., 1972. Locational Models and the Study of Romano-British Settlements. © Informa UK Ltd. Reproduced with permission of The Licensor through PLSclear.**

### 2.2.2 Ethnographic Parallels and Modes of Production

Subsequent research in the late 1970s and early 1980s rejected the conception of CBM as being made and used only locally and worked to understand and explain the complexity of production apparent in the archaeological record. By drawing on a variety of historic and ethnographic evidence for pre-industrial brickmaking from Europe, a range of explanatory modes of production and circulation that might have been found in Roman Britain were proposed (e.g. McWhirr and Viner 1978, Peacock 1979, 1982, Darvill and Timby 1982, Darvill and McWhirr 1984, McWhirr 1984). While the exact terminology differed between authors, the range of scales and intensities of brick and tile production present or coexistent in the historical record was continually emphasised

(Peacock 1979, 1982, Darvill and McWhirr 1984). To summarise, this included everything from seasonal or itinerant activity on a rural estate providing only for immediate needs (Darvill 1980, Darvill and McWhirr 1984), right up to full-time municipal brickyards supplying regional administration (Peacock 1979) and agglomerated kiln sites intensively producing for a wide commercial market (McWhirr and Viner 1978, McWhirr 1984). In many cases the potential for commercialism beyond production of immediate needs was emphasised, for example with historic civic brickyards or small-scale estate kilns selling leftover or surplus bricks and tiles (Peacock 1979). So too was the possibility of part-time activity even on larger kiln sites due to the unsuitability of the cold, wet winters of northwest Europe for brickmaking (McWhirr 1984).

The relevance of these models was demonstrated by applying them in the interpretation of case studies from Roman Britain. As an example, the presence of ungulate animal prints on brick and tile from Silchester was used to argue that the tiles were dried in an open, shared agricultural space like a farmyard (Cram and Fulford 1979). This production site was therefore interpreted as operating part-time around agricultural activities (Cram and Fulford 1979), with tile-making and drying only in the spring and summer, as paralleled in many smaller operations in the ethnographic record (Peacock 1979, McWhirr 1984). The RPG stamps from Gloucestershire (Clifford 1955) and the matching kiln wasters found at St Oswald’s Priory in the city (Heighway and Parker 1982, see figure 2.7) were interpreted in the light of their limited distribution outside Gloucester (McWhirr and Viner 1978, figure 2.6). With the extrapolation of the RPG stamp as signifying *Rei Publicae Glevensium* (“of the commonwealth of the Glevensians”, Clifford 1955: 68, Heighway and Parker 1982: 62), sometimes with an accompanying magistrate being listed (McWhirr and Viner 1978, Heighway and Parker 1982, figure 2.7), this was taken together as firm evidence for municipal production.

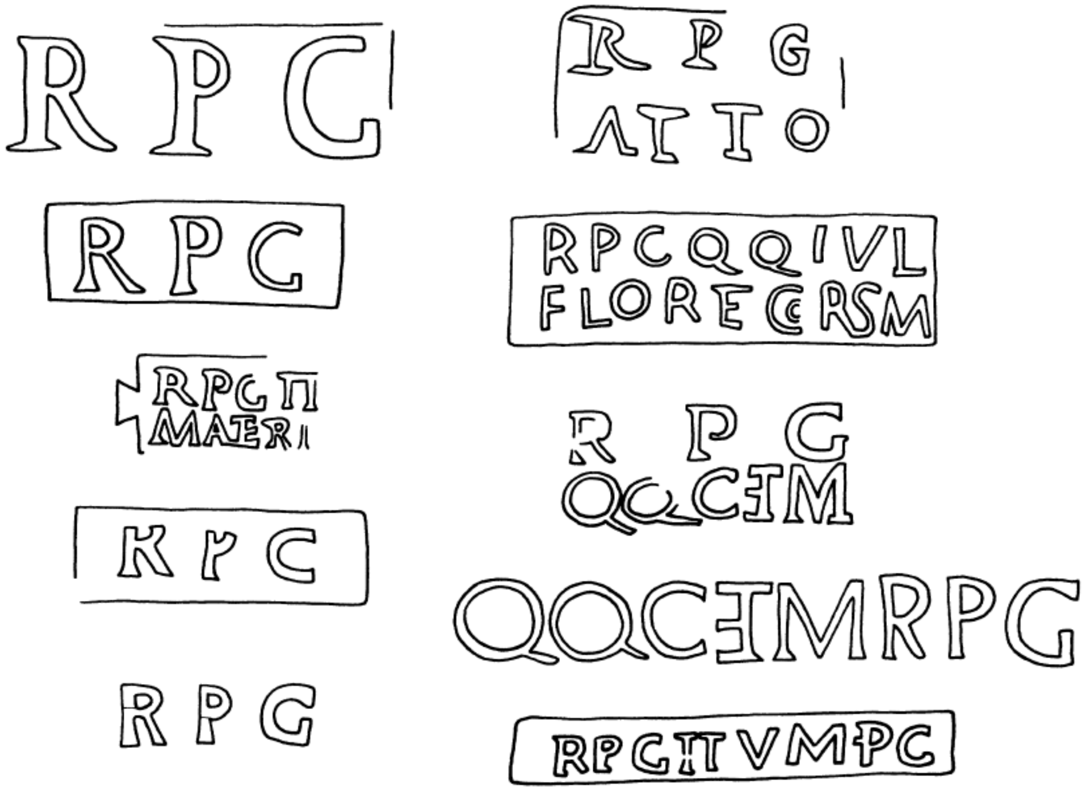

**Figure 2.7: A variety of RPG and magistrates' dies stamps found at the St Oswald's Priory kiln site, Gloucester. Modified from Heighway and Parker (1982: figures 12, 13, 14 and 15). Heighway, C. M., and Parker, A. J., 1982. The Roman Tilery at St Oswald's Priory, Gloucester. © Cambridge University Press. Reproduced with permission of The Licensor through PLSclear.**

The quantity of finds at Minety, with tile scatters, claypits and potentially as many as 10 kiln mounds (McWhirr 1979: 102, see figure 2.8) and the range of TPF and LHS stamps present among topsoil at the site (McWhirr 1984, Scammell n.d.) was used to argue that it represented a nucleated kiln site of multiple different workshops (McWhirr and Viner 1978, Darvill and McWhirr 1984). These may have competed, marking their products with distinct stamps to help identify them (Darvill and McWhirr 1984, sections 10.7-10.8). While Peacock (1969: 7) has acknowledged that such clustered industries were historically more typical of potteries, one only has to consider the Fletton brick trade (Hillier 1981, section 6.2.10) to see that high quality geological deposits could successfully support many competitors providing there was sufficient demand (McWhirr 1984). Reassessment by Warry (2017: 91) has since suggested that specific workshops and batches from Minety were limited to a supplementary role in local supply or to production for a discrete export market. Furthermore, pottery production has also been identified at the site (Scammell n.d.), and it may be that some of the kiln mounds are the results of these activities.

While the organisation of production at Minety is tantalising to consider, it is challenging to make firm conclusions because the chronology of the site is poorly understood, in common with many other Roman kiln sites (e.g. McWhirr 1979, 1984). Fulford and Machin (2021: 212) recently re-evaluated the pottery forms excavated from Minety by Scammell (n.d.), identifying them as typical Claudio-Neronian forms and suggesting a pre-Flavian start date for activity at the site. This is several decades earlier than prior estimates (e.g. Scammell n.d., Betts et al. 1997). Scammell (n.d.: 16) stated that dateable pottery forms were *not* recovered from the excavations of the kiln mound itself, being retrieved from a ditch on the far side of the field. This indicates that the main phases of visible activity at the site are not necessarily also pre-Flavian. Moreover, no pottery kilns have yet been found, suggesting that these activities were divorced from production at the main kiln mound itself, in direct contrast to the kiln site at Little London (e.g. Fulford et al. 2017: 6).

While production at Minety began in the mid to late first century, there is no consensus as to when it ceased (see also sections 10.7-10.8). Proposed end dates include AD 90 (Scammell n.d.: 3) and the middle of the second century (Warry 2017: 95), although Betts et al. (1997:23) have suggested that manufacture continued until at least the early third century. Given the uncertainty over the chronology of the site, it is possible that only a single kiln was in operation at any one time. The finds of a range of both stamped (McWhirr and Viner 1978, Darvill 1979) and relief-patterned (Scammell n.d., Betts et al. 1997) tile at Minety indicate significant production in the first and second centuries (Lowther 1948, Betts et al. 1997, Warry 2017), and may imply multiple workshops or kilns operating at once (section 10.7.3).

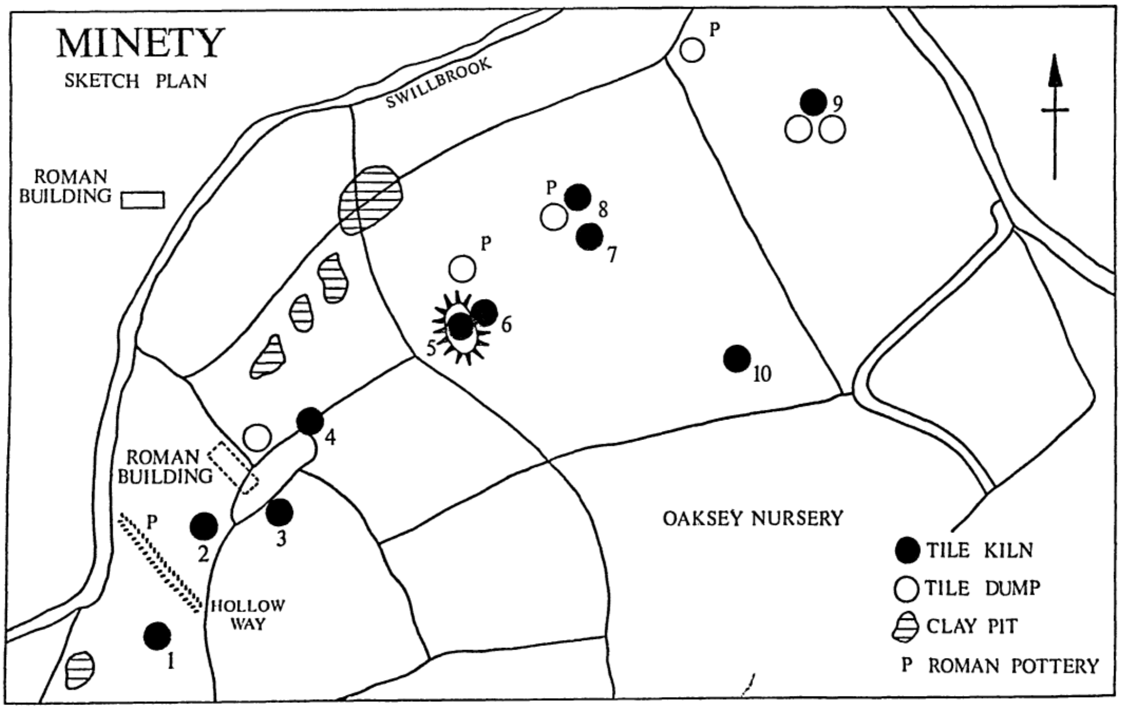


**Figure 2.8: Diagram of the Minety kiln site, Wiltshire. Modified from McWhirr (1984: 182b). © Robert Zeepvat.**

Itinerant activity, while discussed with enthusiasm as ethnographic or historic examples (e.g. Peacock 1979, Johnston and Williams 1979, Darvill and McWhirr 1984) remains less easy to identify. This is because the successful identification of peripatetic industries requires a good understanding of the local geology and the range of fabrics produced by regional kiln sites (see section 4.3.3). Nevertheless, itinerant production has been identified in Roman Britain through the analysis of stamped and relief-patterned tile. Darvill's (1980) thin-section petrographic analysis of TCM stamped tile from a range of sites in Gloucestershire and Warwickshire identified a range of fabrics, with each fabric present at only one or two sites. While some nearby sites may have been supplied by production at a single temporary local kiln (see figure 2.9), the evidence is nonetheless consistent with a brickmaker travelling between a range of locations with the TCM stamp die.

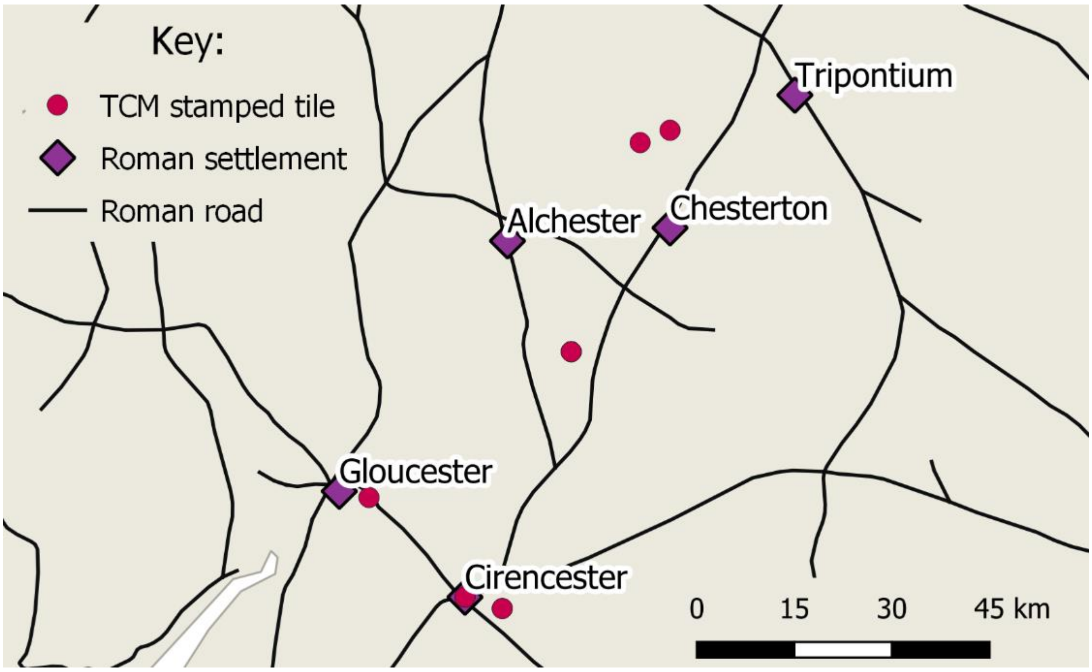


**Figure 2.9: Map showing the location of TCM stamped tile finds from Gloucestershire and Warwickshire.**

The evaluation of the historic and ethnographic record undoubtedly helped to introduce a more nuanced understanding of production, circulation and the value of ceramic building material in Roman Britain. While this literature remains an important resource, its impact has perhaps been less significant than expected due to the nascent recognition of kiln sites and their products at the time of original publication (e.g. McWhirr 1979). The applicability of each model to Roman Britain was thus demonstrated with reference to only a few comparatively well understood sites or assemblages (e.g. Peacock 1979, McWhirr and Viner 1978, Darvill and McWhirr 1984). This approach was therefore top-down, moving from theory to example. While useful on a case-by-case basis, this prevented creation of regional or national syntheses and any diachronic understanding of the modes of production present or coexistent in different parts of Britain throughout the Roman period.

### 2.2.3 Distributions and Synthesis

Significant quantities of new evidence have been recovered during commercial work since the introduction of PPG16 in 1990 (HMSO 1990), some of which has been summarised, synthesised and published through a research project (Betts et al. 1997) and a number of independent research papers and dissertations (Betts and Foot 1994, McComish 2012, Mills 2013, Betts 2016, 2017). Much of this excavation has been concentrated at a range of predominantly urban sites in the south of Britain (Mills 2013). Coverage of certain regions is thus far from complete. Despite this, the mass of new analyses of mostly unstamped brick and tile has enabled a new understanding of CBM production and supply in Roman Britain.

While the range and variation in the products of a number of major production sites and groups have been distinguished (Betts et al. 1997, Mills 2013), the kiln sites themselves often remain unknown (Betts 2016). In contrast to previous studies with only stamped samples (Peacock 1977, Darvill 1979, 1980), recent research has thus had to encompass distinct groups of ceramics without known sources (e.g. Pringle 2006, 2007). Emphasis has therefore shifted away from the modes of production at individual sites, which requires a relatively detailed understanding of a specific workshop (Peacock 1979, McWhirr 1984), in order to meaningfully integrate and understand products found at a disparate range of consumption locales. This understanding has therefore been achieved by working from the ground up, interpreting the evidence into a distinct picture rather than through reference to models (i.e. Hodder 1972) or parallels in other past societies (e.g. McWhirr and Viner 1978, Darvill and McWhirr 1984). The scale and scope of research has therefore broadened, successfully encompassing wider regional and chronological trends of production and supply.

Mills (2013) and Betts (2016, 2017) have both identified a major shift in the production of brick and tile in Roman Britain, although mainly in the southeast, around the mid second century AD. Prior to this transition London was predominantly supplied by local or semi-local kiln sites (Betts 2017), some likely within the bounds of the city itself (Betts 2017: 369-370). This included both procuratorial and civilian manufacture, although the procuratorial shipments were probably reserved for major public building works (Betts 1995). While there were a wide range of medium or long-distance imports to the city, for example from the Sussex (Betts et al. 1997: 20) or Eccles (Betts 2017: 371) production sites, these supplied only a very small proportion of the total (Betts 2017). As an example, the Sussex imports never comprised more than 1% of the total CBM from any site in London where they were present (Betts et al. 1997: 20).

Following the transition, production appears to have switched to a reduced number of kiln sites situated in rural locations much further away from their target markets (Mills

2013, Betts 2017). Long distance transport thus increased in terms of the total proportion of the products being supplied to sites. While local kilns ceased operation, including the state controlled tilery in London (Betts 1995), surprisingly many other production sites also appear to have shut down (Betts 2016), despite having previously had successful, albeit marginal, export markets. This includes both the Sussex and Eccles sites (Betts 2017). The rural brickyards that emerged exported products in much more significant quantities by land, river and sea. The kilns at Harrold in Bedfordshire, for example, produced a distinctive shelly ware that was exported in significant quantities to the southeast (Betts et al. 1997: 22), up to 170km away in the case of finds at Lympne, Kent (Betts 2017: 380, see figure 2.10).

A group of distinctive calcareous tiles have also been found across the southern coast of Britain, from Exeter (Holbrook and Bidwell 1991: 281-2) in the west to London in the east (Betts and Foot 1994: 28-29), and this distribution likely exploited maritime travel from kiln sites perhaps situated in eastern Hampshire (Betts and Foot 1994).

While post-transition products are found in significant quantities in London (Betts et al. 1997, Betts 2016), there were emergent rural production sites with significant distributions further northwest and in the midlands as well (Mills 2013). This includes the pink grog tempered ware from Stowe, Buckinghamshire (Mills 2013, Peveler 2016, 2018) and the Horningsea ware, distributed around East Anglia and Cambridge (Mills 2013). Harrold tiles also circulated widely in the south Midlands and Cambridgeshire (Unger 2009, see figure 2.10), rather than just to the southeast.

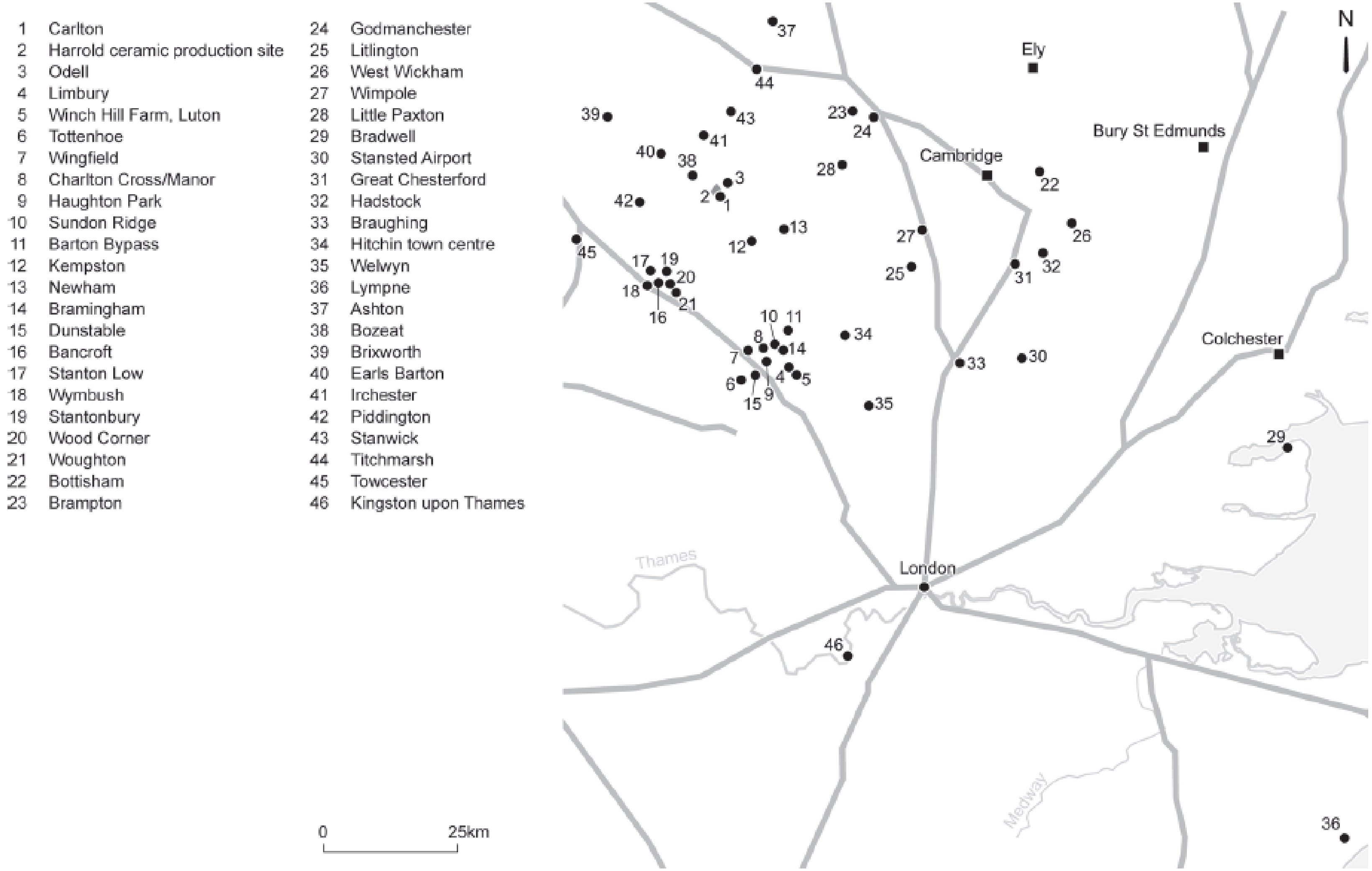


**Figure 2.10: Distribution map of identified Harrold shelly ware ceramic building materials. From Betts (2017: 380). © MoLA.**

While indicating a far-reaching change in ceramic building material supply in Roman Britain, the present picture is incomplete. In particular, it is unclear how applicable the supposed transition is to regions even further west and north. In the west, understanding of CBM from sites like Dorchester, Ilchester and Bath is currently insufficient to compare and contrast, but it is nonetheless interesting that production at Minety may have ceased at around AD 150 (Warry 2017: 95), though earlier and later dates have been suggested too (e.g. Scammell n.d.: 3, Betts et al. 1997: 23). At Gloucester, the stamping of the RPG tiles ceases around this time (Warry 2017: 84). This perhaps indicates a reorganisation or privatisation of the municipal tileworks, for production there continued into the third century (Heighway and Parker 1982: 31). It is perhaps wiser to explore these changes in the context of economic activity and fluctuations in the Roman Empire as a whole (Peveler 2018), and particularly in relation to pottery and coinage (Going 1992). This is necessary as the concurrent changes in supply and demand for CBM are much more likely a response to major economic oscillations than due to a spontaneous reorganisation of well-established and successful industries.

Despite the limitations of the current approach, it still represents a significant advance in the understanding of production, distribution and use. Indeed, a detailed chronological and regional picture of brick and tile supply in the southeast of Roman Britain has been achieved. While not yet a cohesive national picture, the establishment of an initial trend nevertheless presents a model to test and refine with future research in other regions.

## 2.3 Thematic Issues

In this section a range of thematic issues in the present study of brick and tile from Roman Britain will be discussed. These are topics for which a range of evidence has already emerged, but which have not yet been meaningfully synthesised or explored despite their potential to contribute to our understanding of these materials. This includes the value of brick and tile in Roman Britain, the co-production of ceramic building materials and pottery, and the international context of this material.

### 2.3.1 Value

The findings and synthesis of commercial research in the past few decades has yielded other benefits beyond understanding of production or distribution alone. In particular, the identification of systematic long-distance transport of CBM in Roman Britain has contributed to the development of a more nuanced understanding of the value of brick and tile in the past.

There has long been an implicit assumption of ceramic building material as a low value, bulk commodity travelling only short distances prior to use. In this way it has been diminutively contrasted with pottery (Hodder 1974, Millett 1990), and the skills and specialisms of Roman brickmakers sometimes derided (e.g. Rodwell 1978: 24). This dismissive view is probably due to the intrusion of modern conceptualisations of brick into the theoretical frameworks we apply to the past. Although low cost, the vast majority of modern CBM in Britain is produced at a restricted range of large industrial production sites (Bloodworth et al. 2007) and is transported widely across the UK. This stereotype of tile is therefore perhaps more representative of late Victorian or earlier 20th century brickmaking and use, encompassing multiple episodes of urban development and postwar rebuilding across Britain.

Much ceramic building material in Roman Britain does appear to have been produced and used fairly locally, for example in the early period at London (Betts 2016, 2017), at York (Betts 1985, McComish 2012), Gloucester (Heighway and Parker 1982, Warry 2017), Cirencester (McWhirr and Viner 1978, Darvill 1979) and at Dorchester-on-Thames, Oxfordshire (Peveler 2018). However, the range and variety of products being moved across Roman Britain, particularly in the later period (Mills 2013, Betts 2017), means that such a simplistic generalisation of CBM should be reconsidered. As Betts (2016: 106) notes, the long-held assumption that road transport of bulk materials would be too costly to be practicable needs to be questioned, especially if one considers that carts and draft animals could have readily been supplied by a part-time rural brickyard during slack periods of the agricultural calendar. Moreover, similar long-distance transport of stone from Ham Hill and Bath, both in Somerset, and from Leicestershire to London has been identified from early Roman Britain (Hayward 2009), clearly indicating that long distance road transport of bulk commodities was a standard practice. Indeed, the interplay of stone and ceramic building material industries may even have allowed profitable movement of goods in either direction and may explain the presence of a Hampshire CBM fabric in Bath (e.g. Betts 2007: 52, sections 7.1, 10.5.3)

Mere long-distance transport, providing that this was routine and thus cost effective, does not prove the worth of ceramic building materials in the past. Instead, it is important to contextualise this material among other alternatives (Peveler 2018). While brick is a relatively inexpensive and ubiquitous building material in modern Britain, in Roman Britain it was highly resource intensive, requiring substantial clay, water, fuel, skilled specialists in brickmaking and firing and a suitable clamp or kiln. When compared to alternatives, notably; clay, wattle, daub, cobb, timber, thatch or reeds, shingles, and building/roofing stone, the contrast is clear. As such, timber framing with wattle and daub (Russell 1997), or even unfired clay bricks (McWhirr 1984), formed the basis of many structures in early Roman Britain until the second century (Webster 1979: 285). This occurred widely at sites such as London (Betts 2016, 2017), Leicester (McWhirr 1984), Silchester (Clarke et al. 2007), Verulamium (Lowther 1948) and in the Walcot settlement at Bath (Davenport 2000). The majority of early CBM being used was therefore probably roof tile (Betts 2017: 368), although bricks were frequently used as the basis of hearths (Betts 2016: 100).

The more widespread private adoption and use of CBM in urban centres in the early second century (McWhirr 1984, Mills 2013) may actually have been due to the prompting of local government in efforts to reduce fire hazards (Betts 2017: 375), rather than due to any exponential increase in affordability. Indeed, the sometimes-significant cost of brick and tile in the Roman world is illustrated in the Diocletian Edict of AD 301, which authorised maximum prices for a wide range of food, labour, textiles, slaves, animals and building materials (Michell 1947) in *Denarius Communis* (Kropf 2016: 5), here referred to as units. In this decree, the maximum cost of a small brick was 4 units, a box flue tile 6 units, and the maximum daily wage for an unskilled labour was 25 units (Kropf 2016: 17-18, 32). While other brick and tile forms were listed (Kropf 2016: 32), the inscriptions were presumably too fragmentary to read the cost of these components, but they were probably the same price. This implies that the maximum daily wage of an unskilled labourer at the time was equivalent to the purchase of as few as 4-6 ceramic building material components. As a modern equivalent, with the UK minimum wage at £8.72 per hour (GOV.UK 2021), each brick or tile would therefore cost £10-15. These circumstances were, of course, part of an attempt to halt inflation in an economic crisis (Michell 1947, Kropf 2016) during a specific period in the Roman Empire. Their applicability to understanding brick and tile from Roman Britain at any period is therefore limited, and the price of each component may have fluctuated depending upon the scale of the project and when and where the material was required. Given the significant number of bricks or tiles needed for only a single building or roof, the prices of the Diocletian Edict nevertheless indicate that the use of CBM could at times be an expensive proposition.

Many forms of early tile found in London are directly linked to heating systems and bathhouses (Pringle 2006, 2007), indicating early elite demand for ceramic building materials (Lancaster 2012). Particularly during early Roman Britain, heating systems could only be provided by using specialised ceramic building material components (Webster 1979). While many regions eventually experimented with the substitution of certain simple ceramic components with stone alternatives (Williams 1971), for example replacing *pilae* with stone piers (Brodribb 1987: 49), or voussoirs with shaped tufa blocks, ceramic box flue tiles remained an essential mainstay in heating systems until the end of the Roman period (Betts 2016: 108). The construction, maintenance and fuelling of these bathing facilities would have been extremely costly (Webster 1979) and thus restricted to elite clients (Lancaster 2012). While many workshops successfully produced and marketed both roof tiles and components for heating systems, for example Ashtead (Lowther 1948, Betts et al. 1997), the specialisation of the early London-Sussex group (Black 1985: 356-7) demonstrates the significant and profitable demand for aristocratic bathing facilities. This workshop produced box flues, centrally divided double box flues and Westhampnett hollow voussoir forms (Black 1985: 356), all optimised for use in an original heating system (Lancaster 2012: 420). That the production of just these products appears to have sustained the entire workshop for three decades (Betts 2018: 2) indicates that these were valuable products with significant demand.

The value of CBM no doubt fluctuated by component, period and region. Despite this, its early elite association, which must have continued to be fostered through the widespread emergence of villas (Frere 1978), many of which incorporated bathing facilities (Lancaster 2012), as well as widespread use in grand public building programs in the province (e.g. Betts 1995, Fulford et al. 2019) clearly indicates that brick and tile was often a valuable commodity in Roman Britain. The simplistic perception of this material as low-value and only locally used cannot therefore be maintained.

## 2.3.2 Cross-craft Ceramic Production in Roman Britain

Joint production of pottery and brick and tile has been identified at a wide variety of kiln sites in Roman Britain. Despite this recognition, little effort has been devoted to integrating these materials either in studies of production sites or in wider syntheses of these industries.

Co-production of ceramic building materials and pottery has been demonstrated at both civil and military kiln sites in Roman Britain. At Holt, Denbighshire, the twentieth Legion produced brick and tile, pottery and even glazed wares (Grimes 1930). The two Legions successively stationed at York have been shown to be responsible for the production of much Roman brick and tile in the city (Betts 1982, 1985), but also local Ebor Ware (Perrin 1977, McComish 2012). While the evidence is less clear-cut, it appears that civilian contractors at Heworth, just outside York, may also have been co-producing tiles and mortaria to supply the Legions there (Lawton 1993, McComish 2012). A similar situation has been tentatively identified at Caerleon, where a civilian kiln site at Bulmore demonstrated evidence for the co-production of brick and Caerleon ware pottery (Swan and Philpott 2000: 63), presumably for the local fortress.

There is also a range of evidence for purely civilian co-production. In London, procuratorial stamps are present on ceramic building material and pottery (Betts 2016, 2017), with die types 1 and 9 (figure 2.11) uniquely being applied to bricks, tegulae and *mortaria* forms (Betts 1995: 207). While the kiln site has not been located, tile wasters with procuratorial stamps have been found in the Cheapside area of London (Betts and Smith 2014: 69-70), probably indicating local production in the bounds of the Roman city (Betts

2016). The limited use of the same dies on both pottery and CBM implies manufacture under the same oversight (Betts 1995), although the workers and kilns used may have been different.

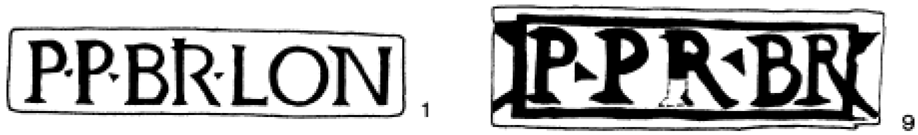


**Figure 2.11: Illustration of the two procuratorial stamp dies applied to bricks, tegula and *mortaria*. Modified from Betts (1995: figure 1). Betts, I. M., 1995. Procuratorial Tile Stamps from London. © Cambridge University Press. Reproduced with permission of The Licensor through PLSclear.**

Co-production of pottery forms, including *mortaria*, flagons and pitchers, and brick and tile has also been identified at Minety (McWhirr 1984, Scammell n.d.). Both tile kilns and smaller pottery kilns and wasters have been excavated at the Neronian-period Little London site near Silchester (Fulford et al. 2017), indicating clear co-production at a securely dated and short-lived site (Fulford and Machin 2021: 211-212). The kiln site at Harrold, Bedfordshire also produced pottery alongside its distinctive shelly CBM wares (Betts et al. 1997: 22). The extensive coarseware Roman pottery kiln sites at Brockley Hill, Middlesex (Castle 1976, Smith et al. 2008) have also been indicated as a possible source of ceramic building materials from London and the southeast (Betts 2018: 5). However, indisputable evidence of tile kilns and definite wasters from the area have yet to be found (Jones 2008: 129). Pink grog tempered pottery and CBM fabrics were produced around Towcester, Bedfordshire, and circulated around the Midlands (Mills 2013). Frequent co-occurrence of these products has been noted (Mills 2013: 465), including at Dorchester-on-Thames, Oxfordshire (Peveler 2016, 2018), indicating use of the same transport networks, if not co-production.

While joint production of pottery and ceramic building materials in the Roman period was not universal, it was certainly not uncommon. The division between these industries has therefore emerged as part of atomistic traditions in archaeological materials and material culture studies more generally (Tite 2008). It must be acknowledged that the two fields of ceramic study are very different, especially in regard to the diversity of forms observed (e.g. Tyers 2014 vs Brodribb 1987) and the sheer depth of research into Roman pottery in Britain (Tyers 1996). McWhirr's (1979: 97-8) division of ceramic production sites into CBM or pottery manufacture on the basis of rectangular or circular kiln shapes has not helped the matter. While broadly correct, CBM can still be competently fired in circular kilns as McWhirr (1979: 98) did in fact observe. Indeed, di Caprio (1979: 91) noted that several historic brickmakers in Italy preferred to use circular kilns as it allowed a better control of the draught and kiln environment during firing. Such a simple binary division between pottery and CBM production potentially excludes much interesting evidence, but it also focuses researchers on only one aspect of a site, rather than enabling a holistic understanding of its total production and local or regional role.

The somewhat artificial distinction between pottery and ceramic building materials has prevented a detailed understanding of cross-craft ceramic production in Roman Britain. Few studies, for example, have compared the fabrics of pottery and CBM from the same sites. Exceptions include Betts (1995), with procuratorial tiles and pottery from London, and Swan and Philpott (2000) with material from Tarbock, Merseyside. If the raw materials, processing and firing techniques and conditions were found to be consistent between pottery and CBM, then this could be interpreted as evidence for cross-craft production, perhaps by the same individuals. The evidence for the production of glazed vessels at Holt (Grimes 1930: 182-3, figure 2.12) is particularly intriguing as it indicates rare glazing skills present alongside pottery and CBM manufacture by the Legions. Peveler (2016: 7) has indicated that the supply of pink grog tempered brick and tile to Dorchester-on-Thames, Oxfordshire, may have been alongside the transport of large storage jars of the same fabric, perhaps containing foodstuffs (Taylor 2004: 61). This would indicate that cross-craft interaction was not necessarily purely ceramic, but that building materials might also have been circulated with the movement of agricultural produce, and perhaps other consumables too. Ultimately, this understanding of co-production and co-circulation may help to shed light on why so many small batches of imported brick and tile are present at sites often well supplied locally, as in early Roman London (Betts et al. 1997, Betts 2016,

2017) at Dorchester-on-Thames, Oxfordshire (Peveler 2016, 2018), Silchester (Machin 2018) and at Bath (Betts 2011, 2015).

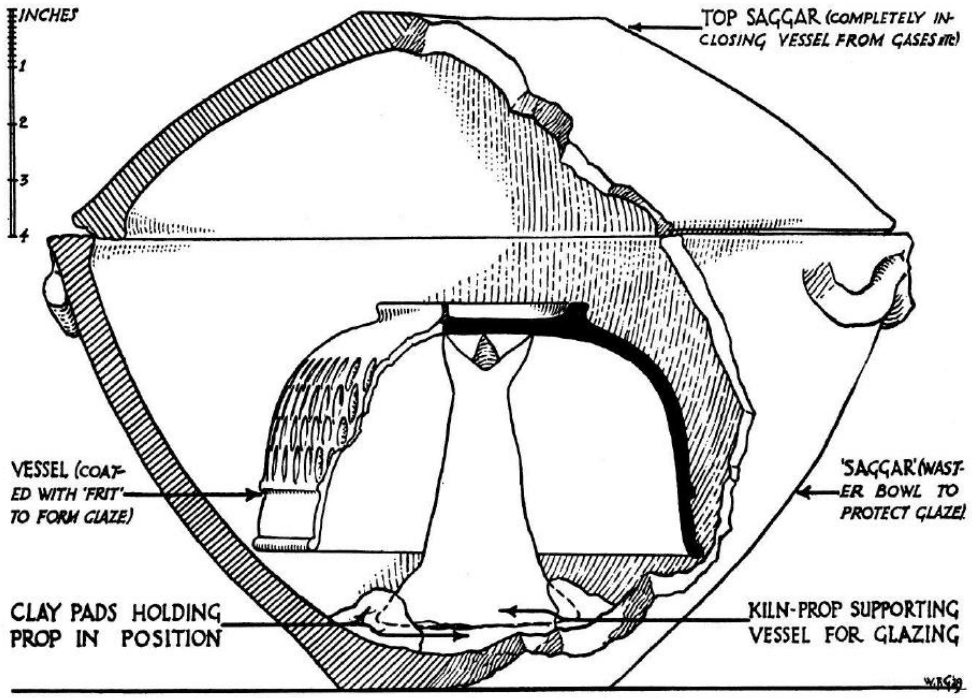


**Figure 2.12: Illustration of a vessel used in the production of green-glazed wares at the Legionary tilery at Holt, Denbighshire. From Grimes (1930: Plate X). © The National Library of Wales.**

At a greater scale, shifts in CBM production should be compared with changes in pottery manufacture and supply in order to define regional or province-wide economic understandings of these industries and societies (Going 1992, Peveler 2018). That it is clear that many sites produced both products only enhances the necessity of this integration.

Given the continuity of certain late Iron Age pottery industries in southern Britain into the Roman period, for example the Dorset Black Burnished Wares (Morris 1994, Gerrard 2008), or Severn Valley Wares (Morris 1994, Timby 1990), this may have offered an alternate route for indigenous communities to adopt the manufacture of Mediterranean-style ceramic building materials, after already supplying pottery and supplies to the Roman army (Gerrard 2008) or emerging local towns. The study of ceramic co-production thus has clear potential to contribute to our understanding of material and economic issues in Roman Britain.

## 2.4 International Context

Despite research into ceramic building materials from Roman Britain spanning more than seven decades, the international context of this material is not well understood. This is not because Continental finds have not been regularly referred to. Indeed, disparate studies have drawn a range of minor conclusions as to the relationship between brick and tile from Roman Britain and the rest of the Empire (e.g., Brodribb 1987, Betts et al. 1997, Lancaster 2012, 2015b, Mills 2013), but these have not yet been synthesised. While the current understanding is far from complete, the present evidence suggests that ideas or prototypes continued to be introduced into Roman Britain (Warry 2005, Lancaster 2009, 2015a), but were rarely transmitted in the other direction (e.g., Lancaster 2012, 2015b).

### 2.4.1 Research Focus

Research in Britain has tended to focus exclusively on material from the province. This is true of total or partial collections from individual sites (Cunliffe 1971, Brodribb 1979, Foster 1985, Viner and Stone 1986), grouped material from a town or city (Mepham 2001, McComish 2012, Peveler 2018, Warry 2021), region (McWhirr and Viner 1978, Betts and Foot 1994, Warry 2017, Machin 2021) or from Britain as a whole (Betts et al. 1997, Warry 2005). Comparative Continental examples are therefore referenced sporadically in the literature, often in response to finds of a specific stamp inscription (e.g. Clifford 1955, Bogaers 1977, Peacock 1977, Swan and Philpott 2000, Warry 2010) or artefact type (e.g. Cunliffe 1976, Brodribb 1987, Mills 2013). An exception to this inward focus is Lancaster (2009, 2012, 2015) and perhaps Mills (2013), who both have strong backgrounds in Continental or Mediterranean Roman research. While comparison of CBM with material from other provinces can draw valuable conclusions (e.g. Betts et al. 1997: 46, Swan and Philpott 2000), these are often disjointed and can be extremely localised in scale. Nevertheless, the present evidence of a range of artefact forms and stamps from Roman Britain indicates a complex relationship with innovation and transmission between the rest of the Empire.

### 2.4.2 Innovation and Transmission of Forms and Features

Many forms of ceramic building material in Roman Britain were ubiquitous across the Roman world (Brodribb 1987), for example tegulae, imbrices, and various sizes of simple flat bricks (McWhirr 1984), among many other components. However, the apparent lack of some common forms in the province has been noted, for example the absence of triangular bricks used to face rubble-core walling (Brodribb 1987: 49). In addition to embracing a wide array of established ceramic building material forms, there is also a range of evidence for the innovation, experimentation and transmission of new brick and tile types in Roman Britain (Lowther 1948, Lancaster 2012, Betts 2017). The best example is the products of the aforementioned London-Sussex group (Black 1985: 356-7). While they invented the Westhampnett hollow voussoir form (figure 2.14), and thus inspired hollow voussoir tiles more generally (Lancaster 2012: 437), this was actually just a part of an innovative new heating system. Full box flue tiles were likely a slightly earlier invention from the Italian mainland (Brodribb 1987: 71). Nevertheless, the Sussex workshop created new double box-flue tiles with a central divider and various cut-outs (figure 2.13) specifically to enhance the movement of air between hypocausts and box flue wall linings (Betts et al. 1997: 8-9). When combined with the Westhampnett hollow voussoirs, this allowed the roof to be part of an integrated system significantly improving air flow and heating efficiency (Lancaster 2012: 420, 431). It may also have prevented condensation dripping onto the bathers, which Seneca recorded as a particularly unbearable phenomenon of earlier heated baths in Italy (Webster 1979: 289).

Westhampnett hollow voussoir forms of the London-Sussex group have been found in London and across much of the southeast of Britain (Black 1985, Lancaster 2012, Betts 2017), although most concentrated around Chichester (Betts et al. 1997: 19). By contrast its successor, the typical hollow voussoir form (figure 2.14), enjoyed much more widespread deployment and was used at more than 100 sites across Roman Britain from the early second century onwards (Lancaster 2012: 437). These ranged from small bathing rooms at villas, for example at Beauport Park, East Sussex (Brodribb 1979), to the Great Bath and Spring Reservoir Enclosure building at Bath (Cunliffe 1969, Cunliffe and Davenport 1985).

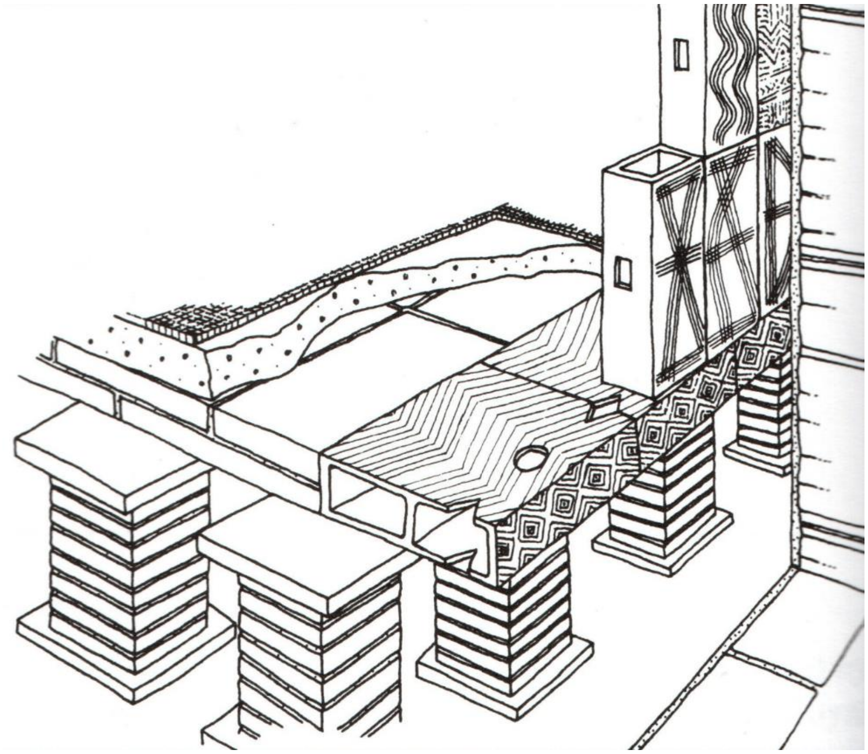

**Figure 2.13: Illustration of an innovative hypocaust heating system using the centrally divided double box flue components of the London-Sussex group laid horizontally. From Betts et al. (1997: figure 4). © Study Group for Roman Pottery.**

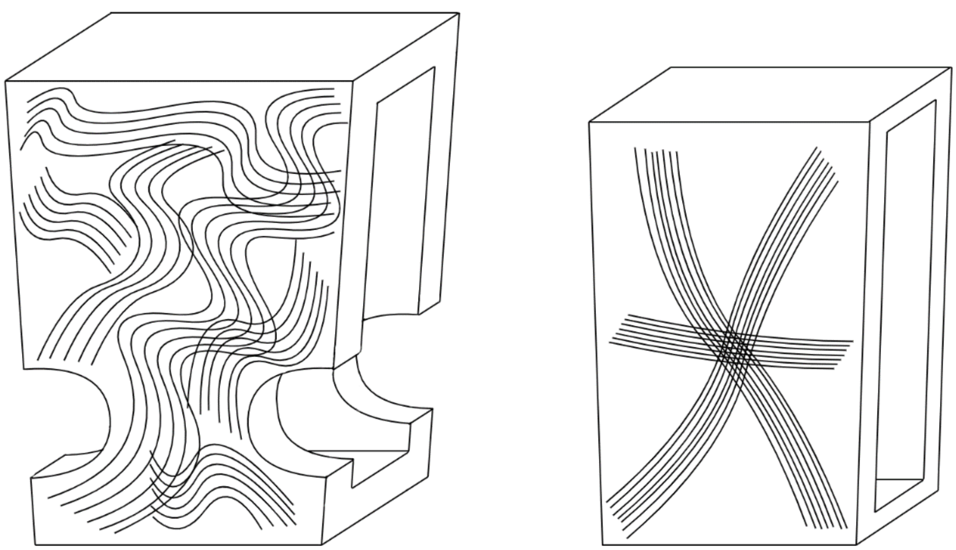

**Figure 2.14: Illustration comparing an early Westhampnett-style hollow voussoir (left) with the later, more typical form.**

Not all experimentation appears to have been so successful. A distinctive type of box flue tile made with a fish-tailed clamp protruding from the upper edge (figure 2.15) has been identified from the kiln site at Ashtead, Surrey (Betts 2016: 100). In-situ examples have also been found at the local villa (Lowther 1948: 6). The intention of the projection appears to have been to allow the fishtail to be mortared into the wall behind, thus anchoring the wall jacketing without the need of the usual iron clamps (Betts 2016: 100). While ingenious, this must have been a fragile component, and thus unable to withstand significant travel (Lowther 1948). The limited distribution of these forms probably implies their lack of success. Together with hollow voussoir forms (Lancaster 2012), and indeed a range of other unique variants (e.g. Betts 2017: 100-103) and oddities (Brodribb 1987: 95-97) this clearly demonstrates that there was experimentation and innovation in brick and tile manufacture in early Roman Britain.


**Figure 2.15: Photograph of a distinctive 'fish-tailed' box flue tile produced at the Ashtead kiln site, Surrey. From Lowther (1930: plate IV). © Surrey Archaeological Society.**

Most new specialised forms appear to have been introduced from outside Roman Britain (e.g. Brodribb 1987, Lancaster 2009, 2015), but for a wide range of ubiquitous components there appears to have been little modification or change (Brodribb 1987). Tegulae provide an exception. While Warry (2005: 143) initially conceived his type C cutaway group as a later introduction to the province, finds from a secure mid first-century context in London (Mills 2013: 466), from the Neronian Little London kiln site (Fulford 2022 pers. comm.), and more widely across urban centres in southern Britain (Warry 2017: 94), show that it was present from an early date, and was probably used in the Mediterranean from the fifth century BC (Mills 2013: 458). One cutaway group that remains consistent with new introduction are the Group D cutaway forms (Warry 2005, Mills 2013). These are highly prevalent on military sites (Warry 2005, 2010), and thus may well be a Legionary innovation introduced from the Continent during the third century, perhaps linked to Severan military reforms (Mills 2013: 459). The apparently isolationist nature of ceramic building material production in the Legions in Britain has been noted by Warry (2010: 145). Further comparison with Continental military tegulae may indicate if the Group D cutaways were indeed foreign innovations, or perhaps a practice that emerged in Britain.

A range of ceramic building material forms used only in vaulting appear to have been introduced into the province sometime after the Conquest. This includes vaulting tubes (Brodribb 1987: 87-8, Lancaster 2009) and armchair voussoirs (Brodribb 1987: 46-7, Lancaster 2015). These are specialised and visually distinctive components, and it may be that this has enabled their identification as foreign innovations, while a range of other novel but less conspicuous forms may have gone unrecognised. In any case, these components do not appear to have been widely used in Britain, perhaps outcompeted by the local and popular hollow voussoir form of barrel vaulting (Lancaster 2012: 437).

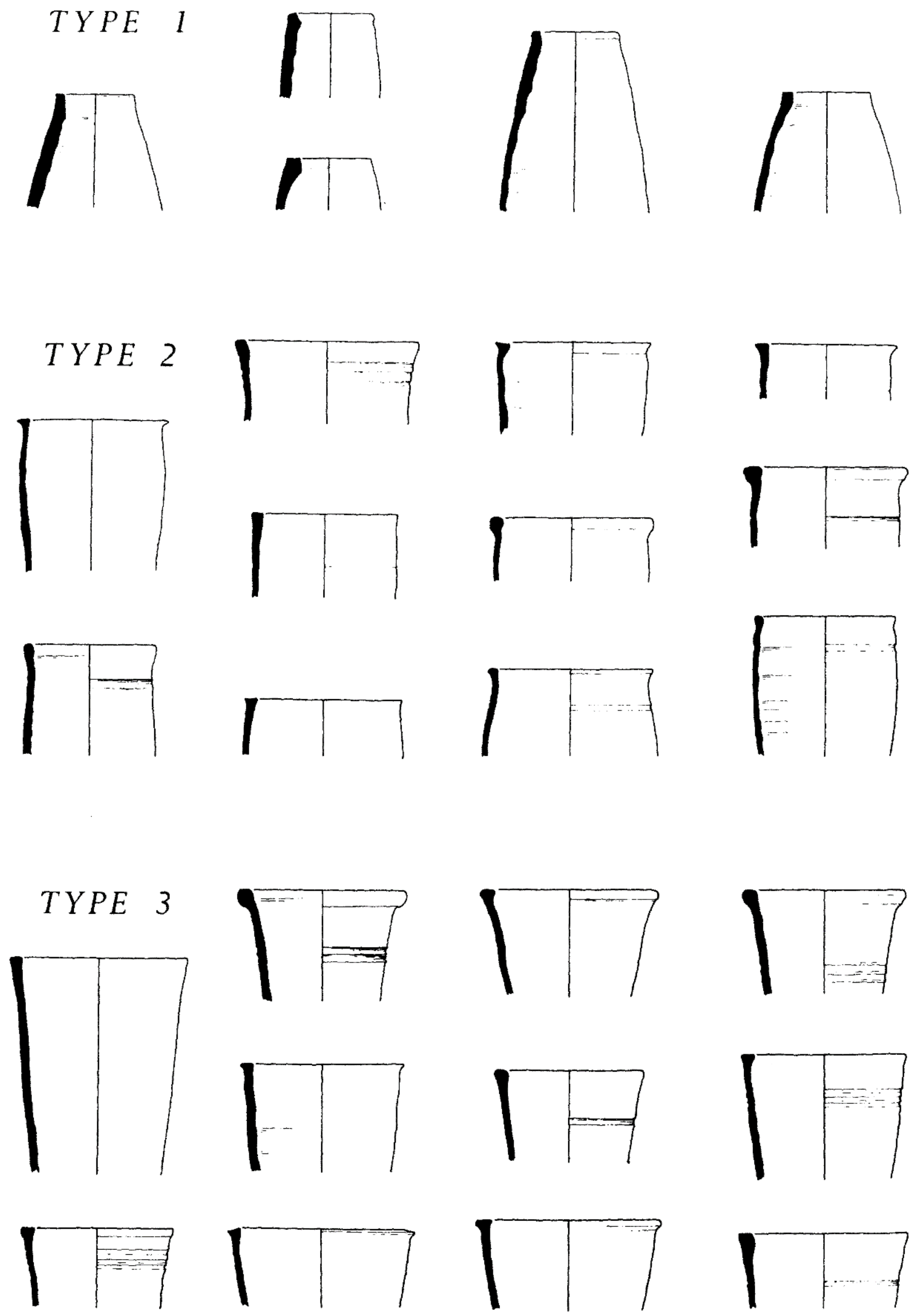


**Figure 2.16: Illustration of ceramic pipe rims found by Cunliffe during excavations in the West Baths. From Cunliffe (1976: figure 14). Cunliffe, B. W., 1976. The Roman Baths at Bath: The Excavations 1969-75. © Cambridge University Press. Reproduced with permission of The Licensor through PLSclear.**

Terracotta vaulting tubes were perhaps invented in the third century BC in Sicily (Wilson 1979: 32). While used sporadically in the Mediterranean Roman world (Lancaster 2015), this method of vault or dome construction became ubiquitous in third-century North Africa (Lancaster 2009: 6). In Britain, these components have so far been identified from the Fortress baths at Chester (Mason 1990), Caerleon (Zienkiewicz 1986: 334), York (McComish 2012: 199-202), Bath (Cunliffe 1976: 28-9) and perhaps other sites, although the forms of these tubes can easily be confused with water pipes (e.g. Brodribb 1987: 84). Indeed, Cunliffe (1976: 31) noted that the terracotta tubes found in the West Baths at Bath bore scant resemblance to North African syringe-type examples, and was thus unsure of his interpretation. Lancaster's (2009: 6) work has since recorded a different style of vaulting tube, or 'pot' (see figure 2.17), which more closely resembles the Roman Baths examples (figure 2.16). This is a form with a distribution predominantly restricted to the Rhine area, its Legionary bases, and the south of France (Lancaster 2009: 5). This perhaps indicates that vaulting tubes were introduced into Britain via the military, and indeed the finds at the military sites above appear to confirm this.

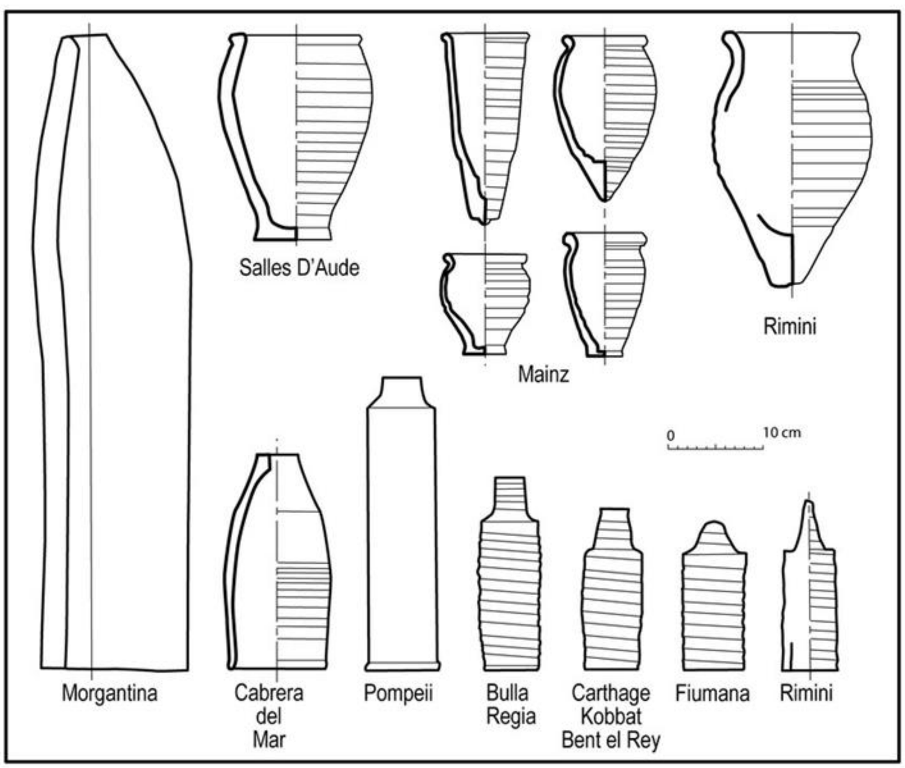


**Figure 2.17: Illustration of a range of vaulting tubes, lower row, and vaulting pots, upper row, from sites across the Roman Empire. From Lancaster (2009: figure 5). Reproduced by permission of the Construction History Society.**

### 2.4.3 Innovation and Transmission of Marks and Impressions

The analysis of stamped and relief-patterned tiles from Britain and the Continent also offers a range of insights into transmission of building materials and practices. Relief-patterned roller dies were used by civilian tilemakers in Britain (section 2.1.2), and these impressions were applied to only a minority of products (e.g. Fulford and Machin 2021: 217), with the remainder combed or knife scored, and have been interpreted as a means to mark batches submitted as part of contracts (Lowther 1948, Black 1985). Relief-patterned tiles were a relatively widespread phenomena in southern Britain (e.g. Lowther 1948, Black 1985, Betts et al. 1997), probably dating to the later first century (Fulford and Machin 2021, see section 2.1.2). On the Continent, similar impressions appear to have only been studied in western Germany (e.g. Baatz 1988). These tiles date to the later second century (Betts et al. 1997: 46), implying that the practice of applying roller-dies to CBM may have been invented in Britain. The German examples are a good deal later than many British examples (e.g. Betts et al. 1997, Fulford et al. 2017), are clearly different in design (Betts et al. 1997: figure 22) and were applied to a different range of tiles (Betts et al. 1997: 46). It therefore seems unlikely that the idea was directly transmitted by an itinerant tilemaker from Britain. Instead, it may be a case of independent innovation derived from an established Continental use of very small roller-dies on pottery (e.g. Lancaster 2012: 435).

Military stamping appears to have originated with Legions stationed on the Rhine during the middle of the first century (Kurzmann 2006: 201-2), with the practice only being adopted by Legions in Britain sometime around the beginning of the second century AD (Boon 1984: 15-16, RIB II(4): 125). The earliest dateable military brick stamps from Roman Britain are those of the Legion IX Hispana from York (*RIB* II(4): 168), which must pre-date their disappearance by the end of the Trajanic period (Frere 1978: 160), i.e. prior to AD 117. The adoption of civilian stamping during the early second century (Heighway and Parker 1982: 62, McWhirr 1984: 30) has therefore been suggested as being inspired by initially foreign military practices (Warry 2017: 83 *contra* Heighway and Parker 1982: 62), or perhaps by integration of serving or retired Legionaries into civilian brickyards (McWhirr 1984: 30). However, circular Imperial stamps were being applied at the Little London tilery just after the middle of the first century AD (Fulford et al. 2017: 9). The procuratorial stamps from London are associated with Flavian public building projects

(Betts 1995: 217-220), indicating that they also likely predate the introduction of military stamping in Britain. A find of an RTVSCVS stamped tile from a secure Flavian context at the Caerleon fortress baths (Boon 1984: 22, Zienkiewicz 1986: 27-8) also points to local civic stamping prior to adoption by Legio II Augusta. The significance of the military in civilian adoption of stamping in Britain has therefore probably been overemphasised. While there was civilian tile-stamping in London (e.g. *RIB* II(5)), the quantity and range of stamps yielded has been limited (Betts 2017: 370), and it is unclear if these practices were spread through familiarity with the procuratorial brickworks. As such, the mechanisms of adoption of stamping in Britain are not well understood, and may be better elucidated through future research and comparison to Continental civilian stamped products.

### 2.4.4 International Transport

The CL BR stamps of the Classis Britannica are the only ones to have been found at sites in Britain and on the Continent (Peacock 1977, Crowley and Betts 1995). However, distribution on the other side of the channel was not significant, being restricted to Boulogne and Desvres (Peacock 1977: 236), both in north-east France. While this research is now dated, it remains the only identified transport of brick and tile across the channel, whether military or civilian. It is possible that other CBM was transported across but has not yet been identified, which is especially likely if the material was unstamped. That this is probably not the case is supported, to some extent, by results from the study of monumental carved stone from Roman Britain. Hayward (2009: 97) has identified Continental building stone being imported into Britain during the early Roman period, particularly *Calcaires a polypier* from the Lorraine border region of France and Germany. These early and probably military imports stopped only a few decades after the Conquest, by which time a range of suitable building stones had been identified and successfully quarried within the province (Hayward 2009: 100). While marble continued to be imported into Britain in negligible quantities (Russell 2013), this implies that bulk material transport of building stone across the channel into Britain became rare even before the end of the first century AD (Hayward 2009). Despite the long-distance transport to the southeast necessitated by exploitation of stone outcrops in the Cotswolds or Leicestershire (Pearson 2006, Hayward 2009), use of high-quality native stone supplies apparently still superseded foreign imports. The same scenario may perhaps have been applicable to any commercial cross-channel transportation of ceramic building materials.

## 2.5 Chapter Conclusion

Roman ceramic building material was introduced into Britain soon after the Roman Conquest in AD 43. While initial production and consumption was largely concentrated in the southeast, by the early second century brick and tile appears to have been widely adopted across southern Britain. Once established, the manufacture of ceramic building materials continued until the end of the Roman period. Despite this continuity, there were substantial changes in the production, use and distribution of brick and tile throughout these four centuries. While the early period was characterised by a range of innovations, a preponderance of local kiln sites and the use of stamps, later production included a restricted range of CBM forms, systematic long-distance transport from rural kiln sites and, eventually, a decline linked to increased recycling and use of roofing stone.

The changes in CBM use and circulation have come to light largely as a result of research in the past three decades. While earlier studies made important contributions, particularly in understanding the range of modes of production present in Roman Britain, these were disparate and targeted select sites or stamped assemblages. More recent research has had to encompass large unstamped assemblages from commercially funded excavations. The analysis and synthesis of this data has, for the first time, enabled the creation of diachronic regional understandings of CBM production and circulation in Roman Britain.

The identification of systematic long-distance transport of brick and tile by road or sea in Roman Britain has had further implications. This has necessitated a re-evaluation of early perceptions of CBM as a high bulk, low value commodity travelling only locally. Given the importance of tile components in the construction of Roman bathhouses, CBM production in Britain could have been fostered by elite demand for these facilities. While the exact value of ceramic building materials in the past is challenging to discern, this long-distance transport and elite patronage nonetheless suggests that at times brick and tile were highly valued and in significant demand.

The production of ceramic building materials should not be considered in isolation. While pottery and CBM manufacture in Roman Britain has largely been considered separately, there is significant evidence for co-production at a range of legionary, procuratorial and civilian kiln sites. In future, studies of such sites should compare and contrast the ceramics present in order to establish the potential for cross-craft production. Future syntheses of pottery or brick and tile should integrate results from the other field of study in order to develop a holistic understanding of co-production, co-transport and the development or decline of ceramic industries in Roman Britain.

To achieve a truly holistic understanding of CBM in Roman Britain, the present evidence must be systematically compared to material from the wider Empire. A brief review indicates that a range of brick and tile innovations were introduced from Western Europe or the Mediterranean throughout the Roman period. By contrast, otherwise successful new forms of CBM invented and used in Britain were apparently never adopted outside the province. The only evidence for cross-channel movement of brick and tile remains the stamped material produced by the Classis Britannica. The introduction of new forms was therefore probably facilitated by the movement of specialists into the province, including the Legions, and there seems to have been little transmission in the other direction. Integrated research in Europe and Britain is required to test this hypothesis.

To conclude, understanding of the ceramic building material from Roman Britain has clearly advanced significantly as a result of more than 70 years of research. The establishment of diachronic regional pictures of production, use and distribution in parts of Roman Britain represents a particularly significant achievement. While understanding of many assemblages from the north and west of Britain remains limited, the provision of initial outlines in other regions nevertheless presents a model for future research to test and compare against. Moving forward, it is important to establish a greater holistic understanding of CBM in Roman Britain, whether through integration of research with pottery studies, building stone syntheses or with Continental brick and tile.

# 3 The Study of Roman Ceramic Building Materials in Bath

This chapter will review the development of the study of the ceramic building materials of Roman Bath. By exploring how previous researchers approached and recorded finds of ceramic or stone building materials, the evolution of the present understanding of the Roman Baths is outlined. This traces a thread from the earliest antiquarian notes of inscriptions and sculptures in the city, though Georgian and Victorian investigations, to the seminal syntheses and excavations of Cunliffe (1969, 1976) and Cunliffe and Davenport (1985) and up to the present. Finally, this chapter concludes by summarising what is known about the origins and composition of each of the four assemblages of ceramic building materials from the Roman Baths that are investigated in this study.

## 3.1 The Antiquarian Period

The antiquarian period, spanning approximately AD 1500-1900, constitutes the longest period of study in Bath's history. Perhaps unsurprisingly it is extremely diverse, with an intersection of local to national-scale studies encompassing the Roman remains from the city over a period of several centuries. For much of this time Roman ceramic building materials from the city were largely neglected in favour of stone sculptures, inscriptions and, eventually, the study of structures. It is nevertheless illuminating to discuss the development of the study of Roman stone remains from the city more generally, in order to contextualise how building materials were viewed and considered at the time.

### 3.1.1 Early Research

The study of Roman remains in the city of Bath began with the visits of the earliest British antiquarians John Leland (e.g. Smith 1907) and William Camden (Gibson 1722) in the 16th century. Both described a range of Roman sculptures and inscriptions that had been incorporated into the Medieval town walls (Smith 1907: 140-141, Gibson 1722: 91-92). Roman material had undoubtedly been extensively excavated in the city prior to these visits, especially for the robbing of stone in the Medieval period (La Trobe-Bateman and Niblett 2016). Indeed, the Old English elegy ‘The Ruin’ evocatively attests to the ruinous, yet still visible, state of the Roman structures in the early medieval period (e.g. Earle 1872, Leslie 1961). However, the presence of Roman remains in the city does not appear to have been widely published before the popular itineraries of Camden and Leland.

While Leland (Smith 1907) and Camden’s (Gibson 1722) notes about the sculptures and finds of Bath were brief, subsequent local or visiting antiquarians devoted more effort to publishing every detail of these and any newly excavated inscriptions and sculptures. In the earlier 18th century, Guidott (1698), Musgrave (1719) and Horsley (1732), among others, produced considerable tracts focussed on the interpretation of these Roman inscriptions. By the very end of the 18th century, discussion more heavily emphasised architectural and sculptural elements, and reconstructions (e.g. Collinson 1791, Englefield 1792, Pownall 1795, Warner 1797), at least in part a result of the momentous discovery of the first fragments of the temple pediment, with its iconic Gorgon head (figure 3.1), in 1790 (Englefield 1792: 325).

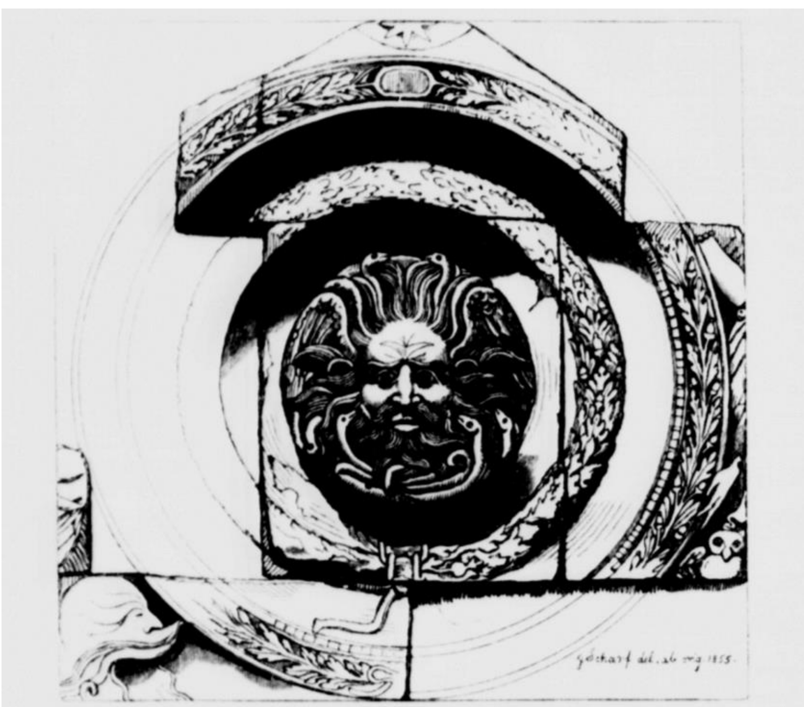

**Figure 3.1: Illustration of the iconic gorgon head of the temple pediment from Bath, discovered in 1790. From Scharf (1855: figure 1). Scharf, G., 1855. Notes Upon the Sculptures of a Temple Discovered at Bath. © Cambridge University Press. Reproduced with permission of The Licensor through PLSclear.**

The Roman carved or inscribed stone antiquities of Bath were becoming increasingly well-known, especially through inclusion in works of a national scope, for example by Carter (1786) or Lysons (1813). In contrast, the ceramic building materials discovered at the settlement received much more limited attention. Finds of Roman bricks and tiles were occasionally noted, described (e.g. Wood 1742: 62-63, Collinson 1792: 9, 15, Pownall 1795: 26, Phelps 1836: 166), and sometimes even measured and illustrated (e.g. Scarth 1864: 95) when excavated in the city, particularly when found as part of a preserved hypocaust. This included areas of hypocausted rooms exposed in the East Baths (Collinson 1791: 9) during destructive works in the mid-18th century (Cunliffe 1969: 90). These materials appear to have been entirely ignored by many other authors, and it is likely that the finds and hypocausts recorded represent only a fraction of the total material encountered. While the functions of pilae and box flue tiles were often correctly surmised (e.g. Wood 1742: 62-63, Scarth 1864: 86-87), especially when found in-situ, no further questions about their production or provenance appear to have been posed.

### 3.1.2 Later Excavations

Towards the end of the 19th century, the emphasis in archaeological research and publications on Roman building materials in Bath began to shift. Instead of the previous focus on inscriptions (e.g. Guidott 1698, Musgrave 1719, Horsley 1732), or architectural reconstructions (Collinson 1791, Englefield 1792, Pownall 1795, Warner 1797), work began to consolidate disparate excavation accounts and finds into a more coherent understanding of the Roman settlement (e.g. Phelps 1836, Scarth 1864, 1876). This continued to the turn of the century with Haverfield's (1906) insightful synthesis. This research was substantially enabled through the excavations of Irvine (1873), Mann (1878), and Davis (1881, 1884) in the late 19th century, which revealed much of the plan of the Roman Baths. These investigations exposed substantial areas of the Great Bath, the Spring Reservoir and parts of the East and West Baths (figure 3.2), enabling a unified interpretation of the different structures of the complex for the first time.

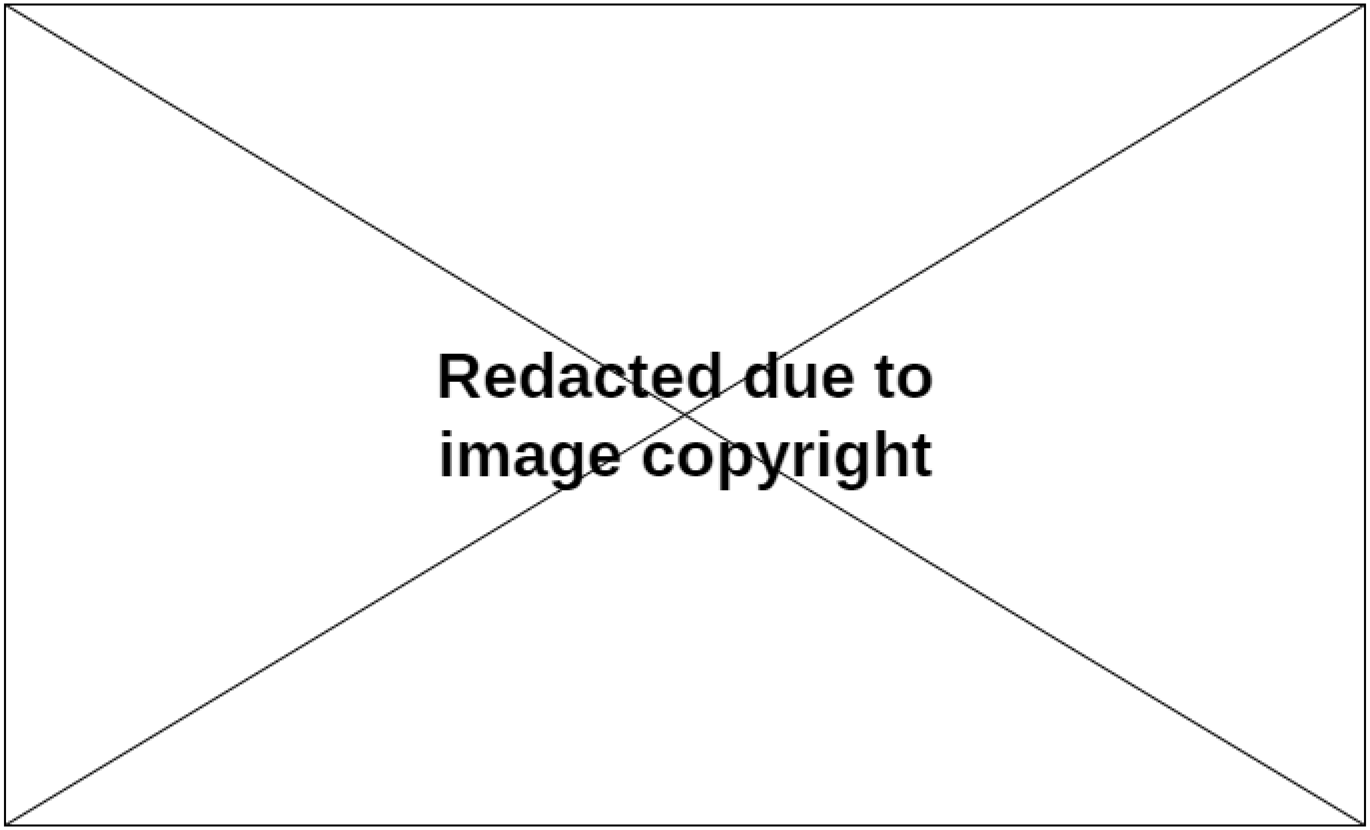


**Figure 3.2: Illustrated plan of the areas of the Roman Baths known by about 1886, largely as a result of excavations by Davis and assistants Irvine and Mann. From Cunliffe (1969: figure 29). © Society of Antiquaries of London.**

While the ceramic building materials recovered from the excavation of the Roman Baths during this period elicited description (Scarth 1883: 266, 1886: 76, Davis 1884: 14), these did not significantly improve on the standard of previous research. Prior observations had focussed primarily on the box flue tiles and pilae from the hypocausts and heated rooms exposed (e.g. Collinson 1791: 9, Pownall 1795: 26, Phelps 1836: 166). In contrast, Davis's (1884) excavations of the baths yielded significant portions of the Period III vaulted roof of the Great Bath, largely made up of hollow voussoir tiles mortared together (figure 3.3), with a large fragment of a brick arch preserved from the western end of the vault (Davis 1884: 14). Scarth (1883: 266), Davis (1884: 14) and later Haverfield (1906: 5.iii.4) described the shape and dimensions of the individual hollow voussoir tiles and speculated on the structure of the roof, but offered no wider insights. The study of Roman ceramic building materials at Bath in this period clearly remained in its infancy, and questions of provenance, production and transport do not appear to have been considered.

**Figure 3.3: Photograph of the Great Bath after excavation in 1884, with fragments of the vaulted roof in-situ where it fell. From Haverfield (1906: Figure 28). Reproduced with permission from "A History of the County of Somerset: Volume 1", Victoria County History, London 1906, © University of London.**

While not actually working in Bath, or indeed even considering ceramic building materials, the research of geologist George Poulett Scrope deserves an honourable mention. His (Scrope 1862) excavation and report of a Roman villa at North Wraxall in Wiltshire, 19km northeast of Bath and just within the bounds of the hinterland area (section 6.1.2), presents a clear contrast to much antiquarian work, and suggests what could have been achieved in the study of the building materials in Bath had many past practitioners had a similar perspective.

As with the work of Irvine (1873), Davis (1881, 1884) and later Haverfield (1906), Scrope (1862) prioritised reconstructing the floorplan of the villa, focussing on the wider picture of the site. Unlike his peers, and indeed many afterwards, Scrope (1862: 60-70) made frequent reference to nearly all the stone encountered during the excavation of the villa, noting locally quarried freestone, fragments of marble, calcareous tuff, quartzose pebbly grit quernstones as well as schistose sandstone roof tiles. While this visual identification may seem unspectacular, in comparison to his contemporaries it constituted a significant improvement. More than this, Scrope (1862: 67) began to conjecture on the selection of the stone and the complexities of its movement:

> "It is remarkable that the Roman builders should have preferred to employ the heavy tilestone of the coal formation which had to be fetched from a distance of at least fifteen miles, instead of that of the lighter Forest-marble beds, which might have been quarried close by, and which has been exclusively used for roofing purposes in the neighbourhood in modern times."

While perhaps of little relevance to the study of Roman brick and tile in Bath, the fact that Scrope was beginning to pose questions about the economics of Roman building material production, transport and use at such an early time is highly significant. It is a shame that his approach and perspectives were not more widely adopted by later researchers in Bath, as the study of Roman building materials in the city might have been much advanced.

# 3.2 The Rescue Period

The period of rescue archaeology in Bath comprised much of the 20th century, from approximately 1900 until the introduction of Planning Policy Guidance (PPG) 16 in 1990 (HMSO 1990). It therefore represents a move away from the often-genteel amateurs responsible for much interpretation of finds before this date (e.g. Stukeley 1776, Pownall 1795, Scarth 1864), and the extensive excavations of the Roman Baths performed by Davis and assistants (Irvine 1873, Mann 1878, Davis 1881, 1884) without formal archaeological training. Instead, the 20th century and the rescue period saw the emergence of several professional archaeologists publishing or excavating Roman finds and sites in the city (e.g. Richmond and Toynbee 1955, Cunliffe 1966, 1969, 1976, Blagg 1979), though in several cases a response to imposing development (e.g. Cunliffe 1976, 1980, Wedlake 1979), often with limited time and funding (Davenport 1999: i). Cunliffe (1969, 1976) and Cunliffe and Davenport's (1985) seminal excavations and syntheses occurred in this period, significantly advancing the understanding of the development of the Roman Baths. Nevertheless, the ceramic building materials from the site and from other excavations in the city received relatively little study, though what was completed (e.g. Foster 1985) still represented a significant advance upon the investigations of earlier researchers.

## 3.2.1 The Early 20th Century

As Cunliffe (1969: v) noted, Bath was relatively quiet in terms of archaeological research until the late 1950's, when a range of new post-war development began in the city (e.g. Cunliffe 1979). This is particularly true for the Roman Baths complex, which after the spectacular discoveries of the previous century (Davis 1881, 1884) experienced only limited investigation in the first half of the 20th century. What little new work there was extended knowledge of extremities of the baths to the east (Knowles 1926), or reviewed already well-known finds and structures (e.g. Taylor 1954, Richmond and Toynbee 1955). Knowles (1926: 4-5) does deserve credit as the first to distinguish specific phases of construction at the baths, and this was later elaborated by Cunliffe (1966, 1969). With the small amount of new research at the Roman Baths during the first half of the 20th century, it is unsurprising that the building materials from the site continued to receive little dedicated study during this period.

In the rest of Bath there was limited archaeological work until the 1960s. These excavations (e.g. Taylor 1913, Bush 1918, Wedlake 1966, 1979a, b) were restricted in size and scope and generally contributed little to understanding the building materials of Roman Bath, with only small amounts of ceramic building materials being found (e.g. Wedlake 1979: 82). As with many previous researchers (e.g. Collinson 1791, Phelps 1836, Haverfield 1906), these materials appear to have been discussed primarily in relation to the structures they comprised, where present (e.g. Wedlake 1979: 82, Cauvain and Cauvain 1991: 130).

### 3.2.2 The Later 20th Century

From the late 1950's onwards the volume of archaeological excavations in Bath increased (e.g. Cunliffe 1979, Davenport 1991, 1999). This appears to have been driven largely by post-war development of derelict buildings, many of which had suffered damage or destruction during the Second World War air raids on the city (e.g. Tucker 2021: 1-2), for example St James Church on Lower Borough Walls (Wedlake 1966: 93). New research at the Roman Baths during this period was instead driven by the formation of the Bath Excavation Committee in 1963 (Cunliffe 1979: 2), which set out to resolve outstanding archaeological questions over the complex (Cunliffe 1969: v), though their remit covered sites across all of Bath (Cunliffe 1979). This mission was later continued by the Bath Archaeological Trust, formed in 1977 (Davenport 2021: 232).

With this slew of new work, the understanding of the building materials from the Roman town, although primarily those used in the monumental baths and temple complex, did improve somewhat. Cunliffe (1966, 1969, 1976, 1979) and Cunliffe and Davenport's (1985) work on the baths, Spring reservoir, Temple and Temple Precinct area was seminal, creating a detailed understanding of the development of the entire site for the first time. Nevertheless, it is clear that the stone and ceramic building materials of the complex did not represent a research priority during these projects. In the earlier publications, Cunliffe (1969, 1976) generally referred to ceramic building materials where they could shed light on the arrangement, function or development of different structures, whether hypocausted rooms of the East (Cunliffe 1969: 113-115) or West Baths (Cunliffe 1976: 12-13), or the Period III vaulted roof of the Great Bath (Cunliffe 1969: 98). The range or dimensions of the components themselves were not presented independently, despite very similar ceramic building materials being described and illustrated in a dedicated chapter (Cunliffe 1971: 43-49) in the near contemporary publication of the finds from Fishbourne Roman Palace by the same author. The reasons for this are not clear, but may perhaps be a result of different funding or time pressures in each project. Despite this, resources could clearly still be found for the analysis of an assemblage of unusual ceramic pipes found in the hypocaust of the main tepidarium of the West Baths (section 2.4.2), which were weighed, measured, visually analysed for fabric types and illustrated as part of Cunliffe's (1976: 28-32) paper on the West Baths. Meanwhile, the ceramic building materials from these excavations (e.g. Cunliffe 1976: 19-23) appear to have been entirely neglected.

Greater efforts were clearly made to understand the range of bricks and tiles recovered during later investigations in the Spring reservoir and Temple Precinct. The publication of these excavations included several summary pages and illustrations of the range of tile types found (Cunliffe and Davenport 1985: 134-135), mostly as they related to the superstructure of voussoir brick ribs that formed the Reservoir Enclosure roof (e.g. Cunliffe and Davenport 1985: 51-55), being preserved when they collapsed into the reservoir silts. Significantly, this project incorporated analysis of parts of the Temple Precinct assemblages by Foster (1985: Fiche 2 C1-10), including recording of the range of tile types and sherd measurements (section 3.4.2) and the completion of fabric analyses (see Appendix A). This represented the most intensive investigation of Roman ceramic building materials from Bath up to that point. Nevertheless, this material does not appear to have been explored to determine provenance, and no comparisons seem to have been made to bricks and tiles from other assemblages of the Roman Baths, or indeed to material from sites in the wider settlement.

The report on the ceramic pipes from the West Baths (Cunliffe 1976: 28-32) and Foster's (1985) study of the bricks and tiles from the Temple Precinct excavations constitute virtually the entire corpus of detailed research on the ceramic building material from one of the best-preserved Roman sites in Britain. It is therefore clear that much work remained to be completed on the ceramic building materials from the Roman Baths. Despite this, these reports do represent a significant step in the study of building materials at the site.

## 3.3 The Modern Period

The modern period of archaeological research in Bath represents largely commercial fieldwork (Davenport 2021: 233) undertaken since the introduction of PPG 16 in 1990. Until the early 2000s these investigations continued under the remit of the Bath Archaeological Trust, which excavated an array of sites across the city (e.g. Davenport 1999, 2007) before its dissolution. While these projects significantly increased the corpus of Roman building materials recovered from Bath (Betts 2007, 2015), many remain unpublished, though much analysis has been completed (e.g. Betts 1999a, b, 2002a, b). Since the Bath Archaeological Trust folded, a range of archaeological contractors have operated in the city, bringing to publication a number of important sites (Davenport 2007, Barber 2015). There have therefore been substantial developments in the understanding of Roman building materials from the city in the modern period, including assemblages from within and without the walled area of the Roman town. While the understanding of Roman bricks and tiles from Bath has been significantly advanced by Betts (e.g. 1999a, b, 2002a, b, 2007, 2015), the important collections from the Roman Baths have also received further research, though with more limited outcomes.

### 3.3.1 Ceramic Building Material Research in the Wider Settlement

The recent study of ceramic building materials from Roman Bath has been dominated by the work of one individual. Ian Betts's (1999a, b, 2002a, b, 2007, 2015) research has included assemblages from a range of excavations by the Bath Archaeological Trust and commercial units subsequently operating in the city. These include sites in the walled area of Bath (Betts 2007, 2015), from the Walcot settlement to the north (Betts 2002a, 2002b) as well as from suburban villas a short distance from the Roman town (Betts 1999a, b). In doing so, a range of Roman brick and tile from different domestic (Betts 1999a, b), industrial (Betts 2002a, b) and public building sites (Betts 2007, 2015) spanning several centuries have been analysed. A wide range of tile types have therefore been identified from diverse contexts across the Roman settlement (e.g. Betts 2015), and a fabric scheme developed and applied across all assemblages analysed (Betts 2011, sections 7.1, 9.2.7, Appendix B). This represents a significant achievement, for a broad understanding of the range of components and material reaching the Roman settlement has been developed for the first time.

The study and syntheses of the ceramic building materials from Roman Bath by Betts (1999a, b, 2007, 2015) is not without limitations. While certain fabric groups were equated (Betts 1999a: 3, 2007: 52) with the Museum of London fabric series (Betts 2018), there appears to have been limited integration of the brick and tile from the settlement with that from the Roman Baths (e.g. Foster 1985) or with research from the wider region (e.g. Darvill 1979, 1980, 1982, 1998, 2001, Mepham 2001). Moreover, while a comprehensive fabric scheme was devised and employed (Betts 2011), the sources of few fabric groups have so far been determined (Betts 2015: 221). Finally, the results of all the different sites analysed (e.g. Betts 1999a, b, 2002a, b, 2007) have received only a brief, yet extremely valuable, synthesis in Betts (2015). It may be that many, or all, of these limitations are the product of the conditions and pressures of post-excavation analysis of assemblages as part of commercial archaeology. The episodic nature of these studies, and analysis of assemblages recovered ahead of development (e.g. Davenport et al. 2007, Barber 2015), not all of which have yet been published (e.g. Betts 1999a, b, 2002a, b), would certainly suggest this. The understanding of the ceramic building materials from Roman Bath developed by Ian Betts (2007, 2015), section 7.1, nevertheless represents a substantial achievement, and a significant advance upon much previous research in the city.

### 3.3.2 Ceramic Building Material Research at the Roman Baths

Several researchers and projects have analysed bricks and tiles from the Roman Baths since 1990, though this has perhaps resulted in a more limited increase in the understanding of these materials than those of the wider settlement during the same period. While Betts (1999a, b, 2002a, b, 2007, 2015) studied ceramic building materials from a range of sites in Bath, this did not extend to material from the Roman Baths itself. This omission is curious, for investigations in the East Baths by the Bath Archaeological Trust between 1995 and 2001 (Davenport 2011a) were virtually contemporaneous with the excavation of sites and assemblages that Betts did analyse, for example Lower Common Allotments (Betts 1999a), Oldfield Boys' School (Betts 1999b) and Beehive Yard (Betts 2002a). Lancaster's (2006: 1831-1836) reanalysis and reconstruction of the vaulted roofs of the Spring Reservoir Enclosure and Period III Great Bath therefore represented the first new analysis of ceramic building materials at the Roman Baths for some time. While the implications of this research (Lancaster

2006, 2015) are significant for the understanding of these structures (section 10.2), little reassessment or recording of the bricks and tiles themselves appear to have been completed. The identification and measurement of Westhampnett hollow voussoir tiles among the assemblages of the Roman Baths by Lancaster (2012: 430), and the interpretation of their relationship to similar components from other sites (sections 2.4.2, 7.1.2), represents an important contribution. However, this study was ultimately limited to a single rare component type among the assemblages at the Roman Baths (section 8.1.2-8.1.3), and therefore achieved little in the wider understanding of the ceramic building materials excavated from the site.

The only other study of the ceramic building materials from the Roman Baths during the modern period was that of the Building Roman Britain Project (BRBP 2017). This research aimed to apply non-invasive chemical analyses using portable X-ray fluorescence (pXRF) to material from across the different assemblages and structures of the Roman Baths (BRBP 2017), including both in-situ and ex-situ material. The application of this technique and the scope of this project was novel and broad, incorporating analyses of ceramic building materials from the complex, from other sites in Bath, and from Fishbourne Roman Palace in West Sussex. The analysis of Roman brick and tile was to be integrated with that of building stone from each of these locations to achieve a highly innovative cross-materials perspective (BRBP 2017). Results from the analysis of the building stone were published (Tucker et al. 2020), though the brick and tile findings were not. As such, the total range of material among the assemblages at the Roman Baths, and their relationship to the bricks and tiles of the wider settlement (e.g. Betts 1999a, b, 2002a, 2007, 2015) or to adjacent regions (e.g. Darvill 1979, 1980, 1982, 1998, 2001) remains poorly understood. The present study was therefore developed to continue the analysis of the ceramic building materials of the Roman Baths, following on from the Building Roman Britain Project.

## 3.4 The Assemblages

The Roman Baths, Spring Reservoir, Temple and Temple Precinct at Bath formed a unified complex throughout the Roman period (Cunliffe and Davenport 1985, Cunliffe 2000, Davenport 2021). However, the ceramic building materials from these structures have become separated into discreet assemblages as a result of recovery during different excavations from at least the 19th century until the start of the 21st century. These consist of the York Street assemblage, the Temple Precinct assemblage, material from the Spring Reservoir excavations and the East Baths assemblages. While Cunliffe (1976: 19-23) noted that substantial amounts of CBM were encountered during investigations in the West Baths, none of this material could be located for inclusion in the present study. Each of the assemblages analysed are described below.

### 3.4.1 York Street

The York Street assemblage comprises ceramic building materials that were left in the vaults under York Street, immediately to the south of the Great Bath, until removed and catalogued in 2016 and 2017 (Matyjaszkiewicz 2021 pers. comm.). There appears to be no clear record of when this material was excavated, by whom, or where in the complex it originated from. The presence of large roof sections of mortared together hollow voussoir tiles suggests that much of this material could have come from Davis's excavations of the Great Bath in the early 1880s (e.g. Davis 1884: 14). However, other parts of this assemblage may well be from different structures and earlier explorations. In particular, Scarth (1864: 95, pl. XXXVI) describes and depicts a Westhampnett hollow voussoir of the same dimensions as those in the York Street assemblage (e.g. Lancaster 2012: 430), despite only the east wing of the Roman Baths having been substantially investigated at that point (Scarth 1864: 15-16). It is also possible that these or other components in the assemblage could have been retained from early 19th century sewer digging in Stall Street, over the West Baths (e.g. Haverfield 1906: 5.i). Despite the importance of this assemblage, comprising the remains of one of the largest vaulted roofs known from Roman Britain (Lancaster 2012: 437), it has received little prior study. While multiple authors have inferred the construction of the Great Bath roof from the surviving fragments (e.g. Davis 1884: 14, Cunliffe 1969: 117-118, Lancaster 2006: 1834-1836), only Lancaster (2012: 430) appears to have examined any other material from the York Street collection.

This assemblage consists of 720 different catalogued sherds and fragments of multiple contiguous hollow voussoir tiles. It has clear potential to include a wide variety of different tile forms from structures across the site.

### 3.4.2 The Temple Precinct

The brick and tile assemblage from the Temple Precinct was collected during excavations in the 1980s directed by Barry Cunliffe and Peter Davenport. The ceramic building materials from contexts of trenches 105, 106 and 109 were analysed by Foster (1985: microfiche 2 C1-10), with a brief summary of these findings in the body of the site report (Cunliffe and Davenport 1985: 134-135). Excavations in the Temple Precinct continued after this, but it appears that the brick and tile from these later excavations were not analysed. While the total volume of unreviewed material is perhaps modest compared to that from trench 105 alone, it still includes sherds from 12 different trenches. Foster (1985) effectively identified and quantified tile types in her study. There was a limited range present, including tegulae, imbrices, bricks and 'box tiles' (Foster 1985: C8), more properly hollow voussoirs from the Spring Reservoir enclosure roof which had collapsed forwards into the Temple Precinct (Cunliffe and Davenport 1985: 134). This material included a single relief-patterned tile of die 53 (Betts et al. 1997: 27); the only relief-patterned sherd so far known from the site.

The assemblage from the Temple Precinct is moderate in size, with Foster (1985: C9) counting 416 sherds, though perhaps reaching a figure of 600 once the material from later excavations is included. Though only retrieved from a single area at the site, the highly fragmented character of much of the assemblage (Cunliffe and Davenport 1985: 135) suggests it may contain a range of CBM from different parts of the complex. This may include the Temple roof and Spring Reservoir Enclosure roof, as well as residual material perhaps from other buildings in Roman Bath (see section 10.1.1).

### 3.4.3 The Spring Reservoir

Ceramic building materials were retrieved from the Sacred Spring during excavations in the early 1980s directed by Barry Cunliffe and Peter Davenport (Cunliffe and Davenport 1985). This material comprised parts of the collapsed roof of the Spring

Reservoir Enclosure building, which had fallen into the waters and preserved the arrangement of the brick ribs and spine of the vault nearly intact (Cunliffe and Davenport 1985: 51, pl.VII). The brick and tile used included voussoir bricks, normal bricks, hollow voussoirs, and a type of moulded brick suggested to have been reused as infill in the ribs (Cunliffe and Davenport 1985: 134). It does not appear that any ceramic building materials from the Spring were analysed by Foster (1985) in her report, despite the excavations in the Temple Precinct being virtually contemporary and even though both assemblages contain brick and tile from the Spring Reservoir Enclosure structure. It is therefore likely that there has been no previous research into, or publication of, this material beyond its use in the structure of the Enclosure building. There appears only limited potential for this assemblage to include any material not derived from the Spring Reservoir Enclosure.

Despite the substantial size of the Spring Reservoir Enclosure building roof, spanning 12.2m (Cunliffe 1969: 17) and extensively utilising ceramic components (Cunliffe and Davenport 1985: 51), the brick and tile assemblage from the Spring currently held at the Roman Baths is extremely small. Only 77 sherds suitable for sampling were counted in this study (section 8.1). A number of large fragments of rib sections of mortared-together voussoir bricks were also present, but were deemed unsuitable for inclusion as they were almost intact and very fragile. There are several possible explanations for the dearth of retained material from the Spring Reservoir Enclosure structure. The first potential reason is that the Spring has been subject to both Georgian and Victorian (Haverfield 1906: 5.iii.1) interventions to ensure the flow of the water. As Cunliffe and Davenport (1985: 43-44) noted, both excavations appear to have removed substantial deposits around the central spring head which could have included extraction and disposal of fragmentary ceramic building materials from the roof, leaving the more substantial brick ribs and spine intact. Alternatively, such material may have been retrieved during Cunliffe and Davenport's (1985) excavations and stored separately to the large fragments of ribs and spine. Assemblages from Cunliffe's (1976) excavations in the West Baths cannot currently be located in the Roman Baths Museum's collections despite assurances (Cunliffe pers. comm. 2021) that the material would have been retained. It may therefore be that more material from the Spring assemblage was collected and similarly awaits rediscovery.

This assemblage may also be small because of hostile conditions in the Spring Reservoir. Cunliffe and Davenport (1985: 135) noted that the moulded bricks found in the Spring were underfired and extremely crumbly. In fact, this comment now appears true of most ceramic building materials collected from the Spring. The fragility of this brick and tile contrasts with the robust preservation of most other CBM inspected from the Roman Baths, and the hardness and durability of Roman tile from the site was also noted by Scarth (1864: 86). This suggests that the hot conditions at the heart of the Spring Reservoir, with the water a consistent 46 degrees centigrade (Roman Baths 2021a), is likely responsible for the deterioration of submerged ceramic building materials from the roof of the Enclosure building. Were this correct, it would be reasonable to expect the thinner components such as hollow voussoirs (c.17-20mm thick) to be poorly preserved, with the thicker components such as bricks (c.35-60mm thick) being more resilient and more likely to be excavated and retained. This appears consistent with the range of material preserved in this assemblage.

### 3.4.4 The East Baths

The assemblage of ceramic building materials from the East Baths were retrieved during a series of investigations in 1994, 1995 and 2001 under the direction of Peter Davenport (Davenport 2011a). These included the excavation of test pits and trenches for mitigation works, repairs and display purposes in the extreme northeast and southeast of the Roman Baths complex (Davenport 2011a). These investigations have not yet been published, though a draft of the report narrative and context descriptions are held by the Roman Baths Museum (Davenport 2011a, b) and have been integrated into Davenport's (2021: 121-2, 130-131) book on Roman Bath. Though some sherds from these assemblages have been taken out on loan by Cotswold Archaeology for drawing, the extent to which these assemblages have previously been analysed is unclear, as is the current status of any specialist report. The composition of the assemblage is thus uncertain.

The excavation of hypocaust structures and extensive rubble and demolition deposits nevertheless suggests that the material from the East Baths is likely to have resulted from the collapse of heated or vaulted structures (Davenport 2011a: 12). Fragments of CBM used in such rooms may therefore be expected, for example hollow voussoir tiles, box flue tiles and hypocaust bricks and pilae. Given the reworking of rubble deposits noted by Davenport (2011a: 11, 2011b: 16-17), this assemblage could also potentially include material from adjacent areas and structures of the East Baths and Great Bath. As some of the structures investigated comprised the southeastern limits of the complex, the inclusion of residual material from Roman structures outside the complex may also be a possibility. At approximately 1050 sherds (estimated by average sherd weights), this assemblage is the largest preserved from the entire Roman Baths, Spring and Temple site and has clear potential to shed light on the structures, development, and supply of tile to the East Baths.

## 3.5 Chapter Conclusion

The depth of research into the Roman remains of Bath is considerable, spanning nearly five centuries and many different enthusiasts, antiquarians, and archaeologists. Yet, for much of this time the Roman building materials of the city have received little of the attention that they are perhaps due, especially those used in the UNESCO World Heritage Site of the Roman Baths. While the stone from the city has been endlessly pored over in inspection of inscriptions (e.g. Horsley 1732, Stukeley 1776, Collinson 1791, Haverfield 1906, *RIB* I), sculpture (Richmond and Toynbee 1955, Blagg 1979, Hind 1996, Henig 1999, Cousins 2016), and architecture (Englefield 1792, Pownall 1795, Cunliffe 1966, 1969, Cunliffe and Davenport 1985), it is only comparatively recently that detailed study of typical Roman ceramic building materials began. This commenced with Foster's (1985) analysis of assemblages from Cunliffe and Davenport's (1985) excavations in the Temple Precinct. This still represents the most detailed and comprehensive analysis of bricks and tiles from the site published to date, despite subsequent excavations in the East Baths yielding substantial quantities of CBM (Davenport 2011a, b). Most ceramic building materials from the site have therefore received little previous research, particularly beyond consideration of their employment in hypocaust structures (e.g. Wood 1742, Collinson 1791, Phelps 1836, Cunliffe 1969) or certain vaulted roofs (Cunliffe 1969, Cunliffe and Davenport 1985, Lancaster 2006, 2012, 2015). The understanding of the sources, procurement and supply of these bricks and tiles to the Roman Baths is therefore extremely limited. In particular, it pales in comparison to our knowledge of the development of the Roman Baths, Temple, and Spring complex (e.g. Cunliffe and Davenport 1985, Cunliffe 2000, Cousins 2020, Davenport 2021) or even of the wider Roman town (Davenport 1994, 2000, 2008b, 2021). In contrast, Betts's (1999a, 1999b, 2002a, b, 2007, 2015) analyses and syntheses of assemblages from sites in the wider settlement has generated a valuable understanding of the range of material and components moving to the settlement. However, few sources have so far been identified (Betts 2015: 221), and little integration has been completed between the assemblages of the Roman Baths or with sites in the wider region. Nevertheless, much has been achieved in the last few decades, laying the foundations for a much more comprehensive and integrated study of the ceramic building materials of Roman Bath.

# 4.0 Previous Methods and Approaches in the Study of Brick and Tile from Roman Britain

A variety of different techniques of analysis have been applied to the study of Roman ceramic building material in Britain. These range from traditional methods of typology or morphology-based examination of artefacts, including the analysis and recording of forms and impressions, to precise scientific techniques of compositional analysis such as scanning electron microscopy-energy dispersive spectrometry (SEM-EDS) and inductively coupled plasma-mass spectrometry (ICP-MS). The objectives of these studies have been varied. These have included the characterisation and sourcing of assemblages as well as a diverse range of non-provenance-oriented research, for example the assessment of evidence for seasonal activity in Roman brickmaking or the experimental reproduction of box-flue tiles. The following section will group and review these studies by the techniques used or the features being studied, including a) marks and impressions present on Roman brick and tile, b) morphometric analyses of form or weight, c) fabric analyses, and d) compositional analyses.

## 4.1 Marks and impressions

A significant amount of research has been conducted into the marks and impressions present on Roman brick and tile in Britain. In part, this is due to the wide variety of marks often present within these assemblages, including animal prints, finger signatures, stamps, relief-patterned impressions, graffiti, comb marks, knife marks, footprints, and hobnail-boot prints (figure 4.1). While the objectives of this work have been varied, studies investigating the provenance or distribution of text or relief-patterned stamps comprise a substantial proportion of this research.

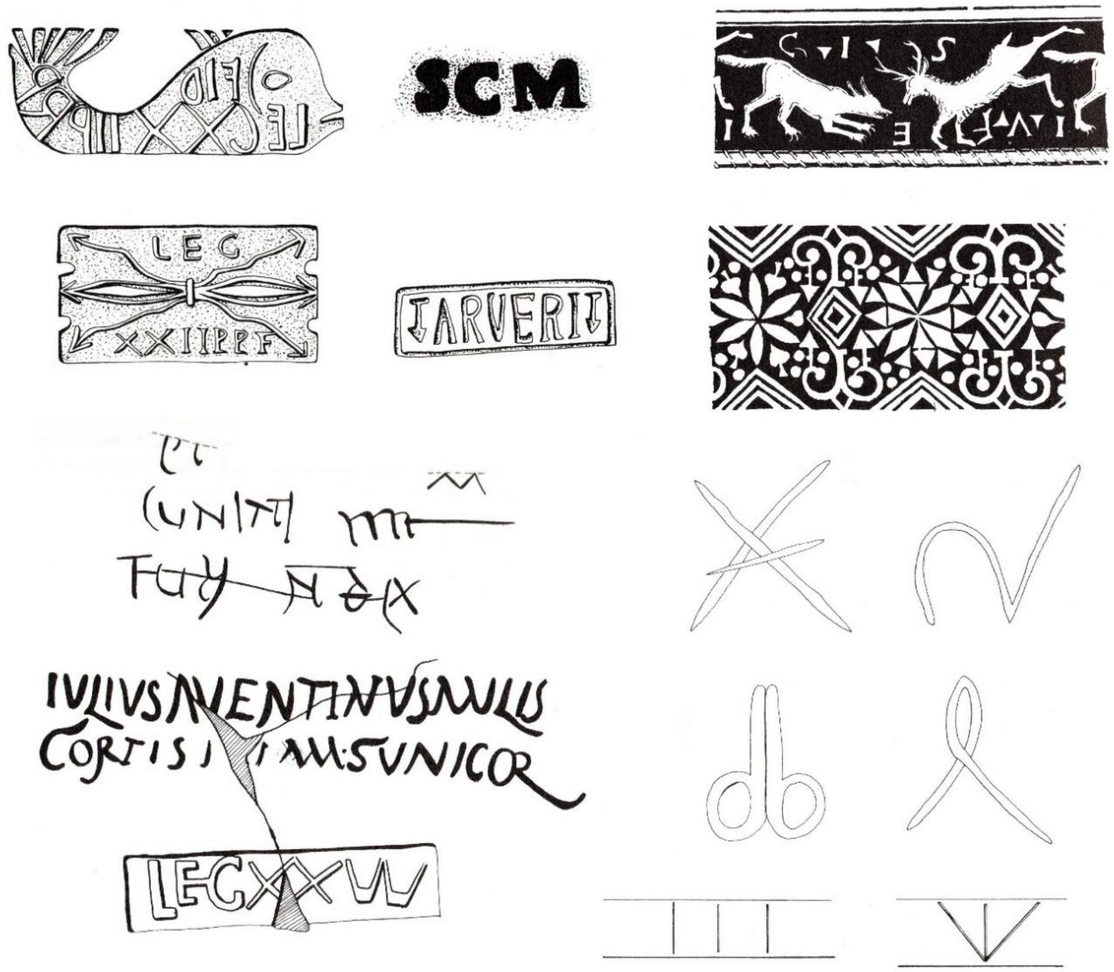


**Figure 4.1: Drawings of marks and impressions found on ceramic building materials from Roman Britain. Not to scale. Clockwise from top left: civilian and military stamps, relief-patterned impressions, signatures, tally marks, graffiti. Modified from Brodribb (1987: figures 47, 51, 55, 58, 61). © The History Press.**

### 4.1.1 Focus and Objectives of Previous Research

The recording and analysis of each type of mark or impression on Roman brick and tile does not have to be exclusive, and indeed co-recording is recommended (ACBMG 2002) and widely practised (e.g. Warry 2005, Poole and Shaffrey 2008, McComish 2012, Betts 2015, Peveler 2018). Nevertheless, there have been a wide range of studies focussing only on one type or form of impression. This ranges in scope from roller-die stamped tiles from across Britain (Lowther 1948, Johnston and Williams 1979, Black 1985, Betts et al. 1997), to specific groups of stamped tiles (Clifford 1955, Peacock 1977, Darvill 1979, 1980, 1982, Boon 1984), animal prints within a single assemblage (Cram and Fulford 1979) and even to the publication of graffiti from a single tile (Brodribb 1982). Given the significant variation in scale and topic of this varied research, it is unsurprising that the aims are also diverse. Provenancing of material is therefore not a universal objective for the study of these marks and impressions, especially in studies of accidental imprints by fauna or humans (Cram and Fulford 1979) or in cataloguing of abstract signature marks or generic comb marks or knife marks (Betts 1985, Brodribb 1979, 1987, Warry 2005). However, it is a question particularly asked of stamped material, especially when combined with research into kiln sites (Middleton et al. 1992, Middleton and Cowell 1997, Betts 2003, Betts et al. 1997) or with methods of scientific characterisation, for example thin-section petrography (Peacock 1977, Darvill 1979, 1980, 1982, 2001) or ICP-MS (Hughes 2013, 2015).

Although more research has been conducted on tile stamps, studies into other marks and impressions have drawn significant conclusions. As an example, the analysis of animal prints, particularly those of livestock, on Roman CBM has demonstrated the part-time nature of brickmaking at certain Roman kiln sites (Cram and Fulford 1979), likely fitting in around slack periods of the agricultural calendar (McWhirr 1984: 56). Analysis of graffiti on CBM, identifying Roman, Celtic, and Gallic names, has also helped to indicate that native people and potentially Continental brickmakers were involved in Roman brick and tile production in Britain from an early period (McWhirr 1984: 30, Lancaster 2012: 434).

### 4.1.2 Research into Stamps

The analysis of stamps and roller-die stamps have contributed far more widely to the understanding of CBM production and distribution across Roman Britain. While this is no doubt a result of the sheer depth of research devoted to these impressions (e.g. Lowther 1948, Clifford 1955, Wright 1976, 1978, Bogaers 1977, McWhirr and Viner 1978, McWhirr 1979, Johnstone and Williams 1979, Darvill 1979, 1980, 1982, 2001, Boon 1984, Black 1985, Betts et al. 1997, Mepham 2001, Warry 2017, Fulford and Machin 2021), it is nonetheless a substantial achievement. To summarise, stamp identification has played a formative role in the study of Roman CBM in Britain as many workshops or organisations appear to have had a discrete and unique range of stamps associated with them (Johnston and Williams 1979: 376). Even without employing any fabric analysis, researchers have therefore been able to distinguish the stamped products of different kiln sites, whether civilian (McWhirr and Viner 1978, Heighway and Parker 1982, Scammell n.d., Betts 1995, Warry 2017) or military (Grimes 1930, Wright 1976, 1978, Peacock 1977, Boon 1984) and how far they were transported. While undoubtedly yielding valuable results for relatively little input, this early emphasis on the study of stamped material has led to the comparative neglect of the unstamped CBM from the same sites. In all cases, this unstamped material forms the vast majority of Roman brick and tile assemblages (Brodribb 1987). While modern commercial work is addressing this disparity (e.g. Mills 2013, Betts 2015, 2016, 2017), there remains the consequence that conclusions about CBM at some sites have been drawn from the analysis of only a handful of stamped sherds. A more problematic result of this stamp-fascination is that in many antiquarian and rescue excavations the only Roman brick and tile retained were rare complete examples and, of course, the stamped material.

## 4.2 Morphometric Analysis

Compared to the literature surrounding marks and impressions, there are relatively few studies based on artefact forms and dimensions of CBM from Roman Britain. In part this is due to the fragmentary nature of much Roman ceramic building material in the archaeological record. While the form of a brick or tile component can often be identified from only a fragmentary sherd, it is unusual to have complete measurements for one or more artefact dimensions. As an example, Brodribb (1987: 12) noted that of the 43,000 roof tiles estimated to have been used in Fishbourne Roman Palace, only three have been excavated relatively intact. Research into distinctive forms or features of brick and tile has therefore made more significant contributions, although the number of such studies is small.

### 4.2.1 Dimensions and Weights

Due to the fragmentary nature of excavated Roman brick and tile, studies of the size and weight of different components have been limited and have typically had to draw on complete examples from a wide range of disparate sites. Brodribb's (1987) seminal work is a clear example. While for the first time cataloguing and synthesising the diverse range of Roman CBM found in Britain, conclusions as to variations in size and weight for different artefacts were limited to average measurements and to pointing out the range in recorded samples (Brodribb 1987: 26-34). Subsequent work (Betts et al. 1997, Warry 2005) has since provided an improved understanding of the variation within and between ceramic forms in Roman brick and tile assemblages. This can be significant, even from the same sites (Warry 2005). This variation has traditionally been ascribed to shrinkage of clay during air drying and firing (Brodribb 1979, 1987, Betts et al. 1997). However, Betts et al. (1997: 13) demonstrated that significant differences were perhaps more likely due to varying component standards between different production sites, although their sample size was small. Further analysis of size variation in the same die stamps on brick and tile by Warry (2005: 64-70) confirmed this, with the most substantial variation between components likely being due to the use of different sized moulds and natural differences resulting from hand production. While clarifying that Roman CBM in Britain was deliberately made to a range of dimensions, even for the same form of component, these debates have achieved little else.

### 4.2.2 Forms and Features

The recognition of different brick and tile forms and features has been more influential. While many Roman ceramic building material forms present in Britain are common across the Roman Empire, forms specific to or largely absent from Britain have been identified (Brodribb 1987, Lancaster 2012, section 2.4.2). This is best exemplified by the double-box flues and Westhampnett hollow voussoir forms produced by early tilemakers in Sussex (Lancaster 2012, inset in figure 4.2), which were distributed in limited numbers to London and sites across southern England (Betts et al. 1997). This hollow voussoir form has been identified as an invention of a Sussex workshop (Lancaster 2012: 419). It was preceded by different and less efficient forms of bathroom heating employing tegula mammata or half box flue tile forms (Webster 1979, Brodribb 1987), and was itself superseded in Britain by the more standard hollow voussoir form. These were used as part of connected hypocaust heating systems (Webster 1979, Lancaster 2012) or as a means to lighten the weight of vaulted barrel roofs, as at Bath (Cunliffe 1969). Other typical studies have sought to catalogue and plot the distribution of specific components in order to understand phasings and the spread of certain types of structures. As an example, Pringle (2006, 2007) plotted the development and distribution of bathhouses in Roman London through the proxy of occurrences of early half-box flue tiles and thin-walled box flue tile forms.

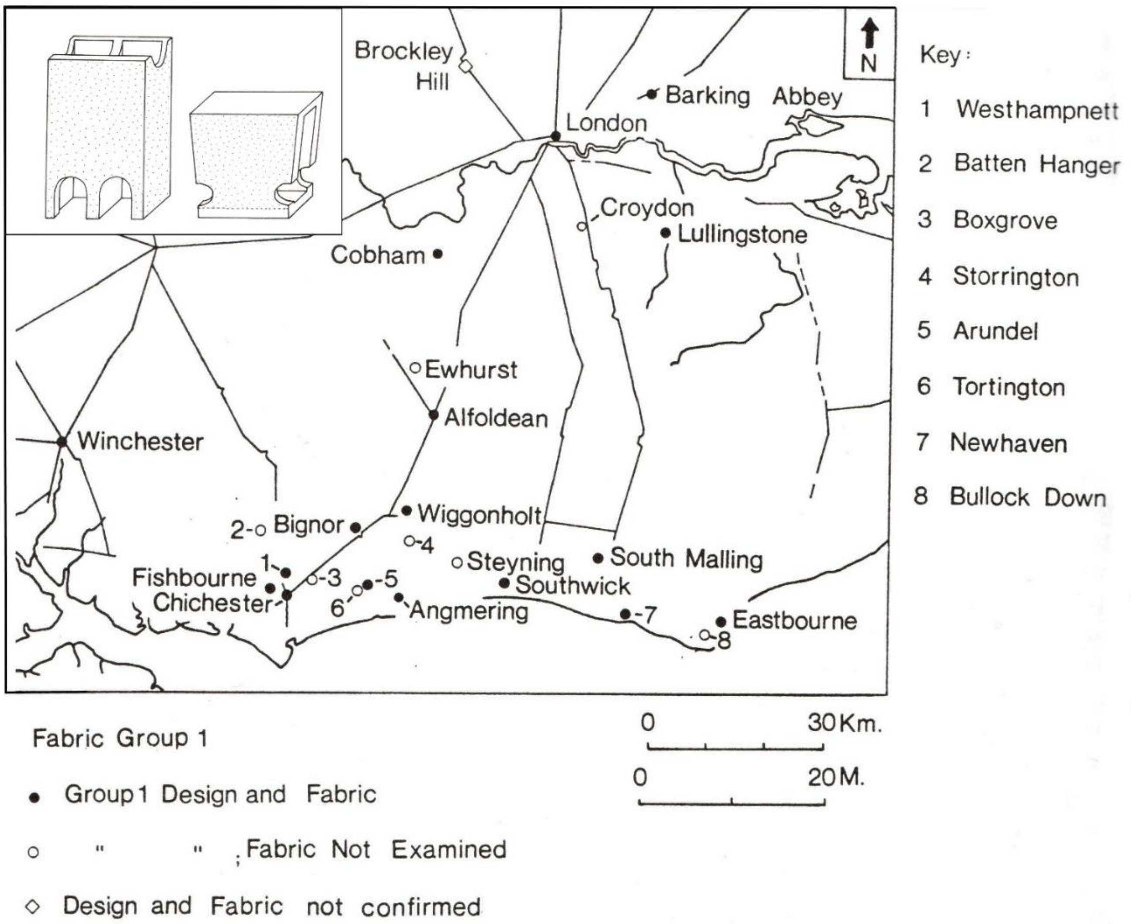


**Figure 4.2: Map showing the distribution of products of the London-Sussex fabric group across southeast Britain. Inset: two of this workshop's distinctive CBM forms. Modified from Betts et al. (1997: figures 2, 7). © Study Group for Roman Pottery.**

## 4.2.3 Tegula Cutaways

Where tile forms are geographically ubiquitous, specific features of those artefacts have been targeted instead, albeit with mixed results. This is exemplified by Warry (2005) in his study of tegula cutaways. While a highly original study on a long-neglected resource, his initial assignation of different cutaway forms to evolutionary groups (figure 4.3) and the use of these groups as a fundamental unit of analysis may be problematic. Review of the dating evidence *after* this assignation (Warry 2005: 104-139) appears to have cemented the validity of this evolutionary typology in a series of circular arguments. While the relative position of some cutaway groups appears incontestable, for example that Group A cutaways are all from late first or very early second-century contexts and thus really are at the start of the sequence, others are contentious. In particular, the consistent assignation of Group D cutaways to later phases of construction than Group C cutaways on the same sites appears, at best, as an uncritical reading of often ambiguous evidence. Moreover, Group C cutaways have been identified in secure first century contexts in London (Mills 2013: 458), indisputably disrupting Warry's (2005) neat sequential proposed chronologies.

Furthermore, Warry's (2005) agglomeration of different cutaway forms into groups from the very start of his analysis means that the usefulness of the resource to other researchers is reduced. To illustrate the point, if a specific cutaway type were identified during analysis of an assemblage, it would not then be possible to use the publication to check other sites where this form had been found. Instead, and as Mills (2013: 454) noted, the researcher is presented with a list of sites where the general group had occurred. This group, however, is not clearly related by production or co-occurrence, but instead by Warry's (2005: 78-9, figure 4.3) interpretation of how forms had developed. This compounding problem is demonstrated by analysis at York (McComish 2012) and Chester (Heke 2017), which used Warry's (2005) groups to refine phasing evidence for these assemblages. As both have been published in reference to cutaway groups and not types, future attempts to usefully cross-reference those sites will require additional work to verify which exact cutaway types were present.

These shortcomings perhaps prevented this research from achieving its full potential, however it is important to acknowledge that Warry's (2005) study nonetheless successfully catalogued and synthesised a range of tegula features and architectural uses. Yet, this does illustrate the potential challenges of drawing conclusive evidence for phasing from recycled and often poorly recorded and contexted ceramic building material. Given the range of modes and scales of production likely to have been present in Roman Britain (e.g. McWhirr and Viner 1978, Peacock 1979, Darvill and McWhirr 1984, section 2.2), it is unlikely that we can expect disparate assemblages from a wide range of different production sites to fall into such neatly drawn categories at anything but the most general level.

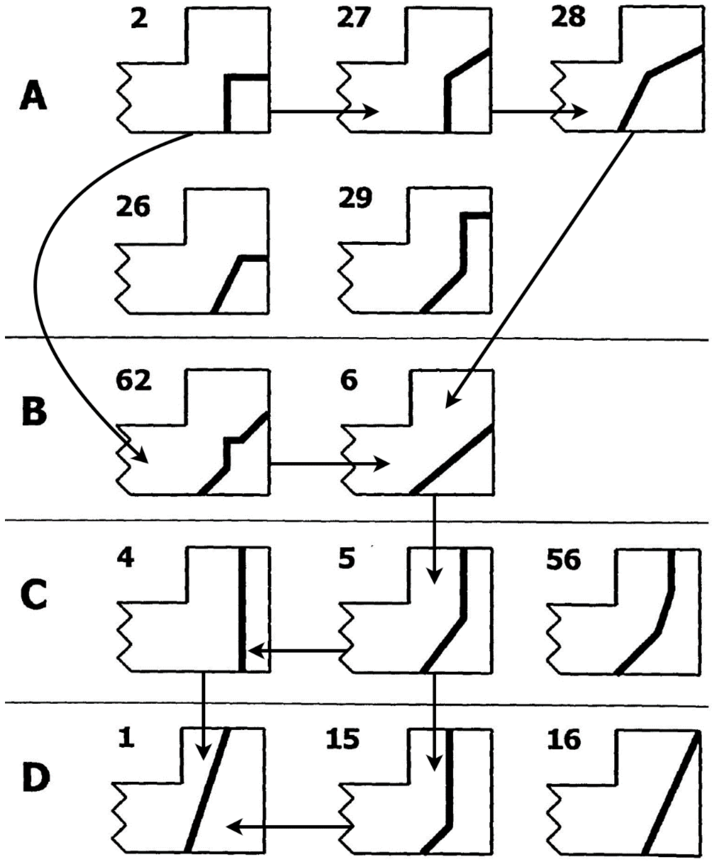


**Figure 4.3: Warry's (2005) tegula cutaway groups and proposed evolutionary pathways. From Warry (2005: figures 1.2, 3.13). © Peter Warry.**

The study of the morphology and morphometrics of Roman ceramic building material in Britain has yielded a range of important insights. The ubiquity of many forms, their severe fragmentation and their generally poor contextual information has nevertheless greatly impeded progress and understanding in this area.

## 4.3 Fabric Analysis

Visual assessment, low power magnification and thin-section petrography have all been used to characterise the fabrics of Roman ceramic building materials in Britain. These techniques have often been used together, with thin-section analysis being used to test initial fabric groupings and identifications made by eye or using x10 or x15 power handlenses (e.g. Betts 1984, Betts and Foot 1994, Finlay 2011, Peveler 2018). However, since the introduction of PPG16 in 1990, the use of low-magnification identification has come to dominate fabric analysis of brick and tile due to its widespread deployment in commercial archaeology.

### 4.3.1 The Application of Techniques of Fabric Analysis

After a period of widespread use in the late 1970's and 1980's (Peacock 1977, Cram and Fulford 1979, Darvill 1979, 1980, 1982, McWhirr 1984, Betts 1982, 1985, 1991), the application of thin-section petrography was supplanted by visual and low-power analysis due to the large assemblages of Roman CBM being unearthed in deep urban excavations in city centres. Whereas thin-section petrography had been applied only to very limited sample numbers (e.g. Peacock 1977, Darvill 1979, 1980, 1982, although to a lesser extent Betts 1985), the large assemblages typical in many commercial excavations required a different approach. Thin-section petrography is a time-consuming and intensive technique. By contrast, visual or low power analysis can be extensive, cheap, and fast to conduct. This is not to say that thin-section analysis has been supplanted entirely, for it continues to be employed in research contexts (e.g. Peveler 2018, Machin 2018, 2021).

The widespread use of low power or visual analysis has not merely been due to issues of cost and assemblage size. Although operating at slightly different scales, and with less precision, fabric analysis at the low magnification or macroscopic scales have been deployed in fundamentally similar ways to thin-section petrography and with the same overall objectives. These include the discrimination and differentiation of parts of the assemblage to different raw material batches or production sites (Darvill and Timby 1982, Quinn 2013), often with the ultimate aim of provenance to a specific kiln site, where these can be recognised (Darvill 1979, 1980, Peveler 2016). As such, there are issues common to all of these approaches, and conversely there are situations where any or all of these techniques are likely to be successful or to yield limited results regardless of which are used. As an example, thin-section petrography has been successfully used on assemblages that are stamped (Peacock 1977, Betts 1982, 1985, 1991) and/or which have regional kiln sites identified (Darvill 1979, 1980, 1982, 1998, 2001, Machin 2018, 2021). The work of Betts et al. (1997: 19-23) on roller-die stamped tile has shown that in similar circumstances, the systematic use of low-power magnification for fabric identification can yield similar results.

### 4.3.2 The Limitations of Techniques of Fabric Analysis

The synthesis of two decades of commercial work in southern England has demonstrated that low-power magnification can be used to provenance materials to kiln sites regardless of whether it is stamped or not (Betts 2016, 2017), although some understanding of the kiln sites and their products remains a necessity. Conversely, where a precise kiln site is not known, there are no stamps to aid identification, and no geological sampling has been undertaken then neither low-magnification identification or thin-section petrography will be likely to achieve significant results. This is demonstrated by the Roman CBM from Dorchester-on-Thames, Oxfordshire. While Peveler (2018: 143-144) identified 22 fabrics through visual examination and thin-section work, supplemented by SEM-EDS analysis, the bulk of these were consistent with local production using available Late Jurassic and Cretaceous deposits. Because the majority of the assemblage was unstamped, as no Roman kiln sites were known locally, and as no geological sampling was undertaken no further conclusions could therefore be made about the sources of these fabrics (Peveler 2018: 257). Similar difficulties have been encountered by researchers studying CBM from Roman York (Betts 1982, 1985, 1991, Finlay 2011, McComish 2012). The vast majority of this brick and tile has been identified as being consistent with legionary manufacture in the city using local lacustrine clay deposits (Betts 1985, Finlay 2011, McComish 2012). Despite these established conclusions, there has been only limited sampling of local tile kiln wasters (Betts 1985: 242) or geological deposits (Finlay 2011) to further refine this understanding. In this example, despite the application of low-magnification assessment (McComish 2012) and thin-section petrography (Finlay 2011), including textural analysis of grain sizes (Betts 1982, 1985) and even neutron activation analysis (NAA) (Betts 1991), the overall conclusions as to the homogeneity of the CBM in York and their geological source were largely consistent, even if the absolute number of different fabrics identified varied (McComish 2012: 80, 282).

Clearly, both low-magnification and thin-section petrographic fabric analysis techniques can be used to successfully characterise, differentiate and ultimately provenance fabric groups to production sites or geological outcrops in similar situations. In cases where this is not possible, it is rarely due to the limitations of these techniques but can instead be attributed to the contexts and material they have been applied to. Thin-section petrography has a range of benefits over visual or low-magnification analysis. The comparative advantages of this method include the precise measurement of grain sizes

(Betts 1982, Darvill and Timby 1982), the accurate identification of a wide suite of mineral or organic inclusions using plain or cross-polarized light (Whitbread 1989, Quinn 2013), as well as the improved estimation of temper or void contributions to the fabric body (Whitbread 1989). Where this technique is most successfully applied is when diagnostic inclusions are present and can be traced back to their geological outcrops of origin (Quinn 2013). As previously noted, (Peacock 1977: 246, Darvill and Timby 1982: 73), this can be a rare occurrence when studying brick and tile. This is because this material is typically sourced from sedimentary mudstones or drift deposits incorporating inclusions from a wide array of rock sources. While each CBM fabric is unique, they are therefore variations on a sedimentary theme rather than demonstrating the distinctiveness and diversity present in other ceramic assemblages (e.g. Quinn 2013). As such, typical CBM inclusions can include quartz, which is generally the dominant and sometimes sole inclusion type (Darvill and Timby 1982, McComish 2012), feldspar, mica, iron ore fragments, shell, grog, clay pellets, limestone, sandstone, flint and chalk. While this is enough to differentiate fabric groups, the occurrence of these inclusions in sedimentary deposits across Britain means that sourcing specific fabrics to certain outcrops is challenging unless the kiln site has been identified. While possible, it can require a disproportionate investment of time in sampling and analysis of geological materials for a relatively small research impact, as Peacock (1977: 246) concluded.

An additional issue of fabric analysis is the potential heterogeneity of ceramic building materials in the past. An average tegulae from Roman Britain, for example, was 43cm x 33cm and weighed over 6kg (Brodribb 1987: 10, 142), and some fabrics and components have shown negligible evidence for systematic processing and mixing of the clays used (McWhirr 1984: 57, for example figure 4.4). Given that the fabric of many of these large sherds are assessed through the creation of only a small fresh break, or the removal of material sufficient for only a single thin section, the potential heterogeneity of this material may be a concern. Betts (1982: 64) assessed internal homogeneity in three quartz-dominated tiles from York by taking thin-sections across them, applying textural analysis and grain size measurements to assess this variation. His conclusions were positive, noting that the different thin sections were largely consistent for each tile (Betts 1982: 64). However, these judgements may not hold true when applied to tiles with a more varied and dispersed range of inclusions. While this concern has been noted in thin section studies (e.g. Betts 1982, Darvill and Timby

1982), it is unclear how much of a problem it presents for visual or low-magnification fabric analysis. Indeed, it seems largely neglected in many publications (e.g. McComish 2012, Betts 2015).

**Figure 4.4: Photograph of a Roman brick or solid voussoir tile likely from the Spring Reservoir sediments and Cunliffe and Davenport's (1985) excavations. The brick is approximately 40mm thick. Photographs taken with permission from the Roman Baths, Bath and North East Somerset Council.**

### 4.3.3 Fabric Analysis and Itinerant Production

The identification of itinerant production of CBM in Roman Britain provides a good illustration of the challenges in applying fabric analysis to the provenance of material without diagnostic inclusions. While it is highly likely that itinerant production occurred in Roman Britain (Peacock 1979, McWhirr 1984), it is difficult to confidently identify. Finds of matching relief-patterned tile at a range of different sites has often been interpreted as evidence for the itinerant movement of craftsmen (Lowther 1948, Black 1985, Betts et al. 1997, Mills 2013), transporting their stamp dies with them between commissions. Given the significant evidence for long-distance transport of CBM in Roman Britain (Betts and Foot 1994, Mills 2013, Betts 2016, section 2.2.3), further analysis of these products is clearly necessary to distinguish between export and genuine peripatetic production. This could potentially be achieved through the use of a range of different techniques of fabric or compositional analysis. Despite this, thin-section petrography and textural analysis of grain sizes (e.g. Peacock 1977, Johnstone and Williams 1979, Darvill 1979, 1980, 1982, Betts 1982) has mostly, although not exclusively (Middleton and Cowell 1997, Hughes 2013), been applied to these questions.

In order to identify itinerant production, there must be a good understanding of the baseline geology of the area and of the range of fabrics from known local or regional kiln sites. As  Darvill and Timby (1982: 74) note, this is because techniques of fabric analysis are discriminatory and thus unable to provide a positive identification. Reasonable alternative sources must thus be considered and gradually ruled out on the basis of differences, leaving the best match(es) available on the basis of *present* evidence. Where the understanding of regional kiln products and local deposits is restricted, the confidence in any assertion of itinerant production is thus reduced. To demonstrate, consider the finds of two TPF-stamped tegulae from Hucclecote Roman villa, Gloucestershire. These tiles were analysed by Darvill (1979: 319), who described them as occurring in a distinctive mica-rich fabric with very fine quartz, which was dissimilar to other CBM at the site or indeed fabrics known from the wider region (Darvill 1979, 1980, 1982). As this fabric appeared consistent with comparative geological samples of lower Jurassic clays taken near the villa (Darvill 1979: 319), these sherds were interpreted as evidence of local production at the site by an itinerant brickmaker. While other stamped tile was found at the site, only this pair of TPF stamped tiles were found in the micaceous 'local' fabric (Darvill 1979: 318-319). Without reanalysis of the Hucclecote tiles no firm assertions can be made, although a number of relief-patterned tile finds from Bath (Betts 2007, 2015) could imply an alternative explanation to Darvill's (1979) conclusion of itinerant production.

The relief-patterned CBM finds from Bath so far include four different dies (Betts 2007: 53, 2015: 222, section 7.1.1), and these occur in a range of fabrics (Betts 2007: 53). The most significant of these is Betts's fabric 16, which is distinguished by high mica content and fine quartz moulding sand, suggestive of Darvill's (1979: 319) descriptions of the two TPF-stamped tiles from Hucclecote. However, Bett's (1999) fabric 16 is also noted for the occasional presence of iron oxide and cream silty bands. In this respect it is similar to the other relief-patterned tile fabrics from Bath (Betts 2011) and, indeed, descriptions of the fabrics from Minety itself (e.g. Scammell n.d.: 12, Betts et al. 1997:

23). It therefore appears that the clays exploited at Minety may have had a variable mica-content. If so, the tiles identified by Darvill (1979) could have been made at Minety, perhaps from a particular batch of micaceous clay not commonly exploited at the site, hence why restricted to certain TPF stamps (Darvill 1979: 319). If used more regularly, it may be that the evidence for this production is present in one of the unexcavated kiln mounds at the site (e.g. McWhirr 1984). That this is perhaps more likely than local manufacture is indicated by the find of a single TPF tile in the typical Minety fabric at Hucclecote (Darvill 1979: 319), indicating that stamped Minety products were indeed moving to the site. Alternatively, perhaps the two TPF tiles were made by another kiln site altogether which also produced the micaceous Bath fabric. It is important to note that an unusually wide array of TPF-series and other stamps have since been recognised from Hucclecote Roman villa (e.g. *RIB* II(5)), including 18 different die types as of 2017 (Warry 2017: 99). This has led to the interpretation of the site as a possible Roman reclamation yard or ancient builders' merchant (Warry 2017: 97-101). If this identification is correct then the range of different kiln site products curated there could be significant, which would further reduce the likelihood that the two TPF stamped tiles were the result of itinerant manufacture at the villa. Without further analysis these questions clearly cannot be resolved.

The cautionary tale considered demonstrates some of the problems of identifying itinerancy in Roman Britain using techniques of fabric analysis. Nevertheless, Darvill's (1980) study of the TCM stamped tile from Gloucestershire, and later northern Wiltshire (Darvill and McWhirr 1984: 255) identified a further potential case for peripatetic production in the region. Despite a small sample size drawn from seven sites (Darvill 1980: 52), six different fabrics were identified on the basis of quartz size and content using thin-section petrography, with each fabric generally specific to a site (Darvil 1980: 52). While Warry (2017: 92) has since noted similarities between some of the fabrics, and indeed fabrics 1 and 5, but also 6 and 3, do appear to cluster together (figure 4.5), there may nonetheless be enough variation to indicate the use of different raw materials (Darvill 1980, Darvill and Timby 1982), perhaps in at least three instances. As all samples have had a TCM stamp applied, a brickmaker must therefore have travelled between sites with the die, whether producing on site in a temporary clamp kiln (Darvill and McWhirr 1984), or perhaps commandeering kiln space at a local brickyard.

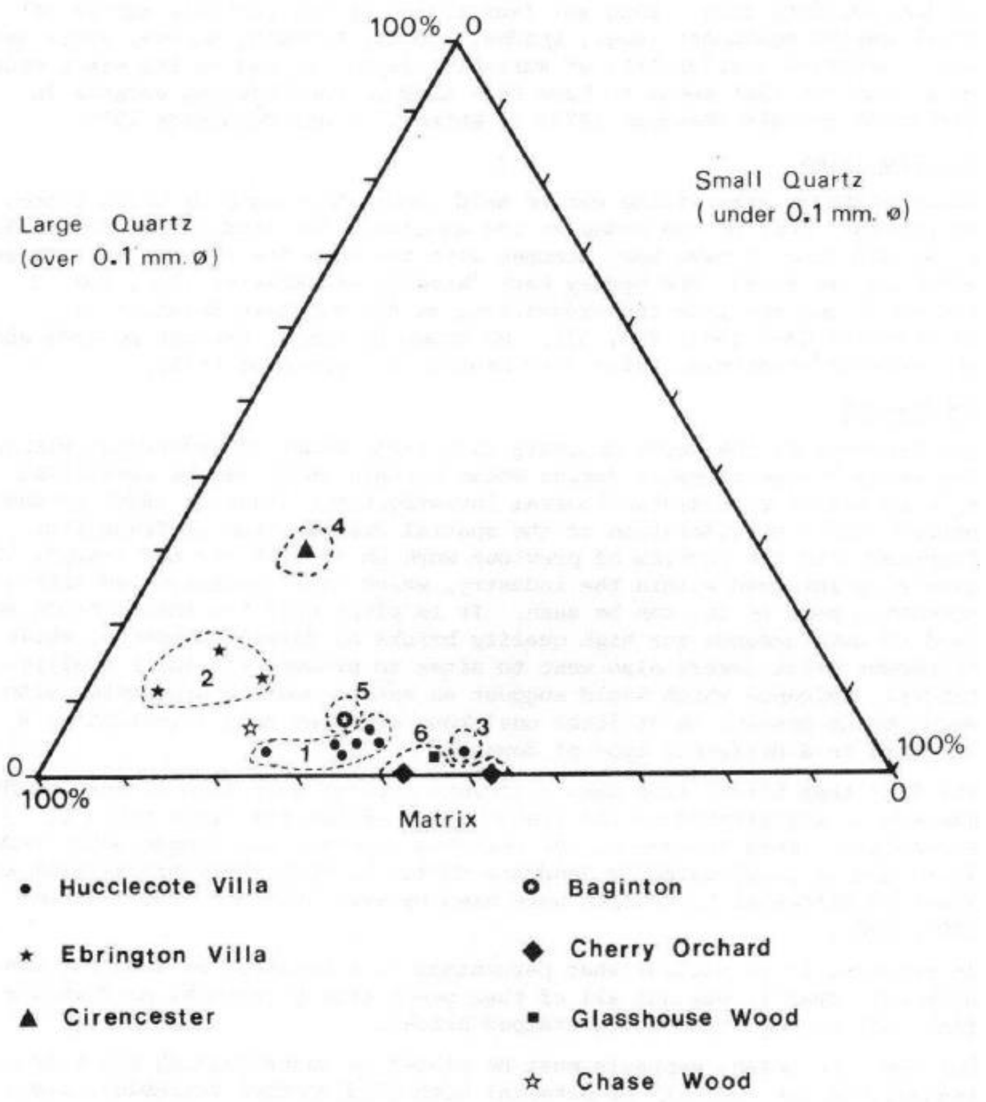


**Figure 4.5: Ternary diagram plotting the results of petrographic grain size analysis by Darvill on TCM stamped tile samples from Gloucestershire. From Darvill (1980: figure 4). © Gloucestershire Archaeology Society.**

## 4.3.5 National Overview of the Use of Fabric Analysis

Despite its limitations, the application of fabric analysis has generally proved successful in identifying different kiln products, matching them to production centres and understanding the distributions of these artefacts (Mills 2013, Betts 2016, 2017). While both low-magnification identification and thin-section petrographic approaches to fabric analysis have been deployed on unstamped assemblages, there has been much more fabric research into text or roller-die stamped brick and tile. Nationally, there is also an imbalance in which areas have received investigations into fabrics (table 4.1).

**Table 4.1: List of research areas for publications, theses and dissertations using techniques of fabric analysis on Roman ceramic building material from Britain.**

| Region | Site or Area | Publications |
|---|---|---|
| South coast of England | | Peacock 1977, Betts and Foot 1994 |
| Southeast England | | Middleton et al. 1993, Middleton and Cowell 1994, Betts et al. 1997, Betts 2016, 2017 |
| Southeast England | London | Crowley and Betts 1992, Betts et al. 1997, Betts 1995, 2016, 2017 |
| Central southern England | Winchester | Poole and Shaffrey 2011 |
| Central southern England | Silchester | Cram and Fulford 1979, Machin 2018 |
| Southwest England | Cirencester & Gloucestershire | Darvill 1979, 1980, 1982, 1986, 1998, Betts et al. 1997 |
| Southwest England | Bath | Betts 2007, 2015 |
| Southwest England | Wanborough | Darvill 2001 |
| Southwest England | Exeter & Devon | Williams 1991, Machin 2021 |
| Central southern England | Oxfordshire | Johnston and Williams 1979 |
| Central southern England | Dorchester-on-Thames, Oxfordshire | Peveler 2016, 2018 |
| East Anglia/East Midlands | | Betts et al. 1997, Mills 2013 |
| Northeast England | York & Yorkshire | Betts 1982, 1985, 1991, McComish 2012 |
| Eastern Scotland | Carpow | Betts 1985, 1991 |

As a result of urban rescue or commercial work, the Roman CBM from cities like London (Pringle 2006, 2007, Betts 2016, 2017), Cirencester (Darvill 1986, 1998), York (Betts 1985, Finlay 2011, McComish 2012), Winchester (Poole and Shaffrey 2008) and even Bath (Betts 2007, 2015) are comparatively well understood. Other research has supplemented this in certain rural or urban areas, for example Dorchester-on-Thames, Oxfordshire (Peveler 2016, 2018), Silchester (Cram and Fulford 1979, Machin 2018), Exeter (Williams 1991, Machin 2021), Carpow (Betts 1991, Finlay et al. 2012), parts of Yorkshire (Betts 1985), Gloucestershire and northern Wiltshire (Darvill 1979, 1980, 1982, 2001), Oxfordshire (Johnstone and Williams 1979) and areas of Sussex, Kent, Essex, and Surrey (Middleton et al. 1992, Middleton and Cowell 1997, Betts et al. 1997). This coverage is evidently far from complete, especially for western and northern Britain. In particular, many important Roman sites and settlements, for example Chester (Grimes 1930, Heke 2017), Caerleon (Zienkiewicz 1986) and Gloucester (Heighway and Parker 1982), lack published reports on the fabrics present despite otherwise developed understandings of regional kiln sites and brick and tile production (e.g. McWhirr and Viner 1978, Darvill and McWhirr 1984, Swan and Philpott 2000, Warry 2017).

Although fabric analysis of CBM has not yet been undertaken in all regions, the partial application of this technique has nevertheless successfully demonstrated the frequent long-distance movement of brick and tile by road, river, and sea in Roman Britain (Mills 2013, Peveler 2016, Betts 2017). Although apparently exceptional, Peacock (1977: 243) has also demonstrated the limited cross-channel movement of Classis Britannica brick and tile (section 2.4.4). While this has had significant implications for our understanding of the production and circulation of CBM, perhaps the most valuable contribution this has made is in helping to reject the conceptualisation of Roman CBM as high-bulk, low-value products only rarely transported beyond the local area (e.g. Hodder 1972, 1974, see section 2.2.1). While local production and supply nonetheless appears to have been important, and indeed long-distance transport often appears limited in quantity (e.g. Betts and Foot 1994) or linked to specific regions and periods (e.g. Mills 2013, Betts 2016, 2017), the rejection of this blanket notion allows a more nuanced understanding of the value and role of CBM in Roman Britain to be developed.

## 4.4 Compositional Analyses

A variety of techniques have been used to analyse the composition of Roman brick and tile from Britain (table 4.2). These methods are diverse and together encompass multiple scales of analysis, including mineralogical, chemical and isotopic, as well as various degrees of necessary sample preparation. Despite the range of techniques applied to these materials, the actual number of published studies is small. This is undoubtedly the result of the cost, equipment, and practitioner requirements of these approaches.

While analysis of marks or dimensions requires little more than a tape measure and scales, methods like SEM-EDS or ICP-MS analysis require substantial funding, intensive sample preparation and access to instruments held only at research organisations. It is therefore unsurprising that these methods have only been used as part of research projects. While there has been some overlap of regions covered, notably York/Carpow (Betts 1985, 1991, Finlay et al. 2012) and parts of the southeast of Britain (Middleton et al. 1992, Middleton and Cowell 1997, Hughes 2013, 2015), there has been little integration between the areas studied or between different techniques used in the same regions (e.g. Hughes 2013). Moreover, the application of these techniques has predominantly been restricted to questions of provenance (Middleton et al. 1993, Finlay et al. 2012, Hughes 2013, 2015). As such, the unique advantages of these techniques over established and widely used methods of fabric analysis have only rarely been capitalised upon (e.g. Peveler 2018). The total research impact of the application of compositional techniques of analysis to brick and tile from Roman Britain has therefore been limited.

**Table 4.2: Research, including unpublished reports and theses, which has applied compositional techniques of analysis to Roman brick and tile from Britain.**

| Technique | Studies | Research areas |
|---|---|---|
| Neutron activation analysis (NAA) | Betts 1985, 1991, Middleton et al. 1993, Middleton and Cowell 1997 | York, Yorkshire, Southeast England |
| Inductively coupled plasma atomic emission or mass spectrometry (ICP-AES or -MS) | Finlay et al. 2012, Hughes 2013, 2015 | Carpow in eastern Scotland, Southeast England |
| Scanning electron microscopy-energy dispersive spectrometry (SEM-EDS) | Peveler 2016, 2018 | Dorchester-on-Thames, Oxfordshire |
| Energy-dispersive portable X-ray fluorescence (pXRF) | BRBP 2017, Machin 2018, 2021, Warry 2021 | The Roman Baths, Bath, Fishbourne Roman Palace, West Sussex, Silchester, Exeter |

### 4.4.1 The Application of Methods of Compositional Analysis

Methods of compositional analysis have often been applied alongside visual/low-magnification or petrographic analysis to test and refine fabric group results (e.g. Betts 1991, Middleton and Cowell 1997, Peveler 2018). Occasionally these techniques have been employed in isolation, for example with the use of ICP-MS on material from Carpow, Scotland (Finlay et al. 2012) or Ashtead, Surrey (Hughes 2013, 2015). While the exact range of elements included in analyses varies between instrument and project, discriminatory statistical measures have been routinely applied to this data in order to separate and identify distinct compositional groupings (e.g. Betts 1991, Hughes 2013, 2015, Peveler 2018). Scientific techniques of compositional analysis have therefore been used with much the same aims as fabric analysis, namely the differentiation and provenance of Roman brick and tile. While these methods have been applied successfully towards these goals (e.g. Middleton et al. 1992, Finlay et al. 2012, Hughes 2013, 2015), this is not universally the case (Peveler 2018). Even in otherwise successful studies there can be a substantial number of samples which can only be attributed to unknown production sites (Betts 1991, Middleton and Cowell 1997, Hughes 2015), not to mention problems caused by overlap between products of different identified tileries (Hughes 2013). These criticisms are, of course, equally applicable to the study of CBM using other methods (Darvill and Timby 1982, Betts 1991). While the potential impact of compositional analytical techniques is therefore significant, the limited scope and infrequency of their use to date means that their contribution has so far been small.

The application of scientific methods of compositional analysis to Roman brick and tile from Britain could significantly contribute to our understanding of these artefacts. However, until these techniques are used to ask novel questions this potential will not be realised. This is because the application of these techniques has overwhelmingly been restricted to questions of provenance (e.g. Middleton and Cowell 1997, Finlay et al. 2012, Hughes 2013, 2015), a research area already saturated by studies employing fabric analysis (e.g. Darvill 1979, 1980, 1982, 1986, Betts et al. 1997). If the use of intensive techniques of compositional analysis are to make a substantial research impact in this field, then these must be used to ask new questions beyond the capabilities of other approaches. For example, they could be selectively applied to well-dated or distinctive tile forms to investigate practices and choices within the manufacturing process, including the selection of tempering materials or firing temperatures, in order to understand how practices changed between components and workshops or through time. Peveler (2018: 160) has demonstrated some advantages of combined microscopy and compositional analysis, for example in exploring the use of calcareous clays and the contribution of calcite in helping to sinter the clay matrix, which could reflect a deliberate selection of raw materials to achieve this result. While an isolated example, systematic materials-based observations could be used to generate novel and valuable understandings of assemblages and production practices, thus vindicating the use of these costly and specialised techniques.

## 4.4.2 Portable X-Ray Fluorescence

Portable X-ray fluorescence presents something of an exception. Like the techniques discussed above, it still requires equipment held largely by research organisations and needs trained practitioners who understand the application of the technique and its limitations (Hunt and Speakman 2015: 626). Where pXRF differs from other approaches is that sample preparation can be minimal, and the time per analysis is small. It therefore has the potential to be widely deployed as a fast, non-invasive compositional technique able to characterise large parts of an assemblage. This is, in fact, how it has already been applied to a wide range of archaeological materials (Forster et al. 2011, Tykot et al. 2013, Tykot 2016, section 5.2.2). While not a match in accuracy or precision for ICP-MS or SEM-EDS, with suitable certified reference materials the technique could still be used to provide internally consistent compositional data (Frahm 2013, Frahm and Doonan 2013) with which to test conclusions drawn from fabric analysis or from the identification of any stamps or relief-patterned impressions present.

Despite its potential, employment of pXRF on CBM from Roman Britain has so far been limited. It has been applied to brick and tile from Fishbourne Roman Palace and the Roman Baths (BRBP 2017), at Silchester (Machin 2018) and at Exeter and other sites in Devon (Machin 2021, Warry 2021). While these applications are hardly exhaustive, a number of issues have so far presented themselves in the use of pXRF on ceramic building materials. A key problem is the frequent disparity observed between fabric groupings made on the basis of visual/microscopic fabric analyses to those produced by compositional analyses. In particular, when sherds of different fabric groups are analysed compositionally then groupings can overlap, instead of forming discrete clusters with sherds of the same apparent fabrics (Peveler 2018). The application of pXRF to CBM from Silchester demonstrated this problem (Machin 2019 pers. comm.). Analysis of data collected by the Building Roman Britain project from the Roman Baths has shown similar disparities when sherds of fabrics previously identified by Ian Betts (2011) were analysed using pXRF. While applying a different technique, Peveler's (2018: 153-154) work has displayed similar disagreements between compositional groups derived from SEM-EDS bulk analysis and fabric groups identified during thin-section petrography. The reasons for these disparities have not yet been explored thoroughly, however a study of pXRF on stone cores from the Roman Baths has demonstrated significant surface contamination to a depth of 3cm (Tucker et al. 2020: 228). While CBM is generally not as porous as oolitic limestone, which is well known for its macro and micro-porosity (Palmer 2008: 73), elemental surface enrichment or depletion due to burial conditions may be a significant factor. Indeed, the potential for modification of Fe and Ca in CBM during burial has previously been noted (Darvill and Timby 1982: 77). In addition, the sometimes-subjective nature of fabric identification of occasionally poorly mixed CBM (McWhirr 1984: 57) may play a role in the disagreement between methods.

While the relationships between fabric groups and compositional groups require further investigation, pXRF still has considerable potential to contribute to the study of Roman CBM in Britain.

## 4.5 Chapter Conclusion

A range of methods have been applied to the study of Roman ceramic building material from Britain, including examination of its marks and impressions, weights, and dimensions. Much research has focussed on characterisation, provenance, and distribution, particularly for features such as stamps (Lowther 1948, Clifford 1955, Black 1985) or for research using methods of fabric or compositional analysis (Peacock 1977, Darvill and McWhirr 1984, Betts et al. 1997, Finlay et al. 2012, Hughes 2015). However, such aims have not been universal, and other studies have investigated the seasonality of production (Cram and Fulford 1979, McWhirr 1984), the literacy or identity of ancient brickmakers (Swan and Philpott 2000, Lancaster 2012) and the development of tegulae cutaway forms (Warry 2005).

While research has been conducted on assemblages from all over Britain, Roman brick and tile from the southeast and London is perhaps the best understood. This is the result of a concentration of both historic studies (e.g. Lowther 1948, Peacock 1977, Rodwell 1978, Brodribb 1979) and more recent research arising from commercially funded excavations in the region (Crowley and Betts 1992, Betts 1995, 2016, 2017). This trend is particularly developed in studies which have employed techniques of fabric analysis or compositional analysis (e.g. Middleton et al. 1993, Middleton and Cowell 1997, Betts et al. 1997, Hughes 2013, 2015).

Moving forward, more research should be directed at ceramic building material assemblages from the west and north of Britain. In particular, the systematic application of fabric analysis to assemblages from these regions would allow comparison with diachronic understandings generated from the synthesis of material from the Southeast. In future, studies employing intensive compositional analysis must exploit the unique advantages of these techniques in order to address novel questions beyond the capabilities of other, more widespread, methods. As part of this, there should also be more integration between studies and different techniques, and indeed commercial and academic research, in order to develop a larger, national picture of ceramic building material production, distribution and use in Roman Britain. This research must be integrated with studies of Continental material, in order to develop a holistic understanding of these materials across the breadth of the Roman Empire.

# 5.0 Portable X-ray Fluorescence Methodological Background

This chapter will investigate the theoretical and practical advantages and limitations of the use of handheld portable energy-dispersive X-ray fluorescence. The introduction of this technique into archaeological science is considered, and the different perspectives in the debate on how this technique should be employed and the quality and validity of data required are evaluated. The range of studies applying this technique to ancient ceramic building materials are then discussed, and the wider employment of this technique on archaeological ceramics reviewed.

## 5.1 Portable Energy-dispersive X-ray Fluorescence Fundamentals

This section will briefly consider the theoretical background of energy-dispersive X-ray fluorescence, in order to better understand the fundamental science behind the technique. Theoretical limitations of this technique, common to employment in both desktop and portable analysers, are then investigated. These include the issues of spectral interference, shallow penetration depths and matrix effects. The specific practical issues arising from the use of this technique on archaeological samples with miniaturised technologies in portable analysers are then considered, which chiefly consist of the lack of vacuum conditions, and the resultant restriction of the range of elements that can be analysed for.

### 5.1.1 The Physics of Energy-dispersive X-ray Fluorescence

X-ray fluorescence is a non-destructive technique that works by bombarding the atoms of the sample surface with photons generated by an X-ray tube housed in the instrument unit (Pollard 2007, Potts and West 2008). These primary photons strike the sample, exciting the electrons of the sample atoms and causing them to ascend energy levels, commonly known as electron shells, within the atoms and escape (Pollard 2007). This creates vacancies in the inner electron shells, which cause electrons at higher energy levels to de-excite in order to fill these gaps (figure 5.1).

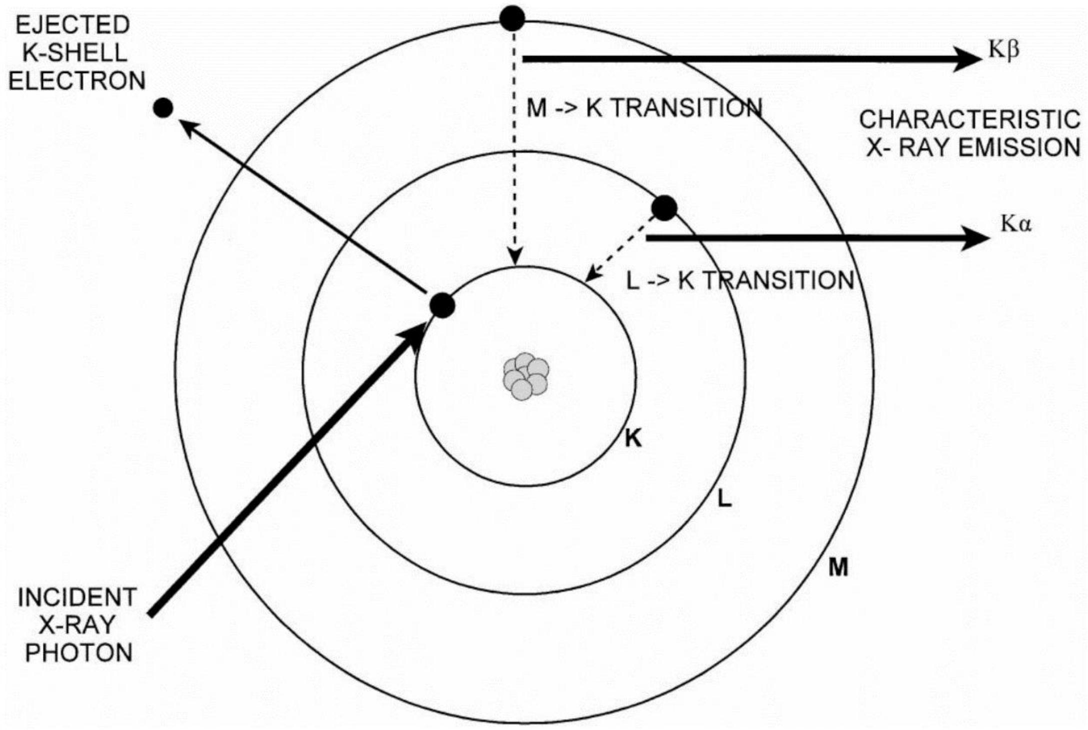


**Figure 5.1: Diagram of de-excitation process during X-ray fluorescence, where secondary photons are emitted as the outer shell electrons move down into inner shell vacancies. From Kalnicky and Singhvi (2001: figure 1). Reprinted from the Journal of Hazardous Materials, Vol. 83, Kalnicky, D. J. and Singhvi, R., 2001. Field Portable XRF Analysis of Environmental Samples, pp.93-122, Copyright (2001), with permission from Elsevier.**

As they de-excite, the electrons emit secondary (or fluorescent) photons which have a characteristic and known energy emission depending on the movement between K, L or M energy levels and depending on the element (Pollard 2007, Potts and West 2008, Tykot 2016). These secondary X-ray emissions are then absorbed by the detector, and the counts of the photons of different elements per unit of time are measured as intensity (Arai 2004, Potts and West 2008) and plotted to produce the distinctive XRF spectra.

The size and area of the spectrum intensity peaks are quantified through comparison to spectra of analyses of known values from certified reference materials (CRMs) and through fundamental parameters calculations (Pollard 2007, Marcowicz 2008, Conrey et al. 2014). This generates compositional data for a range of mostly mid-Z elements (Pollard 2007, Shackley 2012), all of which are measured for simultaneously, typically in only a few minutes.

### 5.1.2 General Limitations of Energy-dispersive X-ray Fluorescence Analysis

One challenge with energy-dispersive X-ray fluorescence as a technique is that several things can go wrong when photons are absorbed by the detector crystal. The first, minor, problem is that two photons can impact the detector at the same time, giving a false reading for the intensity of a specific count (Pollard 2007). This can be a direct consequence of secondary absorption in matrix effects, where a secondary photon is absorbed by the matrix instead of reaching the detector, and triggers another simultaneous emission (Pollard 2007).

A more significant problem is spectral overlap. In a typical spectrum from an X-ray fluorescence measurement, the peaks of photon counts and intensities are not perfect single lines or discrete categories. Instead, they each form a Gaussian, or normal, distribution, in part due to natural statistical variation in the counts (Arai 2004). The characteristic energy values for a wide range of element emissions, from any of the K, L, M and N shells, can therefore be very close to the values of many other emissions from different elements (Feret et al. 2003, Pollard 2007, Marcowicz 2008). This can result in spectral emission line overlap, i.e. where a peak from one element artificially elevates adjacent values (Conrey et al. 2014). This is problematic as it could then be interpreted by quantification software as evidence for the enhanced presence of another element, thus generating a false estimate of its proportion in the sample (Feret et al. 2003, Arai 2004, Pollard 2007, Marcowicz 2008). A good example of this is the enhanced arsenic (As) contents commonly seen alongside lead-bearing matrices (Feret et al. 2003), due to the proximity of the lead (Pb) $L\alpha_1$ emission line at 10.5515 KeV and the As $K\alpha_1$ emission line at 10.54372 KeV (Bearden 1967: 86-99). Without user awareness, integrated XRF software may thus misinterpret the suite of elements present in the sample due to spectral interference. To negate the influence of these factors, together with various scatter and background effects (Pollard 2007, Marcowicz 2008), it is essential that any rigorous study incorporating XRF uses standards with an appropriate matrix form and composition approximating that of the samples (Conrey et al. 2014).

One problem introduced by the varying strengths of the secondary photon emissions is the degree of absorption in the sample depth being analysed. Light element secondary photons are not just absorbed by air, but also by the sample matrix (Pollard 2007, Marcowicz 2008). The depth of absorption for 90% of the secondary X-rays varies hugely between elements and between matrices (see table 5.1), whether a desktop or portable instrument is applied. Here (table 5.1), we can see the difference in analyses from a fresco where sulphur (S), not even the lightest of elements typically measured using energy-dispersive XRF, has 90% of emissions absorbed at only 25μm. In contrast, for tin (Sn) K-lines 90% of absorption occurs at a depth of 10mm in the fresco. While Cesareo et al.'s (2008: 208) values for depths of 90% absorption may be somewhat inflated, especially when compared to those given by Pollard (2007: 102), the disparity between lighter and heavier element emission penetration in the same matrix remains significant. This technique is therefore not presenting data representative of a single slice of the sample at a uniform depth, but rather pockets of information from different elements at different depths.

**Table 5.1: Table showing the depth of 90% absorption of fluorescent X-rays for elements in different matrices. From Cesaereo et al. (2008: Table 9.1). Used with permission of the Royal Society of Chemistry, from Portable X-ray Fluorescence Spectrometry: Capabilities for In Situ Analysis, P. J. Potts and M. West (Eds.), 1st edition, 2008. Permission conveyed through Copyright Clearance Center, Inc.**

| *Object* | *Fluorescent radiation of element* | *Depth involving 90% of the fluorescent radiation* |
|---|---|---|
| Fresco[a] | Sulfur | 25 μm |
| Fresco[a] | Iron | 250 μm |
| Fresco[a] | Lead (L-lines) | 1 mm |
| Fresco[a] | Tin (K-lines) | 1 cm |
| Fresco[a] | Tin (L-lines) | 70 μm |
| Bronze[b] | Copper | 50 μm |
| Bronze[b] | Lead (L-lines) | 15 μm |
| Bronze[b] | Lead (K-lines) | 3 mm |
| Bronze[b] | Tin (K-lines) | 120 μm |
| Gold[c] | Copper | 5 μm |
| Gold[c] | Gold (M-lines) | 1 μm |
| Gold[c] | Gold (L-lines) | 10 μm |
| Gold[c] | Gold (K-lines) | 500 μm |
| Ceramic[d] | Iron | 130 μm |
| Ceramic[d] | Lead (L-lines) | 0.5 mm |
| Stone or marble[e] | Iron | 130 μm |
| Stone or marble[e] | Strontium | 1 mm |
| Paper[f] | Zinc | 3.5 mm |
| Paper[f] | Barium (L-lines) | 0.6 mm |
| Paper[f] | Sulfur | 200 μm |
| Gem or glass[d] | Iron | 130 μm |
| Gem or glass[d] | Lead-Lα | 0.5 mm |
| Wood (painting on)[g] | Copper | 5 mm |
| Wood (painting on)[g] | Calcium | 0.6 mm |

[a]Assuming a composition similar to plaster, with a density of 1 g $cm^{-3}$; the real situation is, of course, much more complicated, and depending on the present pigment.
[b]Assuming a bronze with 100% Cu.
[c]Assuming a gold alloy with 100% Au; notably, measurement of M, L or K-X lines gives information from different penetration depths.
[d]Assuming a composition similar to $SiO_2$, with a density of 2 g $cm^{-3}$.
[e]Assuming stone or marble = $CaCO_4$ with a density of 2 g $cm^{-3}$.
[f]With a density of 0.7 g $cm^{-3}$.
[g]With a density of 0.5 g $cm^{-3}$.

The heterogeneous nature of many archaeological samples can also substantially impact analyses made using energy-dispersive X-ray fluorescence techniques, particularly given the shallow penetration depths for many elements. In a cast metal the structure of the object is generally homogeneous, barring instances where high Pb content, for example, can create discrete segregations (Orfanou and Rehren 2014). In contrast, ceramics and many natural geological specimens are agglomerates of different minerals. When measuring light elements, these mineral crystals can prove larger than the effective escape depth of the fluorescent X-rays (Mori 2007). Furthermore, ceramic matrices can be significantly different to their inclusions, which can again affect the escape depths of the measured elements and may generate unrepresentative compositional readings for the measured artefact surface (Kalnicky and Singvi 2001). While some (e.g. Arai 2004, Craig et al. 2007, Markowicz 2008, Conrey et al. 2014) advocate implementation of calibrations and influence coefficients calculated for specific matrices, others (e.g. Mori 2007, Shackley 2012) promote rigorous sample preparation through homogenisation to negate these matrix effects during X-ray fluorescence analysis.

### 5.1.3 Specific Limitations of Portable Energy-dispersive X-ray Fluorescence Analysis

Portable X-Ray Fluorescence instruments are capable of measuring elements typically ranging from silicon (Si) to bismuth (Bi) when that element is present above limits of detection (Pollard 2007, Shackley 2012). These limits vary. While lead or niobium (Nb) might be accurately measured in concentrations as low as 20 parts per million (Newlander et al. 2015: 537), the detection of a lighter element such as silicon or calcium might require concentrations in excess of 1000 parts per million to be accurately and precisely quantified. It is therefore vital to understand the composition of the material being investigated, and the range and concentrations of target elements in the sample, in order to make sure that pXRF is an appropriate choice of analytical technique for the situation.

New generation pXRF instruments equipped with silicon drift detectors (SiDD), as opposed to older silicon-lithium (Si-Li) or Si-PIN detectors (Pollard 2007, Potts and West 2008), are increasingly able to measure light elements from magnesium (Mg) onwards, albeit with high limits of detection. It is not currently possible to measure the light elements below Mg because pXRF analyses are not performed under vacuum. The secondary emissions from light elements are far less powerful than those of heavier elements, and struggle to penetrate air, any significant depth of matrix or even detector windows (Pollard 2007, Potts and West 2008, Tykot 2016). Without vacuum conditions these light elements cannot be measured, yet portable instruments cannot be equipped to provide a vacuum, unlike desktop XRF units. Helium purges can be applied to portable XRF analysers (e.g.Hunt and Speakman 2015), however this it is still no substitute for measuring under total vacuum.

The usefulness of pXRF is also naturally limited on the other side of the periodic table, typically ending at Bi (Shackley 2012). This is because heavier elements have secondary photon emissions that are either so powerful that they are not absorbed by the detector material (Pollard 2007), or simply require a stronger voltage to excite than the miniaturised X-ray tube used in portable instruments can provide (Potts and West 2008). The weaker energy emissions of these elements typically have intensities too small to accurately quantify the presence of that element in the sample (Pollard 2007, Potts and West 2008), and so do not represent a suitable alternative for measurement. As Shackley (2011b: 8) notes, portable X-ray fluorescence is therefore most useful when wanting to measure mid-range Z elements.

For effective portable X-ray fluorescence analysis, it is also imperative that sample surfaces analysed are as flat and clean as possible. This is because certified reference material analyses used to calibrate the machine are performed on flat samples. To replicate the accuracy and reliability of these analyses therefore requires a similar surface (Shackley 2012). While this may not be as significant for emissions from heavier elements with greater penetration depths (e.g. table 5.1), analysis on irregular surfaces can severely impact the measured results of lighter elements due to increased distance between detector and sample, for this also increases absorption of the emissions by the intervening air. Moisture on sample surfaces during pXRF analyses has also been shown to be detrimental to the accurate measurement of light element values (e.g. Kalnicky and Singhvi 2001, Marcowicz 2008). As such, samples should be dried where possible before analysis, although in true field applications, for example on in-situ building materials (e.g. Everett and Gillespie 2016, BRBP 2017, Worthing et al. 2018), it may not always be possible to prepare samples in this manner.

Overall, portable energy-dispersive X-ray fluorescence has an array of practical and theoretical advantages and disadvantages. It is quick, it can analyse a wide range of elements simultaneously (Frahm 2013a, Tykot 2016), it has acceptable limits of detection for many archaeological applications (Pollard 2007, Shackley 2012) and, perhaps most advantageous of all, it can be non-destructive. On the other hand, as a technique it has a range of limitations which can significantly affect both the accuracy and precision of results if not mitigated for (Shackley 2012). In particular, it has very limited capabilities for elements towards the extremes of either end of the periodic table (Pollard 2007), high limits of detection when compared to many other elemental techniques, and large beam sizes incapable of targeting small inclusions (Shackley 2012, Tykot 2016). Although an extremely capable addition to the archaeological scientist's arsenal, it requires an awareness of the science and limitations of the technique as well as a theoretical awareness to ensure that it is applied to produce genuinely meaningful results (Shackley 2012, Hunt and Speakman 2015).

## 5.2 Review of Portable X-ray Fluorescence Applications to Archaeological Artefacts

The adoption of handheld portable X-ray fluorescence in archaeology initially sparked a series of debates over the quality of data and the validity of conclusions being drawn through widespread employment of this technique of analysis. It has since been successfully applied to a wide variety of inorganic materials in archaeology, anthropology, cultural heritage, and conservation. This includes stone, (Barbera et al. 2013, Frahm 2013a, Frahm et al. 2014, Worthing et al. 2018), ceramics (Hunt and Speakman 2015, Tykot 2016), metals (Orfanou and Rehren 2014, Nicholas and Manti 2014) and pigments and paints (Cesareo et al. 2008, Kopczynski et al. 2017), among other applications.

### 5.2.1 Debates and Controversy

The widespread application of this technique is undoubtedly due to the many virtues of portable X-ray fluorescence analysis. These include its speed, the wide range of elements analysed for simultaneously, the minimal (or non-existant) sample preparation required, the limited training required to operate many pXRF instruments and, most importantly, the fact that it is non-destructive (Pollard 2007, Frahm et al. 2014, Tykot 2016). However, this widespread deployment of pXRF has not been without contention. This is best encapsulated in the debates between Shackley and his associates (Shackley 2012, Speakman and Shackley 2013, Hunt and Speakman 2015) and Frahm and his colleagues (Frahm 2012, 2013a, 2013b, Frahm and Doonan 2013, Frahm et al. 2014). While Shackley (2011a, b, 2012, 2018) acknowledged the many positives of pXRF in archaeological applications, and in his sub-discipline of geoarchaeology, his main point of dissension appeared to stem from concerns over the rising numbers of pXRF studies in archaeology. He (2012: 2) proposed that the wider availability of pXRF enabled users with little understanding of the science of X-ray fluorescence to essentially join the archaeometric party. Thus, users with little understanding of the inherent limitations of the technique, and no experience of established lab-based scientific protocol for using XRF, were allowed to create research projects and data that were only internally valid and did not contribute to or, worse, contributed unreliable and misleading data to wider databases constructed for provenancing (Shackley 2012, Speakman and Shackley 2013). Key to this perspective is the expectation that archaeological data should be of the highest analytical standard. This would facilitate meaningful comparison not just between data from several pXRF instruments, but almost directly comparable, at least in terms of rigorousness if not actual limits of detection, to lab-based analyses using ED- or WD-XRF or other techniques such as SEM-EDS, EPMA, or ICP-AES or ICP-MS. This is all, of course, tied together in a desire for sourcing databases contributed to by different labs, using a range of instruments to characterise outcrops and resources from entire regions, as in ancient marble studies (e.g. Herz 1987, Antonellini and Lazzarini 2015).

While all of these concerns were valid, Frahm and Doonan (2013) approached these criticisms from a practical, rather than theoretical viewpoint. In their synthesis of major archaeological and anthropological journal papers on the use of pXRF, Frahm and Doonan (2013: 1430) noted that the reality of the situation was far from the mass free for all of poor data capture, quality and publishing that Shackley (2011a, 2012) feared. Rather, the use of handheld portable XRF in archaeology did not eclipse the use of benchtop or lab-based ED- or WD-XRF units, and instead studies using handheld pXRF were still largely in the minority, comprising 43% of the total (Frahm and Doonan 2013: 1428). While this does not rule out the analytical quality concerns of Speakman and Shackley (2013), in many instances pXRF has been deployed appropriately as a rapid semi-quantitative technique for bulk element observation and reconnaissance, with the results then informing more detailed study with techniques such as SEM-EDS and LA-ICP-MS (e.g. Barone et al. 2013, Sekedat 2016, Roxburgh et al. 2019). The users in these studies were invariably lab-based personnel who understood the limitations of the technique and applied a similarly rigorous approach to ensuring data quality as they would have when using other lab-based analytical equipment.

While Frahm's (2013a, b) other comments about the acceptability of using pXRF to create an internally valid dataset are also appreciable, it is clear that the contrast between Shackley (2011a) and Frahm (2013a, b) in this regard are to do with two very different research concerns. As Frahm (2013: 1445) noted, archaeological questions do not always necessitate a level of data quality that would allow direct comparison and use by geologists, and it is pertinent that Shackley (2011b: 11) notes that geologists have in any case largely moved from elemental to isotopic analyses to answer their pressing questions. All the same, it is important that operatives are able to generate the same *results,* if not the exact same values, when analyses are compared to those from other techniques. As the corpus of studies comparing pXRF with lab ED-XRF, WD-XRF, NAA and other techniques (Craig et al. 2007, Glascock 2011, Frahm et al. 2014, Orfanou and Rehren 2014) shows, it is clear that pXRF is generally sufficiently capable of accomplishing this aspiration, at least for most bulk and minor elements (Frahm et al. 2014, Orfanou and Rehren 2014).

These debates, although significant and indicative of the growing pains of the use of a novel technique in new and dynamic applications, have now aged somewhat. In particular, in the years since the publication of Shackley's (2011b, 2012) first significant criticisms of the growing availability of pXRF, the increase in the use of Si drift detectors has changed the dynamic of the technique. These detectors, which allow faster counts and far superior quantification of light elements than pXRF units with older Si-Li or Si-PIN detectors (Potts and West 2008, Frahm et al. 2014), have redefined pXRF as a technique that is not merely semi-quantitative. Depending on the material and surface condition, one no longer has to rely only on the bulk values, for even the minor and trace element values can be shown to be acceptably accurate (Frahm et al. 2014). Significantly, with Si drift detectors and inbuilt fundamental parameters calibrations, analyses are becoming increasingly accurate with manufacturer participation, after a rather hazy spell of relations between manufacturer claims and archaeologists' experience (Hunt and Speakman 2015).

While there have been significant developments in the abilities of handheld portable X-ray fluorescence technologies, it is unclear to what extent the importance and contribution of pXRF will continue. Over the past few years micro-XRF methods, many in a portable format, have become increasingly popular in cultural heritage and archaeology applications (e.g. Vaggelli et al. 2014, Flores-Alés et al. 2019, Röhrs et al. 2019). It will be interesting to see how this method and handheld pXRF intersect and interact in future archaeological applications.

### 5.2.2 Applications to Archaeological Ceramics

There are currently only a small number (e.g. Gradmann et al. 2012, Bonizzoni et al. 2013, Holakooei et al. 2015, BRBP 2017, Machin, 2018, 2021, Simsek et al. 2019a, b, Warry 2021) of studies applying portable X-ray fluorescence to archaeological ceramic building material. Bonizzoni et al.'s (2013) study is significant in that it is concerned with characterising the elemental composition of bricks for differentiation of components and achieving the first steps towards provenancing, which is a typical objective in studies using pXRF on pottery (e.g. Stremtan et al. 2012, Tykot et al. 2013, Tykot 2016). In contrast, Islamic glazed tile studies, which includes material from 16th-18th century Uzbekistan (Gradmann et al. 2012), Iran (Holakooei et al. 2015) and Turkey (Simsek et al. 2019a, b), are far more orientated towards understanding the glass phases of tile decoration, and only minimally cover the body ceramic (e.g. Simsek et al. 2019b) or do not analyse it at all (e.g. Holakooei et al. 2015, Simsek et al. 2019a). Aside from this, two projects that have extensively analysed CBM using pXRF are the Building Roman Britain project (BRBP 2017) and Sara Machin's (2018) doctoral study of bricks and tiles from Roman Silchester. The Roman ceramic building materials of Devon and Exeter are also surprisingly well-studied, having been analysed by both Machin (2021) and Warry (2021) using portable X-ray fluorescence. A larger, but not extensive, body of literature analysing ancient CBM comprises the application of a wide range of techniques. These include lab-based and/or micro-ED-XRF (Calliari et al. 2001, Alberghina et al. 2009, Gill and Rehren 2011, 2017), as well as XRD (Sanchez Ramos et al. 2002, Gimenez et al. 2005, Karunaratne 2012), SEM-EDS (Gimenez et al. 2005, Simsek et al. 2012), ICP-MS (Finlay et al. 2012, Gill and Rehren 2017) and

EPMA (Gill et al. 2014, Gradmann et al. 2012), among other techniques. While CBM is understudied using pXRF in comparison to pottery, there is clearly not a complete lack of archaeometric study of this material.

As the published applications of pXRF to CBM are limited, it is necessary to explore the literature on the applications of pXRF to ceramics more generally. While pXRF has been applied to a range of ceramic materials, including technical ceramics and moulds (Kearns et al. 2010, Meanwell et al. 2013, Ioannides et al. 2016) and even ceramic statuary (Pappalardo et al. 2004, Karran and Colstan 2016), it has been used most extensively to study pottery. Portable X-ray fluorescence has been applied to pottery from around the world, from North and South America (Speakman et al. 2011, Tykot et al. 2013, Tykot 2016, Del-Solar-Velarde et al. 2016), East Asia (Mitchell et al. 2012, Fischer and Hsiah 2017) Europe (Frankel and Webb 2012, Ceccarelli et al. 2016, Tanasi et al. 2017, Pirone and Tykot 2017) and the Near East (Stremtan et al. 2012, Simsek et al. 2015, Karacic and Osborne 2016, Emmitt et al. 2018). The extent of deployment of this technique in and around the Mediterranean is particularly remarkable, with recent publications including ceramics from Italy (Ceccarelli et al. 2016), Sicily (Tanasi et al. 2017), Malta (Pirone and Tykot 2017), Cyprus (Frankel and Webb 2012), Croatia (Tykot 2016), Turkey (Forster et al. 2011) and Egypt (Emmitt et al. 2018), among other regions. This technique has also been used on pottery over a wide chronological timespan, from the Neolithic (Pirone and Tykot 2017) right through to the post-Medieval period (Fischer and Hsiah 2017).

In the vast majority of applications, pXRF has been used as a means of understanding the sources and provenance of the assemblages being studied, either to simply differentiate between components of different sources within the assemblage (e.g. Stremtan et al. 2012, Simsek et al. 2015) or to directly trace those artefacts back to a region of manufacture through sampling and comparison of local clay deposits too (e.g. Keracic and Osborne 2016, Tanasi et al. 2017). As such, its employment follows on heavily from the traditions of provenancing ceramics using thin-section petrography and older NAA techniques, and indeed these have been effectively employed with and compared to pXRF in multiple instances (Speakman et al. 2011, Mitchell et al. 2012, Stremtan et al. 2012, Tanasi et al. 2017). One notable limitation it shares with NAA is that it is fundamentally a bulk technique. Due to the large beam size, upwards of 3mm in diameter for recent collimated instruments (Speakman et al. 2011, Forster et al.

2011), it is impossible to sample specific inclusions or tempers within the ceramic, and to do so requires the use of more precise techniques, for example SEM-EDS, EPMA or LA-ICP-MS (Hunt and Speakman 2015). As such, the compositional values generated from the analyses of ceramics using pXRF are not representative of specific discrete inclusions, but include parts of all of them and the sherd body, depending on the location of the sample on the ceramic, the structure of the matrix and the escape depth of the elements being analysed for (Forster et al. 2011, Hunt and Speakman 2015, Ceccarelli et al. 2016). The complex heterogeneous nature of many ceramic matrices, being interspersed with often large grains of temper, can prove a significant challenge for pXRF (Forster et al. 2011, Johnson 2012, Hunt and Speakman 2015). In particular, these forms of matrices often impair light element fluorescence from reaching the detector and, if certain elements are concentrated in clasts in the matrix, then this element will not be measured unless a relevant clast is, distorting results (Forster et al. 2011). Furthermore, when used on typical unprepared archaeological ceramic samples, surface treatments or adherents, sample concavity and sample surface micro-topography have all been shown (Forster et al. 2011) to extenuate attenuation of measured elements, and in particular Si and Ca disproportionately (Forster et al. 2011: 392). Thus, pXRF data from unprepared archaeological ceramics, and particularly for the light elements, has been deemed only semi-quantitative in nature (Foster et al. 2011, Hunt and Speakman 2015).

Surface analysis of many ceramics using pXRF can still provide enough informative to meaningfully distinguish between different fabrics, clay sources and recipes of ceramic production at a single site or regional level (Speakman et al. 2011, Forster et al. 2011). Yet, as Johnson (2012: 564) notes, in comparison to data from more precise analytical instruments, the elemental measurements derived from pXRF may differ substantially even while the assignment of source and provenance proves correct. Any comparison with data from other elemental techniques of analysis must therefore acknowledge this (Shackley 2012, Johnson 2012).

Despite these inherent problems, it is clear that pXRF is still a powerful tool when applied to questions of provenance for archaeological ceramics. As mentioned before, it is fast, portable and non-destructive, allowing analysis of substantial ceramic assemblages otherwise restricted either by location or by limited sampling permissions. Furthermore, pXRF can allow for meaningful differentiation between clay sources and different groups of ceramics in instances where traditional thin-section petrography might not be able to. For example, in many cases petrographic differentiation on the relies on the presence of distinctive minerals, temper or voids. Where these are absent, it can be impossible to provenance fabrics on the basis of petrography alone (Darvill and Timby 1982, Quinn 2013). In contrast, if the ceramic compositions were sufficiently different, pXRF might still be able to provide enough data to successfully discriminate between the fabrics (Forster et al. 2011, Speakman et al. 2011). Each technique has its drawbacks, but combining both pXRF and fabric analysis of ceramics, as is frequently done (e.g. Stremtan et al. 2012, Meanwell et al. 2013, Tanasi et al. 2017), can compensate for some of the limitations of each technique, and produce results far beyond the sum of the individual parts.

## 5.3 Chapter Conclusion

Handheld portable energy-dispersive X-ray fluorescence has many virtues as a technique of compositional analysis. It is fast, it can analyse a wide range of elements simultaneously, it is non-destructive and requires minimal sample preparation, and is easy to learn and apply. However, this technique does have a range of limitations. Matrix effects and spectral overlaps can distort results generated and need to be considered and mitigated for where possible. More critically, the extremely shallow penetration depths of many elemental emissions means that this technique is fundamentally one of surface analysis only, and this must be factored into research design and sampling. These limitations, and indeed benefits, fed into anxieties about a mass of new users producing poor quality data. Ultimately these fears do not seem to have been realised, though these concerns remain valid. Instead, this technique has seen wide and successful application to archaeological ceramics around the world, though the number of studies applying this technique to ancient ceramic building materials remains small. Nevertheless, there is significant potential for further application of this technique to these materials, particularly as a complementary scale of analysis alongside the study of ceramic fabrics.

# 6 Clay Resources and Exploitation at Bath

The geology around Bath is varied, with outcrops of rock from the Carboniferous, Triassic and Jurassic periods all present within the hinterland of the Roman town, along with extensive Quaternary alluvial and colluvial deposits (Forster et al. 1985). As such, there are a range of clays in the region that could have been exploited for use in various ceramic processes in antiquity. This chapter will investigate these clays, providing examples of modern or historic use in brick or tile-making in order to understand and assess their suitability for ceramic building material manufacture. As many of these deposits, and particularly those of the Lower and Middle Jurassic (Cox et al. 1999, Barron et al. 2012), occur in broad outcropping bands stretching from the Dorset coast to Yorkshire, examples will be provided from adjacent areas and counties where appropriate, in particular Somerset, Dorset and Gloucestershire.

## 6.1 Areas of Study

Before beginning, it is necessary to define the two areas of study for clay resources in and around Bath. These are the exploitable threshold model (ETM) radius of 7km, defined and developed by Arnold (1985, 1991, 2000) and others (Arnold et al. 1991, Miksa and Heidke 1995, Kelly et al. 2011), and the Roman Bath hinterland region (Davenport 1994), defined as a 15-20km radius around the ancient town (Davenport 1994: 7).

### 6.1.1 Exploitable Threshold Model (ETM)

The 7km radius of the exploitable threshold model is derived from an ethnoarchaeological cross-cultural synthesis of ceramic producing societies by Arnold (1985, 1988, 1991, 2000), though since developed by other researchers as well (Arnold et al. 1991, Miksa and Heidke 1995, Kelly et al. 2011). It encompasses both clay resources and inorganic tempers. Arnold (1985: 35-57) found that, of 117 societies surveyed, the vast majority used clay resources and tempers available within 7km of their settlements. Moreover, significant proportions of potters used resources that were even closer, with 49% using temper resources from up to 1km away (Arnold 1991: 340), and 37% using clay within 1km (Arnold 1991: 339). As such, the model, as applied in archaeology, assumes that pottery makers from pre-industrial societies will generally use clay resources and temper located within 7km of their home base or settlement (Arnold 1991, 2000, Arnold et al. 1991), if not closer. Others (e.g. Miksa and Heidke 1995) have also employed this 7km limit to designate and differentiate local and imported ceramics.

More recent work (Miksa and Heidke 1995, Kelly et al. 2011) has highlighted the limitations of this model. There are, for example, significant variations in the distance potters are willing to travel to obtain different types of tempers, and this variation is obscured by grouping all tempers together (Miksa and Heidke 1995). Furthermore, the model does not account for the co-exploitation of resources at the same place in preference of closer, but dispersed, resources (Kelly et al. 2011). Despite these criticisms the model appears to have maintained its relevancy, with applications in varied archaeological ceramic studies spanning 35 years (Kelly et al. 2011, Quinn 2013).

Although the ETM is a generalisation of the patterns of resource exploitation for a range of pottery-making modern societies (Arnold 1985, 1991), and could therefore be argued to have limited relevance to studies of pottery-making past societies, much less to the study of CBM from Roman Bath, it will nonetheless be used here. The rationale for the employment of the 7km radius of the ETM is that there are a range of Roman kiln sites which demonstrate relevant proximity to other target centres. The early Roman kiln site at Little London, Hampshire, is situated 3.1km from *Calleva Atrebatum* or Roman Silchester (Fulford et al. 2017), and the contribution of the kiln site to the construction of the Roman town has been confirmed by the discovery of Neronian stamps and by fabric analysis (Fulford et al. 2017, Machin 2018, Fulford and Machin 2021). The early second-century tile-making site at St Oswald's Priory, Gloucester, was situated less than one kilometre from the northwest corner of the Roman *Colonia* (Heighway and Parker 1982). Though no kiln structures were found, the site has been suggested to have produced more than half of the stamped tile so far discovered from the city (Warry 2017: 77). The late first- to early second-century tile kilns at Minety, Wiltshire, though little analysed (Scammell n.d.), have been confirmed as the source of a significant proportion of stamped building material from Roman Cirencester (Darvill 1979, 1986, 1998, Darvill and McWhirr 1984), located 9.4km to the northeast of the site. While outside the 7km limit of the ETM, its proximity is still sufficient to illustrate the value of a scale of analysis at this approximate level. While no definite tile kilns have yet been located, the excavation of dumps of first century AD brick and tile wasters at Cheapside and Paternoster Square (Betts 2017: 368-369, Watson 2006: 53, 76), within the Roman walls of London, also serve to demonstrate the close proximity of certain early Roman CBM production sites to major consumption locations. While these examples are by no means exhaustive, and there are numerous cases of CBM from Roman Britain travelling more than 50km by road, by river or by coastal transport (e.g. Peacock 1977, Betts and Foot 1994, Mills 2013, Peveler 2016, Betts 2017), they serve to indicate that there is potential for the discovery of a Roman kiln site using local deposits within the bounds of the ETM area.

Given the size, weight and significant quantities of the ceramic building materials being supplied to the Roman town of Bath and nearby 'suburban villas' (Davenport 2000, Betts 2015), with 527kg of Roman CBM recovered from excavations at the New Royal Baths alone (Betts 2007: 52), it is plausible that a Roman brickyard supplying the town would be situated close to the settlement, using nearby clays in order to minimise transport. However, there is always the possibility that a CBM kiln site may have been set up further away to exploit demand from Bath and another adjacent town or region. Bath was the main Roman settlement in the local area (Davenport 1994, 2000, Cunliffe 2000), and was relatively distant from the nearest *Civitates* of Cirencester, 45km to the northeast, and Winchester, 80km to the southeast (Davenport 1994, 2000). It is therefore likely that it would have acted as the main consumption centre for CBM in a considerable area. This would perhaps render this dual-exploitation unlikely.

The 7km radius of the ETM model, here centred on the Roman Baths as no undisputed Roman tile kiln sites have yet been found locally, has therefore been employed to assess the range of local clays potentially suitable for exploitation in CBM production near the settlement (figure 6.1). While it is highly likely that part of the material from Roman Bath was sourced from outside the ETM and hinterland areas (section 7.1), this proportion may have been small. As the deposits of the ETM area are largely representative of those found over much of the hinterland, with a number of important exceptions which have been included in the survey, the delineation of the ETM area is adopted with a somewhat flexible approach. This smaller scale of analysis will nevertheless merit more intense investigation than the wider hinterland area.

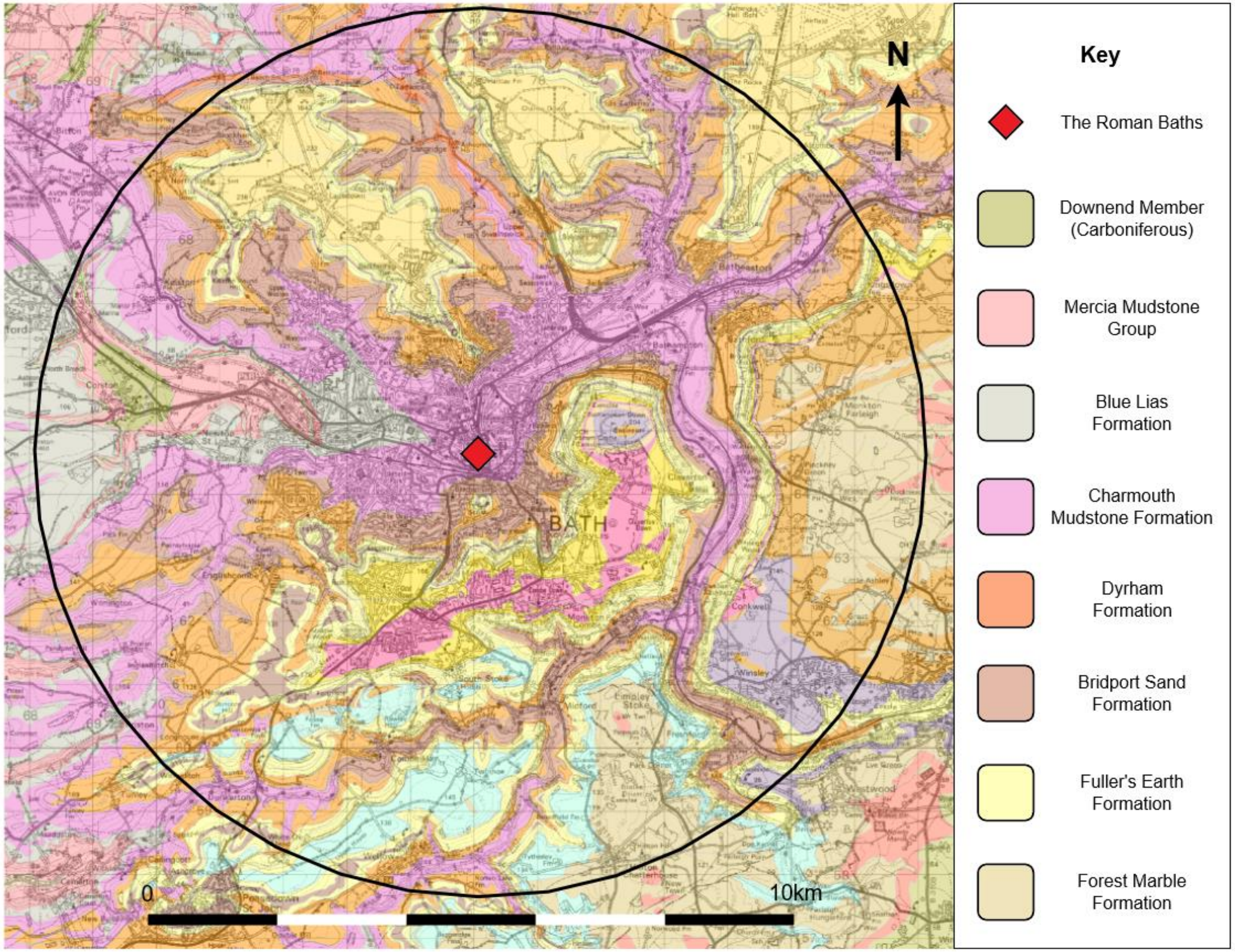


**Figure 6.1: Geological map of the exploitable threshold model region around the Roman Baths. Modified from BGS (2020a). © BGS.**

### 6.1.2 Roman Bath Hinterland

The Roman Bath hinterland area has been employed as a second scale of analysis, defined by a radius of 15-20km around the Roman town, following Davenport (1994). This radius figure is derived from the maximum length of a typical day's return journey on foot, presuming the need to travel to market in Bath (Davenport 1994: 7), though probably not allowing for the herding of animals as well, which might significantly slow progress. Neither does it allow for topography, ancient roads, or traversable waterways in the region. This radius is therefore not a firm boundary derived from ancient historical sources, of which there are few concerning Roman Bath (e.g. Scarth 1864, Haverfield 1906, Cunliffe 2000). It is instead an approximate indicator of the Roman town's likely influence on surrounding communities, as a major market and centre of commerce in the local area (Davenport 1994, 2000, Cunliffe 2000).

The hinterland model is used here in order to understand the range of clay resources accessible around Bath, although most of the deposits outcropping in the hinterland (figure 6.2) are also represented within the exploitable threshold model radius of 7km (figure 6.1). It is worth reiterating that although many Roman CBM fabrics from Bath may be local (Betts 2015: 221), they may instead have been produced using similar geological deposits in the wider hinterland area and transported to the town. It is thus pertinent that Murless (2000: 6) noted a maximum practical daily cartage of 10 miles, or 16km, for CBM from brickyards in Somerset at the turn of the 19th century. While the mode of production, distribution and even traction was likely different from that of Roman CBM, it is interesting that this figure roughly aligns with the lower boundary of the Bath hinterland radius defined by Davenport (1994: 7). Indeed, it perhaps suggests that we might expect local Roman tile kiln sites supplying Bath overland to be situated within the lower bounds of the hinterland. While the ETM area will therefore be the primary scale for analysis, historic or ancient exploitation of clay resources in the wider hinterland (that is, outside the ETM zone) will also be discussed where relevant.

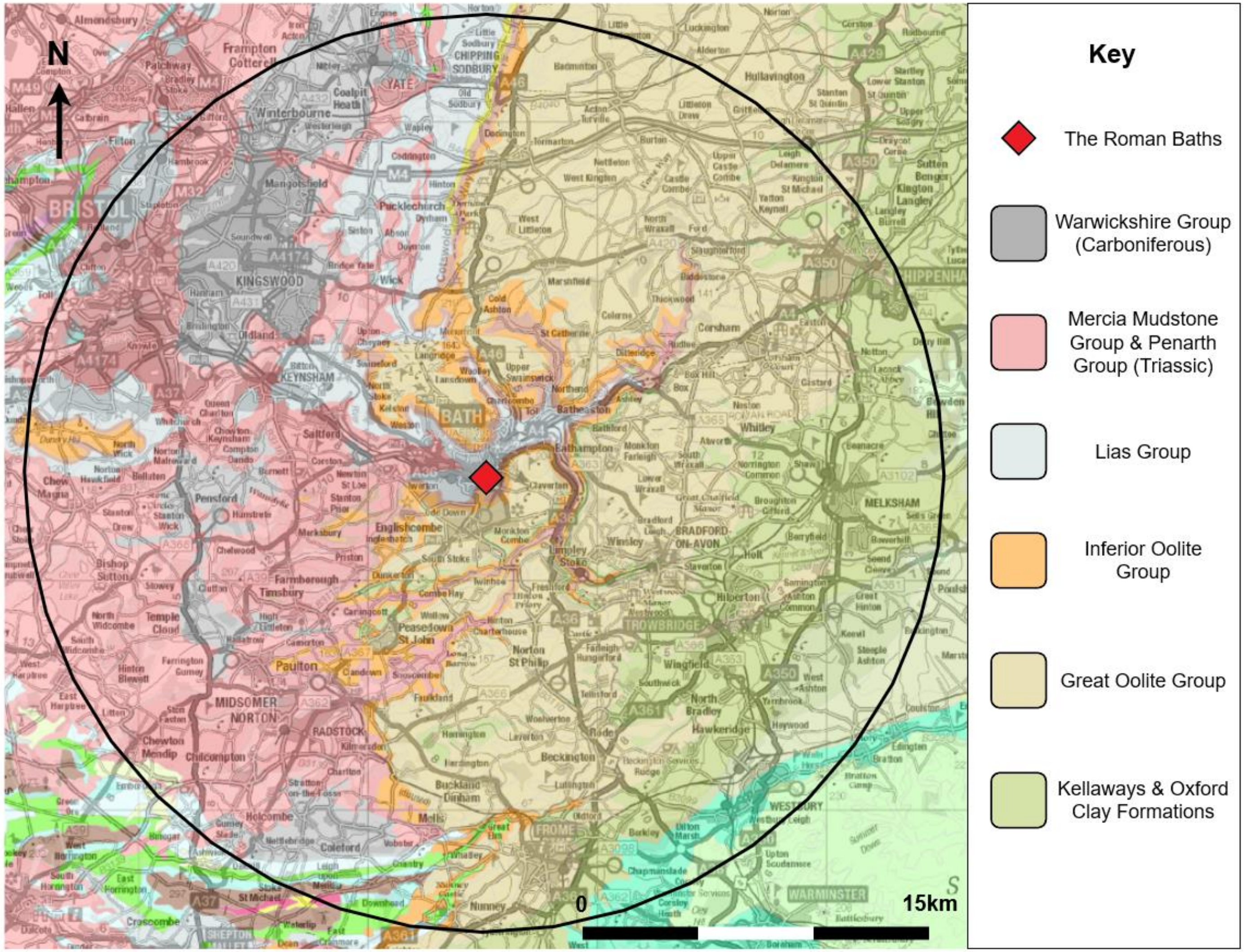


**Figure 6.2: Geological map of the Bath hinterland area. Modified from BGS (2020b). © BGS.**

## 6.2 Clay Resources

A range of clays can be sourced from outcropping Early and Middle Jurassic deposits within the ETM radius of Bath. To the west and southwest, particularly in the Bath hinterland, a range of Carboniferous and Triassic clays also occur. Quaternary deposits, the product of the ancient flooding of the River Avon or the cambering and landslip of the heights surrounding Bath (Forster et al. 1985), are also extensive in the valley floors and on the lower slopes around the settlement. However, it is unlikely that all of these clay deposits were exploited in the past, as some were probably unknown, unsuitable for a desired use, difficult or not economically viable to extract, or were just ignored in favour of another closer or more accessible source (Miksa and Heidke 1995, Kelly et al. 2011). It is also important to acknowledge the roles that less tangible aspects could have played in the selection of resources, for example territorial or land-ownership restrictions (Arnold 1985, 2000), or the choice of materials based on cultural or ritual categories (Arnold 1991, Arnold et al. 1991).

Much of the rock discussed in this chapter is a form of mudstone. This is a very soft and fine-grained sedimentary rock, with individual grains less than 32 micrometers in size, whose original constituents were typically mud or clay (Merriman et al. 2003). While often unsuitable for ceramic manufacture in its raw state, surface weathering can break this material down into a plastic clay. With some degree of further processing, many of the mudstones listed below have been successfully used in historic ceramic building material production in adjacent counties and therefore have potential to have been exploited in the Roman period at Bath. A few non-mudstone rock units have also been included in this survey. This is either because they are interbedded with mudstones, for example the limestone of the Lower Jurassic Blue Lias Formation (Cox et al. 1999), or because historic brickmaking in the Bath region or slightly wider afield has previously exploited them successfully.

| Period | Epoch | Group | Formation | Member |
|---|---|---|---|---|
| Jurassic | Upper | Oxford Clay Formation | | Peterborough Member |
| | | Kellaways Formation | | Kellaways Sand Member |
| | | | | Kellaways Clay Member |
| | Middle | Great Oolite Group | Cornbrash Formation | |
| | | | Forest Marble Formation | |
| | | | Chalfield Oolite Formation | Bath Oolite Member |
| | | | | Twinhoe Member |
| | | | | Combe Down Oolite Member |
| | | | Fuller's Earth Formation | Upper Fuller's Earth Member |
| | | | | Fuller's Earth Rock Member |
| | | | | Lower Fuller's Earth Member |
| | | Inferior Oolite Group | Undifferentiated | |
| | Lower | Lias Group | Bridport Sand Formation | |
| | | | Beacon Limestone Formation | |
| | | | Dyrham Formation | |
| | | | Charmouth Mudstone Formation | |
| | | | Blue Lias Formation | |
| Triassic | | Penarth Group | White Lias Formation | |
| | | | Cotham Formation | |
| | | | Westbury Formation | |
| | | Mercia Mudstone Group | Blue Anchor Formation | |
| | | | Undifferentiated | |
| Carboniferous | | Warwickshire Group | Grovesend Formation | Publow Member |
| | | | | Radstock Member |
| | | | | Barren Red Member |
| | | | | Farrington Member |
| | | | Pennant Sandstone Formation | Mangotsfield Member |
| | | | | Downend Member |
| | | South Wales Coal Measures Group | South Wales Middle Coal Measures | |
| | | | South Wales Lower Coal Measures | |
| | | Carboniferous Limestone | | |

**Figure 6.3: Diagram showing the stratigraphy of the main geological units that outcrop within the Bath hinterland area.**

### 6.2.1 Carboniferous Rock

Unlike other potential clay sources in the Bath region, Carboniferous sources will be treated as a whole, despite their diversity. In particular there are two types of sources for Carboniferous clays in the Bath hinterland, namely limited surface outcrops of mudstones from the Radstock, Downend or Publow Members (Forster et al. 1985, Waters et al. 2009), and clay extracted from coal measures during mining. Both of these types of deposit predominantly occur outside the 7km radius ETM zone from the centre of Bath (figure 6.1), although still present in the wider hinterland of 15-20km (figure 6.2). The Carboniferous mudstones outcrop to the west and northwest of Bath, with the closest at Pensford 12km to the west of central Bath. The Somerset Coalfield was located predominantly to the southwest, with mines just south of Pensford and around Camerton, 10km southwest of Bath, and further south towards Radstock (Gould 1999). However, Scarth (1864: 3) did note an active coal mine at Newton St Loe, only 5km from Bath. The Bristol Coal Measures were instead concentrated to the northwest around Coalpit Heath in South Gloucestershire (Cornwell 2003), 17km from central Bath.

These Carboniferous strata are the oldest exposed stratigraphy in the Bath region (figure 6.3), underlying much of the later Mesozoic rock unconformably and outcropping at the surface only in the west due to the incline of the later strata (Forster et al. 1985). The nature of these deposits is variable, and mudstone is often interbedded with siltstone, sandstone, or seams of coal (Waters et al. 2009). These Carboniferous deposits have been included here as a frequent by-product of coalmining is fireclay. This refractory clay was critical to a number of ceramic building material industries in Gloucestershire (Richardson and Webb 1911), the West Midlands (Woodward 1876) and the North of England during the late 19th and early 20th centuries (Woodward 1876, Highley et al. 2006). Regionally this included Cattybrook, north of Bristol (Richardson and Webb 1911), which even now remains in production as part of Ibstock Brick. Carboniferous mudstones and fireclays are still heavily exploited for CBM manufacture in the north of England and central Scotland (Bloodworth et al. 2007), in 2007 accounting for 30% of brick production in England, and 90% for Scotland (Bloodworth et al. 2007: 8). Providing that there was Roman coal mining within the Bath hinterland, it would therefore be possible that fireclays could have been used in Roman ceramic production in this area.

Coal mining was an important industry in Roman Britain (Webster 1955, Dearne and Branigan 1995, Smith 2005), and there is evidence for the exploitation of all major coalfields in southern Britain, barring those of North and South Staffordshire, by the end of the second century AD (Smith 1997: 323). While no Roman coal mines in the Somerset and Bristol coalfields have yet been located, analyses of coal from Roman sites across Somerset, Wiltshire, Gloucestershire and South Wales have indicated that several different sources in the Radstock and Coalpit Heath, South Gloucestershire, Basins were probably exploited (Smith 1996, 1997). Furthermore, the proximity of the Fosse Way to the Radstock Basin and many Roman sites yielding coal consistent with that of the Somerset coalfields (Smith 1996, 1997), including Camerton, Nettleton, Ilchester, Lufton and Marshfield (Smith 1996), implies the importance of this route as a means of distributing coal from mines in north Somerset. Solinus, writing in the third century AD, described a coal-like fuel used in the Temple of Sulis Minerva at Bath (Scarth 1864: 3). Coal cinders have also been recovered from several Roman sites around the city, most notably from the Temple Precinct (Irvine 1873, Cunliffe 2000) and at Little Down village (Davenport 1994), although none have yet been analysed to determine provenance. Given the proximity of the Somerset coalfield to Bath, as well as the important Fosse Way directly connecting them, it seems highly probable that these sources would also have supplied Roman Bath with coal. It is therefore also possible that Roman Bath may have been supplied with ceramics produced using fireclay from these coal mines. While there is currently no evidence for the ancient exploitation of Carboniferous outcrops or fireclays in ceramic production in the Bath hinterland, there clearly exists some potential for their successful use in antiquity.

### 6.2.2 Mercia Mudstone Group

Except for its uppermost unit, namely the Blue Anchor Formation, the Triassic Mercia Mudstone Group is undifferentiated in the Bath region (Howard et al. 2008: 24). Both are considered here together for convenience. Near Bath the Mercia Mudstone Group, formerly known as the Keuper Marl (Howard et al. 2008), sits unconformably upon the underlying Carboniferous deposits, which have been folded almost perpendicular to the later Triassic sediments (Forster et al. 1985). The Mercia Mudstone Group is therefore stratigraphically above the Carboniferous deposits of the Grovesend Formation, with the Blue Anchor Formation comprising the Mercia Mudstone Group's uppermost unit (see figure 6.3). The Blue Anchor Formation is stratigraphically below the Penarth Group, and particularly the basal Westbury Formation. These Triassic sediments are extremely variable in depth (Howard et al. 2008), being virtually absent in the centre of Bath (Forster et al. 1985) but reaching a maximum thickness of 77m or more within the ETM area (Forster et al. 1985: 17). The Mercia Mudstone Group outcrops only to the west of the city, with the nearest surface exposure a little south of Newbridge, just within 3.5km of the Roman Baths (figure 6.1). However, BGS (2020a) mapping shows these deposits outcropping more substantially in the northwest, west and southwest of the hinterland area (figure 6.2).

The Mercia Mudstone Group consists mainly of brown or red-brown silty and sandy calcareous mudstones and subordinate siltstones, with occasional green-grey patches, streaks, or intermittent bands (Forster et al. 1985, Hobbs et al. 2002, Howard et al. 2008), with the mudstones weathering into heavy red-brown silty clays that are very soft to hard in firmness (Forster et al. 1985, Hobbs et al. 2002). The Blue Anchor Formation comprises pale green-grey dolomitic silty and sandy mudstones with thin argillaceous lenses (Forster et al. 1985, Howard et al. 2008). It is unclear to what extent the Blue Anchor Formation specifically has been used in ceramic production, but other Mercia Mudstone Group sediments have been used extensively for brickmaking (Bloodworth et al. 2007). While Mercia Mudstone Group clays are not exploited for CBM production in the Southwest of England at present, they are still used in brick production at a range of sites in the Midlands (Bloodworth et al. 2007). Historically, Mercia Mudstone Group clays were used in brickmaking at Honiton, Devon (Woodward 1876), at Taynton pottery and brickworks in Oxfordshire (Richardson and Webb 1910), at Stoke Gifford north of Bristol (Richardson and Webb 1910) and at Shortwood near Mangotsfield, northeast of Bristol, prior to its purchase by the Cattybrook brick company in 1903 (Richardson and Webb 1911, Doughty and Ward 1975). Richardson and Webb (1910: 278) also refer indirectly to other claypit sites around Bristol that exploited Mercia Mudstone Group sediments but were forced to close due to competition from the highly successful Cattybrook and Shortwood sites (Doughty and Ward 1975). More locally, indeed within the southwestern extremities of the Bath hinterland area, the North Somerset Brick and Tile Works at Midsomer Norton (Murless 2000) probably exploited Mercia Mudstone Group clays. It is likely that the Emborough Quarry brickworks, Emborough (Murless 2000), did too. The Greyfield brickworks at High Littleton (OS 1900), also in the southwest of the hinterland area, may have used these Triassic sediments in the production of CBM, although the use of fireclay from the neighbouring mines, as at Cattybrook in the late 19th century (Richardson and Webb 1911), remains an alternate possibility.

The Mercia Mudstone Group clearly comprised an important regional resource for historic brickmaking in England. Despite this, there is little evidence for the exploitation of these clays in the Bath ETM area in either the historic or ancient periods.

### 6.2.3 Penarth Group

The Triassic Penarth group has historically, and even recently, had quite a confused nomenclature system (Gallois 2007, 2009). The scheme proposed by Gallois (2007, 2009) has here been adopted. The Penarth Group in the Bath region appears to comprise only three distinct units (Forster et al. 1985), namely the basal Westbury Formation, lower-middle Cotham Formation, and upper-middle White Lias Formation. It therefore lacks the upper Watchet Mudstone Formation observed more widely on the Somerset and North Devon coasts (Gallois 2007, 2009). Of these units only the Westbury and Cotham mudstones are of relevance here, the White Lias being known instead as the source of a good-quality pale limestone (HE 2017a). These Triassic mudstones are stratigraphically above the Mercia Mudstone Group deposits in the Bath region, but stratigraphically below the Lias Group (figure 6.3), and are each only 3-4m in thickness (Forster et al. 1985, Gallois 2009). In the Bath ETM area, the Penarth Group strata outcrop in the same few locations as those of the Mercia Mudstone Group. The nearest outcrops are therefore 3.5km to the west of the Roman Baths, just south of Newbridge (figure 6.1). The BGS (2020b) mapping also indicates greater exposures further west, into the wider hinterland area (figure 6.2). The basal Westbury Formation consists of dark grey to black laminated mudstones, weathering to a very dark clay, with occasional dark grey limestone bands and thin beds of calcareous sandstone (Gallois 2009, Forster et al. 1985). The higher Cotham Formation consists of greyish-green mudstone with thin bands of interbedded limestone and sandstone (Forster et al. 1985, Gallois 2009) and at the top of the formation the famous ‘Cotham Marble’, a thin pale algal limestone with mammilated or vermiform upper surface (Forster et al. 1985, HE 2017a).

The Westbury and Cotham Formations are not used in modern brickmaking in the UK. This is presumably because it is more economic to exploit other Triassic deposits, particularly the Mercia Mudstone Group, in any regions where they occur. Similarly, these mudstones do not appear to have been exploited to any significant degree in historic ceramic manufacture in the Southwest of England. Richardson and Webb (1910: 277) note that they were ground up and mixed with Keuper Marl (i.e. Mercia Mudstone Group clays) for brickmaking at the Glen Parva brickworks in Wigston, Leicestershire, during the early 20th century, although no Gloucestershire brickmakers were actually recorded as using these clays (Richardson and Webb 1910). Woodward (1876: 146) notes only that Penarth Group rocks were exploited for lime-making or occasionally in the marling of fields, confirming that these sediments were probably not used in any quantity in brickmaking. While this does not preclude the use of these mudstones in ancient CBM manufacture at Bath, it does indicate that their usage is unlikely, especially when more suitable and more extensive deposits were widely available.

### 6.2.4 Blue Lias Formation

The Lower Jurassic Blue Lias Formation comprises the basal unit of the Lias Group. It is therefore stratigraphically above the uppermost formation of the Penarth Group, specifically the White Lias, and below the Charmouth Mudstone Formation (figure 6.3). Within the Bath ETM area it has relatively few surface exposures, although it outcrops more extensively in the western half of the Bath hinterland. It comprises much of the Avon valley floor (Forster et al. 1985) and is therefore largely concealed by the stratigraphically later Charmouth Mudstone Formation and by the extensive alluvial and colluvial sediments at Bath (Forster et al. 1985). The closest outcrop of the Blue Lias Formation to the Roman Baths is only c.1.6km to the northwest at Lower Weston (BGS 2020a, figure 6.1). More extensive exposures occur within the bounds of the ETM radius further to the west beyond Corston, continuing into the wider hinterland area.

The Blue Lias Formation consists of interbedded argillaceous limestone and calcareous mudstones or siltstone in the Bath area (Cox et al. 1999). The limestone is thinly-bedded throughout the formation, at a maximum of 0.3m thick (HE 2017a), and the ratio of limestone to mudstone varies from approximately 1:1 to 1:4 or more (Forster et al. 1985: 22), with the limestone comprising approximately 40% of the total succession

(Hobbs et al. 2012: 22). The mudstones of the Blue Lias are mid to dark grey, variably calcareous and can be laminated and bituminous, weathering to paper shales (Forster et al. 1985, Cox et al. 1999). It is unclear to what extent the Blue Lias Formation mudstones have previously been used in ceramic manufacture at Bath and in adjacent counties, as traditionally this formation was exploited instead for its limestones, whether for building, road construction or in lime and cement-making (HE 2017a, Hobbs et al. 2012). While other Lias Group mudstones have been widely recorded as being quarried for historic brickmaking in the southwest of England (e.g. Woodward 1876, 1893, Richardson and Webb 1910), brickyards exploiting the Blue Lias itself are seldom mentioned. It is therefore likely that co-occurring stratigraphically later formations were exploited in preference.

### 6.2.5 Charmouth Mudstone Formation

The Lower Jurassic Charmouth Mudstone Formation, previously known as the Lower Lias Clay (Cox et al. 1999: 10), outcrops significantly in the Bath hinterland. It is a member of the Lias Group and is positioned stratigraphically above the basal Blue Lias Formation and below the Dyrham Formation (Forster et al. 1985, Cox et al. 1999, figure 6.3). The Charmouth Mudstone Formation consists largely of dark to pale or bluish grey mudstones and laminated shales, with sporadic beds of argillaceous limestone (Cox et al. 1999). Locally, the upper mudstone parts of the formation have been observed to be silty, micaceous and pyritous, with occasional clay-ironstone nodules (Forster et al. 1985: 23). The formation ranges in depth from 12-110m at Bath (Forster et al. 1985: 17), and outcrops widely within the 7km radius of the ETM (figure 6.1). In the Bath hinterland area its outcrop is much more restricted, being exposed only in the centre and southwest along parts of the floor and lower slopes of the Avon valley (Forster et al. 1985), particularly around Weston and South Twerton. The nearest outcrop is therefore close to the Roman Baths, with the BGS (2020a) survey indicating exposures of the Charmouth Mudstone Formation only 200m to the northwest and continuing to Walcot and beyond.

Today the formation is only quarried for brickmaking at Wellacre Quarry in northeast Gloucestershire (Bloodworth et al. 2007, Hobbs et al. 2012), however in the past it was significantly exploited both regionally and locally. In Dorset, the Charmouth Mudstone Formation appears to have predominantly been used in ceramic building material manufacture at Lyme Regis (Woodward 1893: 298). By contrast, it was utilised throughout southern and eastern Somerset during the late 19th century, including at Butleigh, near Street (Woodward 1893), at several works around Glastonbury (Murless 2000), at North Barrow and Hornblotton Mill, near Castle Cary (Woodward 1893), at the Somerset Pipe, Tile and Brick Works at Evercreech, Shepton Mallett (Woodward 1893), at Monger, Midsomer Norton (Woodward 1893) and probably also at Meadgate Brickworks, Red Hill, Camerton (Murless 2000). In Gloucestershire the deposits were also heavily exploited for brickmaking, for example at the Atlas Works, between Stroud and Stonehouse (Richardson and Webb 1910), at the Cotswold Potteries Ltd. in Leckhampton, Cheltenham (Richardson and Webb 1910), at Battledown Brickworks, Cheltenham (Richardson and Webb 1910), and at brickyards near Hempsted and at Hucclecote, near Gloucester (Woodward 1893). Even beyond Gloucestershire the formation was often exploited, being used in historic brickmaking in Oxfordshire and at sites across the Midlands (Woodward 1893, Hobbs et al. 2012).

Of the few known historic brickworks within the Bath ETM area, all appear to have exploited the Charmouth Mudstone Formation. The Victoria Brickworks in South Twerton (Murless 2000), the Moorfields Brick Works and its successor the Moorlands Brickworks (Harper 1989) all appear to have extracted clay on site, and all are situated on Charmouth Mudstone Formation deposits. A further possible brickworks at Bath, the 'brick kiln fields' labelled on a mid-18th century map just west of the Avon at Dolemeads (Chapman et al. 1998), has left little trace of any clay exploitation. This perhaps implies clay was imported to the site, although in-situ extraction appears more probable. Indeed, given the later development of the area into a canal lock system it is possible that any evidence of exploitation could have been destroyed by subsequent landscaping. As the site is located close to another exposure of Charmouth Mudstone it may therefore represent an earlier episode of clay extraction at Bath, although the use of nearby alluvial sediments remains an alternative.

There is limited evidence for Roman clay extraction in Bath, but a possible Roman claypit was identified during excavations at the Old Walcot School in Walcot (Beaton 2001), being dug into Charmouth Mudstone deposits. A nearby tentatively identified Roman pottery or tile kiln excavated at St Swithin's Yard, Walcot (Bradley-Lovekin 2001), is also sited on these deposits. It is an interesting parallel that a Roman pottery kiln found at Shepton Mallett has also been suggested to have exploited the Charmouth

Mudstone Formation (Scarth 1866, Haverfield 1906), perhaps indicating a wider awareness of this resource even in the Roman period.

There is significant evidence for the historic use of Charmouth Mudstone deposits in CBM manufacture at Bath, although the evidence for its use in ancient ceramic industries is more restricted. While the Charmouth Mudstone Formation has been used very successfully in both historic and modern CBM manufacture (Hobbs et al. 2012, Bloodworth et al. 2007), Richardson and Webb (1910: 246) do note that the clay is very 'strong' and can significantly shrink and disfigure during firing without sufficient temper. This is reinforced by Hobbs et al. (2012: 44), who emphasise the significant shrink-swell potential of Lias Group clays from southern England. However, with sand or other non-plastic tempers added in sufficient quantities the deformation may be lessened and "a very good brick can be produced" (Richardson and Webb 1910: 246), by historic standards at least. Clearly, the Charmouth Mudstone Formation constitutes a highly significant clay resource in the Bath ETM and hinterland areas, and one that may well have been employed in CBM production for the Roman town.

### 6.2.6 Dyrham Formation

The Dyrham Formation, previously known as the Dyrham Silts or Middle Lias Sandy Beds (Cox et al. 1999: 12) is part of the Lias Group. As its old title suggests, it sits near the middle of the group, stratigraphically above the Charmouth Mudstone Formation but below the Beacon Limestone Formation and the Bridport Sand Formation (figure 6.3). Unlike other members of the Lias Group, it outcrops only a little in the Bath region, and appears largely obscured by landslips. Forster et al. (1985: 24) has identified outcrops of the deposit predominantly around North Stoke, to the northwest of central Bath and just within the 7km resource radius (figure 6.1). The BGS (2020a) survey indicates closer exposures north of Walcot, particularly along the cutting of the Lam Brook, though much of this is likely concealed by colluvium.

The Dyrham Formation comprises pale to dark grey, bluish- or greenish-grey micaceous silty and sandy mudstone, weathering to brown or yellow in colour (Forster et al. 1985, Cox et al. 1999). While not used in modern brickmaking in England, it was historically exploited at a range of sites in adjacent counties (Woodward 1876, 1893). This includes Gloucestershire, where in the late 19th and early 20th centuries the formation was used at the Stonehouse Brick and Tile Company at Stonehouse, the Robinswood Hill Brick and Tile Works in Gloucester and the Aston Magna Brick and Terracotta works at Aston Magna (Richardson and Webb 1910). While all of these brickworks have long since closed down, with the Stonehouse Brick and Tile Company the last to shut in 1968 (Wilson 1997), several of the old quarries for these works have now been assigned as type sites or reference sections for the Dyrham Formation (e.g. Cox et al. 1999: 12-13).

This clay source was also probably exploited in brickyards across south Somerset. As Woodward (1893: 201-207, 298) is the chief source for the geology of these sites, these assignations must be tentative. This is because Woodward (1876, 1893, 1894, 1895) tended to describe the entirety of sections and fossils exposed at claypits instead of the precise stratum being exploited or its physical characteristics, especially where they pertained to brickmaking, in the way that Richardson and Webb (1910, 1911) did so effectively. As such, it is entirely possible that the Dyrham Formation was exploited at various brickyards south of Ilminster, at New Cross and West Lambrook near South Petherton, at Mudford near Yeovil and in brickyards north of Glastonbury (Woodward 1893). However, it may well be that any or all of these actually dug the underlying deposits of the Charmouth Mudstone Formation.

As with many other local clay sources there is presently no evidence for the ancient or historic use of this formation in ceramic manufacture at Bath. Given its restricted outcrop in the Bath ETM area its local use in ancient ceramic manufacture is perhaps unlikely, especially given that many outcrops are partially or fully concealed by Pleistocene and Holocene landslips and cambering (Forster et al. 1985). There is, of course, potential for the Roman or prehistoric exploitation of exposures of the Dyrham Formation that have since been buried, although accessible exposures do still remain.

## 6.2.7 Bridport Sand Formation

The Lower Jurassic Bridport Sand Formation, previously known as the Midford Sands or Upper Lias Sands (Cox et al. 1999: 9), is part of the Lias Group. It lies stratigraphically above the other Lias Group deposits of the Beacon Limestone and Dyrham Formations in the Bath hinterland area (Forster et al. 1985, Cox et al. 1999), and below the Inferior Oolite Group (figure 6.3).

Locally, this formation outcrops higher up than the rest of the Lias Group sediments and is exposed in the lower-middle slopes of the Avon valley at Bath. The formation outcrops throughout the ETM area (figure 6.1), predominantly being exposed through the cuttings of the many tributaries that lead into the River Avon. These include, moving anti-clockwise from the southeast, the Newton Brook, the Cam and Wellow brooks, the River Frome, St Catherine's Brook, and Lam Brook. The most extensive outcrops of the Bridport Sand Formation lie to the immediate south of the city centre, with the BGS (2020a) survey indicating a broad surface outcrop stretching from Bathwick in the northeast to just south of Newton St Loe in the southwest. It is this band which provides the nearest outcrops to the Roman Baths, with exposures at Beechen Cliff, only 450m to the south, and on Bathwick Hill, around 700m to the east. Outside the boundaries of the ETM area the formation is largely buried by later sediments, although it is exposed in the wider hinterland to the north, outcropping between Bath and Dyrham, and by river cuttings around Colerne in the northeast.

The Bridport Sands comprise yellow-brown micaceous silt and fine-grained sand, locally with calcite-cemented beds and occasional more argillaceous deposits (Forster et al. 1985, Cox et al. 1999). Richardson and Webb (1910: 245) note the excellence of the lower argillaceous part of the Bridport Sands for historic brickmaking in southern Gloucestershire, perhaps surprisingly given its sand content. These sediments were probably used in brickyards at Brimscombe, at Rock Mill near Painswick, at Colesbourne and near Andoversford (Woodward 1893). The Bridport Sand Formation was also exploited for brickmaking in southern Somerset and in parts of Dorset, being used at sites around Yeovil (Woodward 1893, Osborn 2020) and to the north of Sherborne (Woodward 1893), at Lye's brickyard in Crewkerne (Woodward 1894, Richardson and Webb 1910), and at the Allington and Bradpole Yards in Bridport itself (Smith 2012).

While there is limited evidence for the use of the Bridport Sand Formation in historic brickmaking in the Bath ETM area, the formation appears to have been exploited for different purposes. Woodward (1894: 95) remarks that, according to a local Reverend, the calcareous sand immediately under the Inferior Oolite rock was used by cooks at Bath to scrub their kitchens. It was supposedly supplied from outcrops on the hills behind Camden Place, now Camden Crescent in Walcot, and at Sydney Gardens, across the river at Bathwick (Woodward 1894). This sand was of course from the Bridport Sand Formation, and the BGS (2020a) survey confirms that both locations are underlain or very close to these deposits. Given the high sand content of some of the CBM fabrics from Roman Bath, particularly local fabrics 3, 4 and 7 (Betts 1999a, Appendix B), and Richardson and Webb's (1910: 246) observation of the need to add temper to certain Lias Group mudstones, it is possible that the Bridport Sand Formation may have been used in the past at Bath as a source of temper for ceramic production. Its use as a clay source appears less likely.

### 6.2.8 Fuller's Earth Formation

The Middle Jurassic Fuller's Earth Formation comprises three constituents at Bath, namely the Lower Fuller's Earth, the Upper Fuller's Earth, and a dividing Fuller's Earth Rock member (Barron et al. 2012). All are discussed together here. The Fuller's Earth Formation is part of the Great Oolite group, and is therefore stratigraphically above the Inferior Oolite Formation, and underlies the limestone of the Combe Down and Bath Oolite Members (figure 6.3).

Commercial fuller's earth, i.e. clay with a very high smectite-group and particularly montmorillinite mineral content (Highley et al. 2006: 1), was traditionally used in the cleaning or 'fullering' of wool. Misleadingly, this comprises only a thin band in the Upper Fuller's Earth member at Bath (Barron et al. 2012). These true fuller's earth deposits are up to 3.3m thick (Highley et al. 2006: 3) and are only present to the south of the city (Forster et al. 1985). They were mined extensively at Combe Hay, Odd Down, South Stoke, Midford, Lyncombe, Widcombe and Wellow (Woodward 1894), however the last commercial Fuller's Earth mine at Bath closed in 1979 (Macmillan and Chapman 2009). The Fuller's Earth Formation otherwise consists largely of grey, variably calcareous silicate-mudstone, with units of thinly interbedded shelly limestone (Forster et al. 1985, Barron et al. 2012).

The BGS (2020a) survey indicates that the closest outcrops to the Roman Baths occur at the top of Beechen Cliff, only 700m to the south of the site. In the ETM area there are more extensive surface outcrops in the upper slopes of the heights surrounding the city, particularly at Bathampton Hill, Odd Down, Lansdown, Charmy Hill and Banner Down (figure 6.1). Beyond the ETM area, in the wider Bath hinterland, the Fuller's Earth Formation outcrops only sparsely to the north and northeast.

While it seems unlikely that true fuller's earth was ever used in ceramic manufacture, being reserved instead for wool processing and other specialist purposes (Forster et al. 1985, Highley et al. 2006), the accompanying mudstone may have proved suitable. Indeed, in counties to the south the Fuller's Earth Formation was used in historic brickmaking, for example in Dorset at Toller Porcorum, near Maiden Newton, at Broadwindsor, near Beaminster, and Bradford Abbas (Woodward 1894), as well as at several yards in or near Bridport (Smith 2012). In Somerset, Fuller's Earth was used in brickyards at Crewkerne, Haselbury Plucknett and at Maperton, Wincanton (Woodward 1894), as well as within the southeast of the Bath hinterland area at Mells, near Frome (Woodward 1894: 492). Although Richardson and Webb (1910: 243) note that the Fuller's Earth was used for brickmaking in Gloucestershire until the 1880s, they suggest no claypits or brickyards which exploited these deposits. This probably implies it had little importance as a resource for brickmaking in that county, and this is likely also true of the Fuller's Earth deposits to the north of Bath.

While there is significant evidence for the successful use of Fuller's Earth in historic brickmaking in Dorset and Somerset, its use in the Bath ETM area appears limited. Although sometimes asserted (e.g. Highley et al. 2006, Macmillan and Chapman 2009) that exploitation of the true Fuller's Earth at Bath began in the Roman period, the evidence is rarely elaborated, though doubtless many traces would have been destroyed by later mining. If indeed exploited at Bath during the Roman period, then waste clay could have been utilised in ceramic production. As this was not the case at Bath during later periods of significant mining, it might imply that the mudstone itself is locally not suited for brickmaking, as in Gloucestershire (Richardson and Webb 1910).

### 6.2.9 Forest Marble Formation

The Forest Marble Formation is principally known for its limestones and calcareous sandstones, used for rubble walling and roughly dressed ashlar masonry (HE 2017a). Despite this, it is very variable and can also comprise greenish-grey calcareous mudstones and clays (Forster et al. 1985, Barron et al. 2012), so has been included here.

The Forest Marble Formation is part of the Middle Jurassic Great Oolite Group (figure 6.3), and at Bath is stratigraphically above the Chalfield Oolite Formation, and more specifically the Bath Oolite Member, and below the Cornbrash Formation (Forster et al. 1985, Barron et al. 2012). At Bath, the BGS (2020b) mapping shows comparatively limited outcrops of Forest Marble on several of the heights to the south and east of the city, including on Bathampton Down and around Combe Hay (figure 6.1). It outcrops more prominently in the eastern and southeastern limits of the ETM area, in a sweeping band from Bathford and Monkton Farleigh to Bradford on Avon and Limpley Stoke. These outcrops comprise just a small part of an extensive north-south running exposure which encompasses much of the eastern half of the hinterland area. This runs from beyond Badminton, Gloucestershire, in the north of the hinterland to Frome in Somerset in the south.

There is very limited evidence for the use of this formation in historic CBM manufacture at Bath and in adjacent counties. Woodward (1894: 493) notes the use of Forest Marble mudstones in brickmaking in parts of Gloucestershire and Oxfordshire, notably at Siddington near Cirencester, at Badminton and at Blackthorn near Bicester, Oxfordshire. In contrast, Richardson and Webb's (1910: 242) slightly later account asserts that they could not find any brickyards in Gloucestershire exploiting the Forest Marble. This implies either that these sites had closed down in the intervening period, were omitted by accident or that Woodward's (1894) identifications of the quarried deposits had simply been wrong. The BGS (2020c) survey does indicate that the Forest Marble Formation underlies all three areas, but at Siddington and Blackthorn much more substantial and accessible outcrops of the Oxford Clay Formation also occur. As Richardson and Webb (1910: 242) recorded the exploitation of Oxford Clay at Siddington and nearby South Cerney, this likely indicates that Woodward (1894) misidentified the deposits or received incorrect information, and this may also be true of the other sites. In any case, it seems that exploitation of the Forest Marble for brickmaking in the counties adjacent to Bath was very restricted, especially compared to the apparently popular Lias Group mudstones.

More locally, there is very little evidence for its use in ceramic manufacture in the Bath ETM region. In the wider hinterland, a kiln site and brickfield in Frome recorded on historic maps (OS 1880) was situated on Forest Marble. The label 'brickfield' strongly suggests the digging of clay on site, although it could perhaps be interpreted in the sense of a work area for making and drying CBM. Either way, no extraction pits were recorded on the map and the area was later infilled by housing developments. The use of Forest Marble at this site is therefore impossible to verify, although if indeed quarried it would serve to indicate very limited localised use of this resource when necessary.

Although present in the Bath ETM area, the potential for ancient use of the Forest Marble mudstones therefore appears small, especially given the abundance of other suitable clay resources locally.

### 6.2.10 Kellaways and Oxford Clay Formations

The Kellaways and Oxford Clay Formations, dating to the very end of the Middle Jurassic, are treated together. The Kellaways Formation comprises both a basal Kellaways Clay Member and an upper Kellaways Sand Member at its nearby typesite at Kellaways in Wiltshire (Barron et al. 2012: 93), just 3km northeast of the upper boundary of the Bath hinterland. Despite this, the BGS (2020b) survey shows the formation as undifferentiated in the Bath hinterland area. As Forster et al. (1985: 28) note, this is likely due to the shallowness of the local outcrops, at only 1.37m deep in boreholes taken near Whitley. In contrast, the Peterborough Member of the Oxford Clay is estimated to be around 20-25m thick locally (Forster et al. 1985: 28, Barron et al. 2012: 93). Although not present within the 7km radius of the ETM, both formations outcrop in the east and southeast of the Bath hinterland area (figure 6.2), although only the lower Peterborough Member of the Oxford Clay Formation is present (Forster et al. 1985). They have been included in this survey as both have been utilised in historic CBM manufacture in adjacent counties. The Peterborough Member of the Oxford Clay, in particular, dominated brick production in England for much of the 20th century (Bloodworth et al. 2007: 8).

The Kellaways Formation is stratigraphically above the Great Oolite Group (figure 6.3), and specifically above the Cornbrash Formation (Forster et al. 1985). The Oxford Clay Formation, in turn, is stratigraphically above the Kellaway Formation, and the lower Peterborough Member of the Oxford Clay sits directly on the upper Kellaways Sand member (Barron et al. 2012). Both formations outcrop to the east of the hinterland area in discontinuous bands stretching from Chippenham, in the northeast, to Frome, in the southwest (figure 6.2). The BGS (2020b) survey indicates that the closest substantial outcrops of the Kellaways Formation to Bath are therefore 9km to the southeast, just south of Bradford on Avon. The closest Oxford Clay outcrops to Bath are 13km to the east, around Whitley, and 13km to the southeast, around Trowbridge.

The Kellaways Formation predominantly comprises grey silty mudstones with intermittent beds of calcareous siltstone or sandstone, particularly in the upper part (Foster et al. 1985, Barron et al. 2012). It is not used in modern brickmaking in the West of England and is unlikely to be used in other regions of Britain today. It was once used for CBM production at Putten Lane Brickworks at Chickerell, near Weymouth, Dorset, in the mid-19th century (Smith 2012: 90), and in historic brickmaking at Upper Studley, near Trowbridge in Wiltshire (Woodward 1895: 19). More widely, Woodward (1895: 322-3) recorded its use at brickyards in Northamptonshire, Cambridgeshire, and Oxfordshire, and observed that bricks made from the sandy beds of the Kellaways Formation were superior to those of the Oxford Clay, being more refractory (Woodward 1895: 323). As such, it is clear that the Kellaway Formation was sometimes locally and regionally exploited.

This limited local exploitation also appears true of the Bath hinterland, which demonstrates some evidence for the historic use of the Kellaway Formation in brickmaking at Rode near Frome. Here, successive brickyards were recorded on a 1792 enclosure map and on the 1839 tithe map (Murless 2000). The BGS (2020b) survey indicates that these sites are underlain by the Kellaways Formation, implying that it was this formation which supplied them.

While outside of the Bath hinterland area, the Roman kiln site of Minety in north Wiltshire may also have used the Kellaways Formation in the production of ceramic building materials. While Scammell (n.d.: 4) assigned the underlying deposits to the Oxford Clay Formation, the BGS (2022b) survey presently indicates that the site is located on an exposure of the Kellaways Formation, although the Oxford Clay is present only 350m to the southeast. Alluvial deposits from the Brayden and Swill Brooks, to the immediate north and west of the site, are also present. Despite evidence of significant ancient excavation on site (e.g. McWhirr 1984: 42), Scammell (n.d.: 4) insisted that clay from Triassic and Lias Group sources was probably imported and used in preference, citing the range of red and yellow hues and streaking present in the fired brick and tile (Scammell n.d.: 12). Given the distance to the alternate proposed sources, which the BGS (2020c) survey indicates are all *at least* 13km to the northeast, this seems extremely unlikely. It is therefore reasonable to assume that Kellaways Formation clay and/or Oxford Clay comprised the raw materials of this kiln site. Indeed, the streaking observed (Scammell n.d.: 12) may be the product of blending of different clays, perhaps the alluvial sediments with the local Middle Jurassic deposits. This site is particularly relevant to the study of the hinterland resources as various Roman relief-patterned tiles from Bath have been identified as possible products of the kilns at Minety (Betts et al. 1997: 23-24, section 7.1.1), and its products have also been identified in assemblages from Cirencester (Darvill 1986, 1998) and Silchester (Machin 2018, Fulford and Machin 2021).

While used successfully in brickmaking (Woodward 1895), the close stratigraphic and spatial relationship of the Kellaways Formation to the Oxford Clay Formation (Barron et al. 2012) probably caused this deposit to be under-utilised in preference to the Oxford Clays. This favouritism does not appear to be due to any inherent deficiencies of the formation when used in ceramic production (Woodward 1895). Instead, it is more likely due to the special firing properties of the competing clays. The Peterborough Member consists of dark or brownish-grey silicate mudstone which can be very organic rich, bituminous, and shaly with fossil-packed partings (Forster et al. 1985, Barron et al. 2012). Its popularity in brick manufacture, exponentially increasing in the late 19th century (Hillier 1981), is partially due to the presence of this carbonaceous matter, which combusts when the clay is fired and allows for significant savings in fuel (MIA 2013, BLGG 2020). A limitation of traditionally made 'Fletton' bricks of Oxford Clay (Hillier 1981) is that they have a low compressive strength compared to other modern bricks (MIA 2013: 3) and are potentially more susceptible to weathering (BLGG 2020: 2). It is unclear if this is due to the material properties and special firing process of the Oxford Clay or can instead be attributed to the traditional processes of semi-dry moulding (Bloodworth et al. 2007) and usage of freshly dug and unseasoned clay (BLGG 2020).

The Oxford Clays were most heavily exploited in historic brickmaking in the east of England, and particularly in Cambridgeshire and Bedfordshire (Woodward 1895, Bloodworth et al. 2007). Yet, they were also used in Dorset (Smith 2012), Gloucestershire (Richardson and Webb 1910), Wiltshire and, as the name suggests, around Oxford (Woodward 1895). In Dorset, the Peterborough Member was used at

Bothenhampton Yard in Bridport during the early 19th century (Smith 2012) and at brickyards in West Chickerell, near Weymouth (Woodward 1895). In Wiltshire, Woodward (1895: 28-31) noted brickworks at Chippenham, Purton, and Ashton Keynes, and in the Vale of Chippenham to Oxford more generally, all exploiting the lower Oxford Clays around the turn of the 20th century. Although outcrops of the Oxford Clay are more restricted in Gloucestershire, Richardson and Webb (1910: 242) recorded its use by the Cirencester Brick and Tile Company at Siddington, as well as at other brickpits in the South Gloucestershire area. To give an indication of these resources' importance in later brickmaking, the London Brick Company's peak output during the 1930's was 1.75 billion bricks a year (Hillier 1981: 37), all using Peterborough Member clays. The importance of this industry and its clay resource has nevertheless significantly declined (Hillier 1981, BLGG 2020), although there is still production using the Oxford Clays at three large sites in the east of England (Bloodworth et al. 2007: 8).

In the Bath hinterland there is little evidence for the use of the Oxford Clay Formation either historically or anciently. Outside the hinterland area, this formation may have been used at the Roman kiln site of Minety (Darvill 1979) in northwest Wiltshire, perhaps in combination with Kellaways Formation clay or alluvial sediments. While the Kellaways and Oxford Clay Formations ultimately lie outside the ETM radius of Bath, although in its hinterland, they represent a potentially significant regional clay resource.

# 6.3 Quaternary Deposits

## 6.3.1 Alluvium

The alluvial deposits in the valley floors of the Bath ETM area are considerable (Forster et al. 1985), being the product of high floods of the River Avon (Jordan 2007). They have been recorded at several Roman sites in and south of the walled area of Bath (Cunliffe 1969, 1979), including the New Royal Baths site (Davenport et al. 2007) and the Southgate excavations (Barber 2015). These deposits have a basal layer of gravel, with flint and limestone cobbles and sand (Forster et al. 1985), but an upper layer of greyish-brown silty clay, grading to yellowish or reddish brown in colour in some parts, and occasional iron-staining and brown mottling (Jordan 2007: 11, Davenport et al.

2007: 14). Forster et al. (1985: 31) note that the river gravel components of these sediments locally contain elements of their parent rocks. The aplastic inclusions typically seen in the Roman Bath CBM fabrics, for example sand, limestone and fossil shell fragments (Betts 2011, Appendix B), might therefore have been sourced from alluvial deposits instead of being quarried from landslips or from the in-situ Jurassic parent rock.

In adjacent regions alluvial sediments were heavily exploited for brickmaking, most famously at Bridgwater and Sedgemoor, Somerset (Baggs and Siraut 1992, Murless 2000), where alluvial deposits of the River Parrett supplied a thriving brick and tile industry during the 19th century (Murless 2000). Alluvial sediments were once widely dug for brickmaking by the River Severn in Gloucestershire (Richardson and Webb 1910: 239), although by the early 20th century only the brickyards at Lower Lode, Walham, north of Gloucester, remained. In Dorset, Smith (2012: 85-6) has suggested the historic exploitation of sediments from the River Wrackle at brickyards in Ash Hill, Stratton, near Dorchester and those of the River Frome in clamp kilns at Throop Farm, also near Stratton. Within the Bath ETM area itself there is much more limited evidence for the use of Avon alluvial sediments in historic or ancient ceramic manufacture. The previously noted 18th century brick-kiln fields west of the Avon at Dolemeads (Chapman et al. 1998), only 500m to the southeast of the Roman Baths, may have exploited Avon alluvial sediments. This is just one possible clay source, however, with the Charmouth Mudstone Formation also outcropping very close to the site. Furthermore, without firm evidence of extraction, the importation of clay to the site remains a possibility.

More significant to the study of Roman clay extraction at Bath is the identification of a large but shallow Roman-period hollow dug into alluvial sediments at James Street West (Lewcun 2004), only 350m to the west of the Roman Baths. This depression yielded intermixed clays from several clearly discrete components, demonstrating several different colours, physical properties, and evidence of heating. Lewcun (2004: 8) has suggested this to be the result of industrial activity. While these deposits cannot be firmly linked to brick and tile manufacture (Lewcun 2004), and may instead be the remnants of the production of pottery, of technical ceramics or the mundane preparation of clay for puddling or daub or cobb, they nevertheless provide some evidence for the use of alluvial sediments in the Roman period at Bath.

### 6.3.2 Colluvium

The colluvial deposits in the Bath ETM area are numerous and extensive. The BGS (2020a) survey indicates that they occur almost universally at the base and on the sides of the valley slopes around the city, with the nearest only 500m to the south of the Roman Baths at Beechen Cliff. Another close landslip deposit is that at Walcot, 700m to the north of the site. This colluvium is the product of the landslipping or cambering of Lower-Middle Jurassic strata (Forster et al. 1985), particularly the Inferior and Chalfield Oolite Formations, which is exacerbated by the instability of the underlying Lias Group strata (Hobbs et al. 2012: 66).

The colluvial deposits at Bath incorporate weathered material from a range of different geological units, including the Lower and Middle Jurassic Charmouth Mudstone, Bridport Sand, Inferior Oolite, Fuller’s Earth and Chalfield Oolite Formations (Forster et al. 1985). They are therefore varied in character and dependent upon the specific local source deposits but are generally rocky and unsorted (Forster et al. 1985). While many of the landslipped units incorporate mudstones, the stony nature of much of the colluvium indicates that their use in ceramic production would perhaps require more intensive sorting and processing than with other available clays. In turn, this might imply that they are perhaps less likely to have been used in ceramic production at Bath. Indeed, these deposits were not used in historic CBM production at Bath, and unlike the alluvial sediments in the ETM area there is no evidence of their exploitation in the Roman period either.

The use of clay in the past is obviously dependent on many more factors than simple processing requirements. The range of deposits practically accessible, the possible importance of the co-occurrence of water, fuel, clay and/or temper resources at these locations (Miksa and Heidke 1995, Kelly et al. 2011), the suitability of the clay for creating the desired product (Arnold 1985), as well as less economically-oriented concerns, such as land ownership and access restrictions (Arnold 1985, 2000) or ritual connotations to specific deposits (Arnold 1985, 2011) will all have played their part. Nevertheless, the greater need for raw material processing could have proved significant. It must be acknowledged that as these deposits incorporate fragmented material from a wide variety of Jurassic rock units, they could also have provided an easy and close supply of aplastic temper for any ceramic production taking place on the floor or lower slopes of the Avon valley.

## 6.4 Chapter Conclusion

The range of mudstone and clay deposits accessible within the Bath exploitable threshold model radius and hinterland areas is considerable. Comparatively few demonstrate substantial evidence for widespread historic exploitation either at Bath or in adjacent areas or counties, particularly Dorset, Somerset, Gloucestershire, and Wiltshire. When the evidence for ancient exploitation of these deposits in the Bath ETM area is inspected, this number is reduced even further. Indeed, the only strata outcropping at Bath which demonstrate firm evidence of Roman exploitation are the Charmouth Mudstone Formation and Quaternary alluvial sediments. Even these are each confined to a single extraction pit (Beaton 2001, Lewcun 2004), neither of which can be definitively linked to the production of fired ceramics, much less ceramic building material specifically. Despite these limitations, the significant historical evidence for the successful use of each of these deposits in brick and tilemaking at Bath (Harper 1989, Murless 2000) or in adjacent counties (Woodward 1893, Richardson and Webb 1910, Murless 2000) argues in favour of their possible exploitation in Roman ceramic industries at the settlement.

# 7 Ceramic Building Materials from Roman Bath

Despite research having been conducted in the city itself (e.g. Foster 1985, Betts 1999a, b, 2007, 2015), and significant attention devoted to assemblages from neighbouring Gloucestershire and northwest Wiltshire (Clifford 1955, McWhirr and Viner 1978, Darvill 1979, 1980, 1982, 1998, 2001, Darvill and McWhirr 1984, Warry 2017), the understanding of the ceramic building materials from Bath is far from complete. While a range of fabric groups have been identified, with the exception of a few long distance imports no production sites have yet been matched to this material. A range of relief-patterned tile has also been excavated and analysed and while this material could have been manufactured at Minety, it may instead be the result of production closer to Bath. Intriguingly, very little stamped CBM has yet been recovered from the settlement or its hinterland, despite the frequency of examples to the north and east. This absence likely reflects systemic trends of ancient use and deposition, rather than a lack of archaeological investigation in the Bath area. As such, the limited stamped CBM from the city and hinterland is significant and may be the result of economic factors, for example the dominance of the Bath market by local brickyards during the main period of regional stamping, or may be due to administrative concerns, perhaps with specific stamps reserved for brick and tile supplied to certain areas.

## 7.1 Overview

Ceramic building materials from the Temple Precinct excavations were analysed by Foster (1985, Appendix A). More recently, Betts (1999a, b, 2002a, b, 2007, 2015) has analysed the brick and tile from a range of commercial excavations in the city. The two recording systems are difficult to relate to each other, but Betts's (2015) work provides the best understanding of CBM supply and use at Bath. To summarize, 12 different Roman CBM fabrics have so far been identified (Betts 2015, Appendix B). Of these, fabrics 8, 17, 18 and 23 were equated to MoLA fabrics 3019, 3006, 2452 and 3004 respectively (Betts 2011: 1); these are shaded in grey in table 7.1. Fabrics 17, 18 and 23 represent probably local products that are fairly undiagnostic in character and inclusions (Betts 2021, pers. Comm.) and thus appear similar to several generic sandy MoLA fabrics (e.g. Betts 2018: 5, 7-8), rather than representing definite London-region exports. In contrast, fabric 8 was likely produced at a kiln site in Hampshire, perhaps Braxell's Farm or Little London (Betts 2018: 5), both of which are situated upon London Clay outcrops (BGS 2021a, b). The overall contribution of long-distance imports to CBM assemblages from Bath may therefore be small. The bulk of the other fabrics have no identified production sites but may be local, although perhaps representing the products of three or more different kiln sites (Betts 1999a: 64). A range of products were made in each of these fabrics, including bricks, roofing tiles, box flue and hollow voussoir components.

**Table 7.1: Summary of Betts's (2011) Roman CBM fabrics found at sites in Bath. P represents possible identification. The suburban villa category consists of sites located only a short distance away from Roman Bath, but outside the bounds of the walled area and settlement at Walcot. Fabrics equated to different MoLA fabric groups (Betts 2011: 1) have been shaded grey.**

| Context | | | CBM Fabrics Present | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Site** | **Site Date** | **Area** | **1-4** | **5** | **6** | **7** | **8** | **9** | **16** | **17** | **18** | **23** |
| Lower Common Allotments | Late | Suburban Villa | Y | Y | P | Y | Y | Y | Y | | | |
| Oldfield Boys School | Late | Suburban Villa | Y | Y | | Y | | | Y | Y | | |
| Tramsheds and Beehive Yard | Early to unknown | Walcot Settlement | Y | | Y | Y | | Y | Y | Y | Y | |
| Hat and Feather Yard | Early to Late | Walcot Settlement | Fabric analysis not completed | | | | | | | | | |
| New Royal Baths | Early | Walled Area | Y | Y | | Y | Y | Y | Y | Y | Y | P |
| Southgate | Unclear | Walled Area | Y | Y | | Y | | Y | Y | Y | Y | Y |
| St Swithin's Yard | Mid to Late | Walcot Settlement | Fabric analysis not completed | | | | | | | | | |

Few ceramic building material kilns have been confirmed locally or regionally (McWhirr 1979, Betts 2015), although there are a range of possible production sites (section 6.0). At Walcot Street a potential Roman tile or pottery kiln was found during commercial excavations by the Bath Archaeological Trust (Davenport 2008b: 419) and scatters of roofing tiles and batches of mixed alluvial clays found at St James Street West (Lewcun 2004: 8), in the walled area, may indicate that another workshop was somewhere in the vicinity. While Minety remains the only confirmed kiln site with relevance to Bath, especially given its significant export market (McWhirr and Viner

1978, Warry 2017), there is perhaps a closer Roman kiln site opposite Tracey Park, Wick in Abson, South Gloucestershire (McWhirr 1979: 108-109). The site has yielded large quantities of hypocaust and roofing tiles and wasters (HER 2020a) and features perhaps indicating claypits and kiln structures may also be present (HER 2020b). Despite being identified more than 50 years ago, no material appears to have been collected and it is unclear if any excavations were undertaken to substantiate these claims. As such, although a range of *possible* production sites have been identified for the Bath material, only Minety has so far yielded significant evidence for manufacture (e.g. Scammell n.d.).

### 7.1.1 Relief-patterned Tile from Bath

A range of relief-patterned tile has been recorded from excavations in Bath and the hinterland area. The die types represented from finds in the city include Betts et al.'s (1997) types 25, 53, 54 and 56 (figure 7.1), and these occur in fabrics 2, 4, 7 and 16 (Betts 1999a: 68, 1999b: 5, 2002: 2, 2007: 53), i.e. those of presumably 'local' manufacture. A die 53 stamped sherd was also found in a post-Roman context in the Temple Precinct excavations (Cunliffe and Davenport 1985: 76, plate LXVII). In spite of this range of finds, only a single relief-patterned tile is known from Bath's hinterland area, and this is a type 56 die from a villa at Truckle Hill, North Wraxall, Wiltshire (Betts et al. 1997: 118).

With the exception of die 54, all of these relief-patterns have either been linked to Minety through fabric analysis of roller-die stamped sherds at other sites (Betts et al. 1997: 23) or have actually been found as fragments at the kiln site itself (Scammell n.d.: 15). Even die 54 co-occurs with confirmed Minety products impressed with die 56 at the Roman settlement site of Lower Wanborough, Wiltshire (Betts et al. 1997: 118-120). Fabric descriptions of Minety brick and tile (e.g. Darvill 1979: 318, Betts et al. 1997: 23) do admittedly sound similar to the fabrics identified at Bath (appendices A, B), particularly in the occurrence of cream silty bands and inclusions and fragments of iron oxides (Betts 2011: 1). However, these features are present in many different sedimentary deposits (e.g. Peacock 1977: 237, Betts and Foot 1994: 21-22), and thus do not solely indicate Minety products. While a range of hollow voussoir tiles have been identified at Minety (Scammell n.d.: 14), none have yet been found that appear to correspond to the dimensions of those used at the Roman Baths (e.g. Davis 1884: 14, Lancaster 2012: 430). Moreover, the mica in Betts's (2011: 1) fabric 16 contrasts with typical descriptions of Minety products (e.g. Darvill 1979: 318-319). This suggests either that the full range of Minety fabrics and products remains to be identified or that these relief-patterned stamps indicate the movement of craftsmen and roller dies to another production site, perhaps closer to Bath.

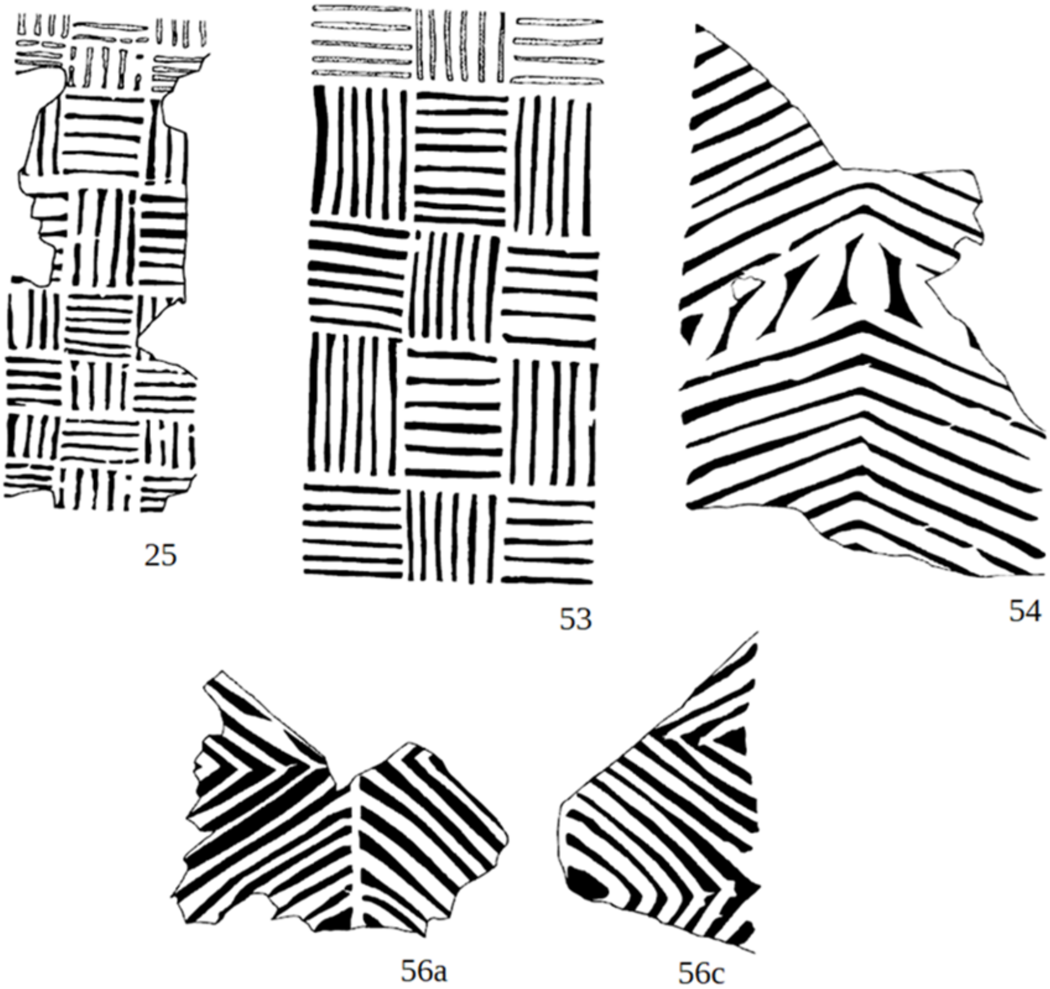


**Figure 7.1: Drawings of the relief-patterned die impressions so far found in Bath. Modified from Betts et al. (1997: 100, 116, 119). © Study Group for Roman Pottery.**

### 7.1.2 Bath-Sussex Connections

A range of ceramic building material evidence suggests links between Bath and West Sussex in the early Roman period. Several examples of the distinctive Westhampnett hollow voussoir form were recorded by Scarth (1864: 95) from Bath (figure 7.2), and have been found in the York Street assemblage held at the Roman Baths Museum

(Lancaster 2012: 430-431). This form is distinguished by its semi-circle cutouts on the sides of the faces (Brodribb 1987: 81) and by the unusual thickness of these components (Lancaster 2012: 420). It was likely the invention of the aforementioned early London-Sussex group workshop (Betts et al. 1997: 19-20), perhaps based near Chichester (Lancaster 2012: 419). At Bath, Betts has noted that these sherds are in a fabric which does not match those of the Sussex group (Lancaster 2012: 430). In another contrast to typical Sussex forms, all four known examples from Bath had the same wavy combing applied (Lancaster 2012: 430, see figure 7.2), rather than being impressed with a roller-die typical of the wider group. The copying of the Westhampnett form in the Bath components and the range of differences from more conventional London-Sussex group products suggests manufacture by someone familiar with their output but perhaps located away from the usual kiln sites and clay deposits exploited.

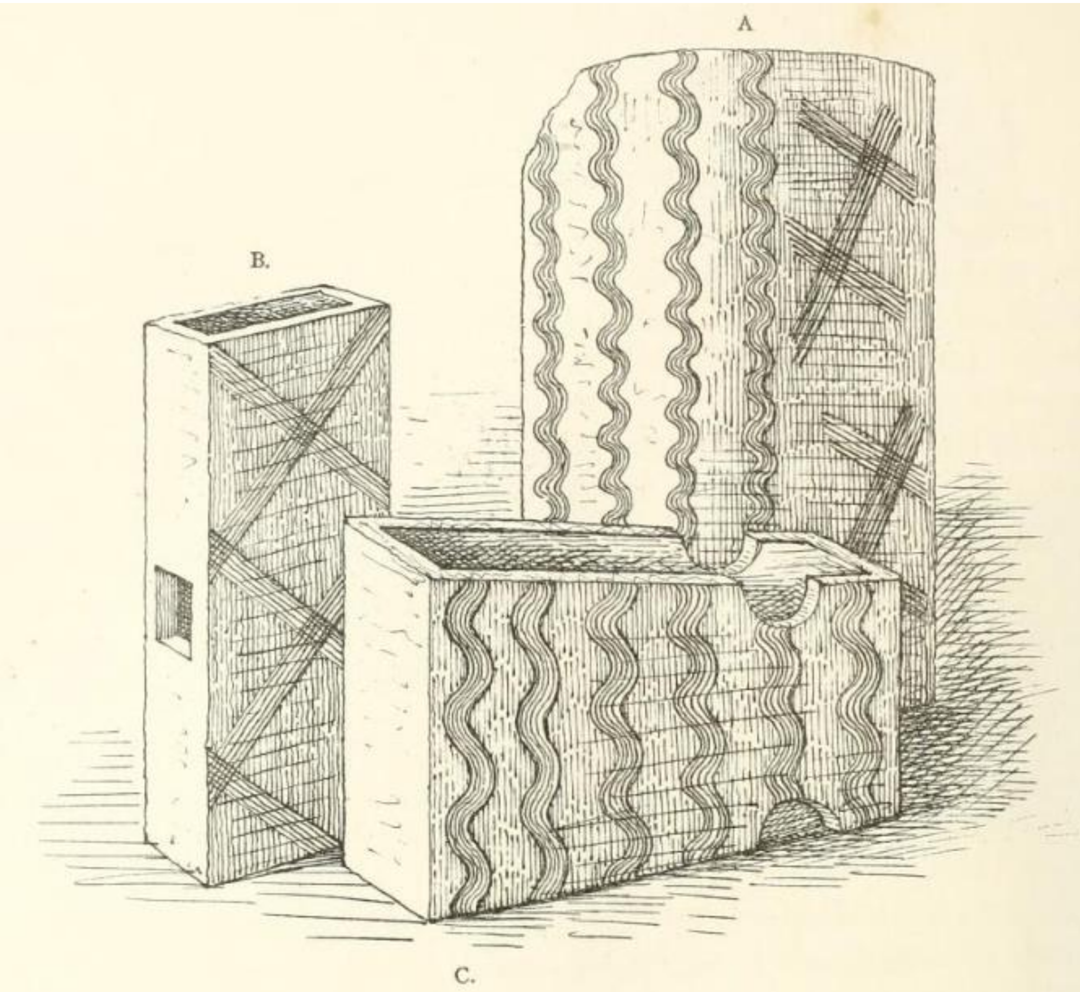


**Figure 7.2: Illustration of a box-flue tile (B), Westhampnett hollow voussoir form (C) and an unusual large curved semi-circular tile found at Bath (A). Modified from Scarth (1864: plate XXXVI).**

There may be further corroborating evidence for a connection between the London-Sussex group workshop and the Bath material in the same antiquarian drawing of Roman brick and tile from the city (figure 7.2). While Scarth (1864: 95), and later Brodribb (1987: 56), both assumed the large curved semi-circular tile (A) was part of a Roman brick column, it bears a resemblance to a rare find from Roman London (figure 7.3). The large and similarly curved tile from London was identified by Betts (2016: 103) as a unique product of the London-Sussex group workshop. It measures 571mm long and up to 250mm in breadth (Betts 2016: 103) and was perhaps placed above the top row of box flue tiles to direct heat laterally to a central vent (Betts 2017: 373). It is difficult to compare these tiles as, sadly, the Bath find has since been lost and Scarth (1864: 95) only recorded a measurement for its diameter. However, the hollow voussoir (C) in the illustration was noted as being 13 inches (330mm) tall (Scarth 1864: 95), and the large, curved tile may therefore have been a little longer, perhaps 400mm. While shorter than Betts's (2017: 373) component, it could still have performed the same function and in any case may not have been of complete length. The presence of the distinctive tight wavy combing on much of its surface explicitly links it to the Westhampnett hollow voussoirs at Bath (Lancaster 2012: 430), and indicates that the brickmaker was likely producing elements of the *entire* Sussex system, not just isolated components.

**Figure 7.3: A large curved and relief-patterned tile likely made by the London-Sussex group workshop and found at the Bloomburg site, London. From Betts (2017: 375). © MoLA.**

Given the untypical fabric of the Bath components (Lancaster 2012), the range of different London-Sussex group forms recorded at Bath may indicate production by a member of the workshop at a new site. It is tempting to interpret this material as the result of itinerant production, perhaps with the despatch of an individual or a team to Bath from the Sussex production site as part of a commission. Indeed, there have been proposals that construction of the Roman Baths, Temple and Spring Reservoir at Bath were in part driven by elites from West Sussex (e.g. Henig 1999: 423-4) and that the Sussex workshop itself thrived due to early local elite patronage (Lancaster 2012: 437). Yet, and as discussed previously (section 4.3.3), itinerant production is challenging to confidently identify. These finds may therefore represent local production, long-distance import from a new kiln site or even previously unrecognised manufacture at the original workshop. Further fabric analysis of the Bath sherds could shed light on these issues, but at present these finds cannot therefore be taken as substantial evidence for such arguments. The connections between the Bath and West Sussex ceramic building materials are nonetheless significant, although their exact nature remains to be clarified.

## 7.2 Roman Stamped Tile at Bath

There is a comparative lack of stamped tile from Bath and the hinterland area. This is likely the result of systematic ancient practices, rather than due to sampling biases or to phases of local Roman activity taking place outside the period of civilian stamping. This absence may imply at least two possible explanations. The first is that supply at Roman Bath was dominated by kiln sites, presumably local, which did not stamp their products. The second is that there was supply from regional brickyards which deliberately did not stamp batches despatched to Bath. Both of these scenarios might feasibly be the result of a range of ancient economic or administrative factors. At present, our understanding of the ceramic building materials from Roman Bath is insufficient to confidently determine between these hypotheses, or indeed whether commercial or territorial aspects were responsible. Research into the provenance of the brick and tile from Roman Bath may yet provide further evidence for one of these alternatives.

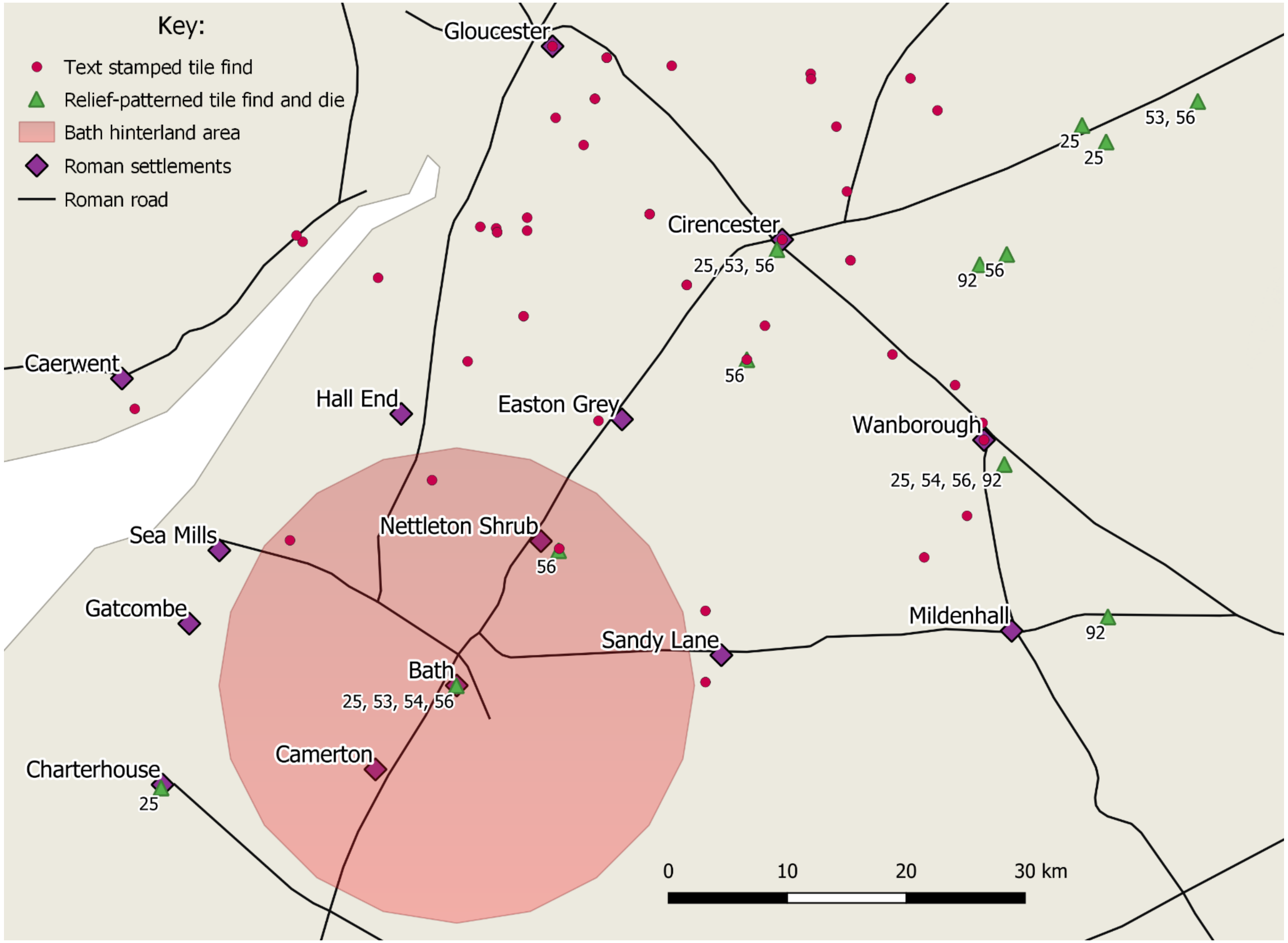


**Figure 7.4: Map showing the location of Roman stamped and relief-patterned tile finds from Gloucestershire and adjacent counties.**

## 7.2.1 Finds from Bath and the Hinterland Area

In contrast to surrounding areas of Wiltshire and Gloucestershire (e.g. McWhirr and Viner 1978, Warry 2017), Bath and its hinterland have yielded few Roman brick and tile stamps (figure 7.4). The only examples found within this area are a single LCH stamped sherd from Chipping Sodbury, Gloucestershire (*RIB* 2489.20(iv)), two LHS stamped tiles from the villa at Truckle Hill, North Wraxall (Tomlin 2017: 482) and a TPF stamped sherd from a villa at Lockleaze, Bristol (Warry 2021, pers. comm.). It is interesting that all of these finds occur fairly close to the projected bounds of the hinterland area, suggesting a possible difference in supply at the centre.

## 7.2.2 Sampling Bias

While the disparity in stamped CBM finds could perhaps be attributed to biases in excavation and sampling, this does not appear a convincing explanation. Bath and its hinterland have been subjected to extensive archaeological research from the antiquarian period onwards (Aston 1986, Cunliffe 2000, Davenport 2021). Indeed, the city itself has perhaps experienced as much archaeological investigation as Gloucester (e.g. Heighway 2006) or Cirencester (Holbrook 2006), though both have yielded abundant stamps (McWhirr and Viner 1978, Warry 2017) whereas Bath has not. Much research in Bath has been the result of antiquarian observations (e.g. Pownall 1795, Irvine 1873, Mann 1878, section 3.1) or rescue work (Cunliffe 1969, 1979, Davenport 1991, section 3.2) rather than modern commercial development. Stamped tile has therefore been perhaps less likely to be identified and curated from the city. Scarth's (1864: 95) discussion and illustration of unstamped Roman CBM nevertheless indicates that there was clearly some historic interest in these mundane building materials. Certainly, if the extensive antiquarian discussions of stone inscriptions from Bath (e.g. Horsley 1732, Pownall 1795, Phelps 1836, Scarth 1864) are any guide, it seems highly unlikely that stamps on any Roman brick and tile from the area would have gone entirely unremarked (e.g. Scarth 1876: 21). More recent excavations at the Roman Baths (Cunliffe 1969, 1976), Temple Precinct (Cunliffe and Davenport 1985) and in other parts of the modern city (Betts 1999a, b, 2002a, b, 2007, 2015) have confirmed the absence of stamped material. It therefore appears that the sample of Roman ceramic building material so far known from Bath and the hinterland is representative, and thus that the low quantities of stamped brick and tile so far found in this area represent systematic and significant practices of ancient use and deposition.

### 7.2.3 Phases of Roman Activity at Bath

One explanation for the dearth of stamps at Bath is a lack of overlap between the duration of regional stamping practices and phases of development at the Roman settlement. Warry (2017: 83-84) has suggested that civilian stamping in the west of Britain occurred in the period AD 100-150. Any major building projects at Bath before or after these dates were therefore unlikely to have incorporated new stamped material. This is probably true of the major episodes of construction at the Roman Baths, Temple and Spring Reservoir.

The first period of construction at the Roman Baths is estimated to have occurred during the late 60s AD (Davenport 2000: 8), though perhaps slightly later (Blagg 1979: 106). It included the building of the Spring Reservoir, the Great Bath, adjacent parts of the East and West Baths and the Temple and its precinct (Cunliffe 1969, Cunliffe and Davenport 1985). The second period for the Spring Reservoir and Temple also encompassed the Period III reroofing of the Great Bath and adjoining areas (Cunliffe and Davenport 1985: 65), though the reroofing of the westernmost baths may have been completed earlier (Cunliffe 1976: 25). This unified project is thought to have taken place after the middle of the second century (Cunliffe and Davenport 1985: 65, though see section 10.2), likely in concert with a major restructuring of the surrounding walled area of the settlement (Davenport et al. 2007: 68). The two most significant phases of construction at the Roman Baths and Temple complex therefore likely occurred outside the period of CBM stamping. However, the dating of the Period III development is not precise (Cunliffe and Davenport 1985: 65, Davenport 2008b: 410), and neither is the final date of stamping (Warry 2017: 84). There may therefore have been a short period of overlap after AD 150. While there were a range of minor additions and redevelopments at the Roman Baths, Spring and Temple between initial construction and the later second-century project (e.g. Cunliffe 1976), these are not well dated (Cunliffe and Davenport 1985: 65) and appear to have been small in scale. Regardless, they must have had the potential to integrate small amounts of stamped tile.

The development of the walled area around the Roman Baths is not well understood. At the New Royal Baths site, scatters of early CBM forms used in bathhouses have been interpreted as evidence of a grand and early public building somewhere in the vicinity, perhaps a military headquarters or administrative centre (Davenport et al. 2007: 69), although apparently demolished and the remnants used as hardcore in later structures

(Betts 2007: 52). While much of the walled area appears devoid of activity until the significant building projects of the mid second century onwards (Davenport 1994, 2000, 2021, Barber 2015), it may well be that there were other, earlier grand public buildings in this space that have not yet been detected (Davenport et al. 2007), particularly in the little-excavated northern half of the walled area (La Trobe-Bateman and Niblett 2016: 160), or under the abbey (Davenport 2000: 11). Whether there was significant demand for brick and tile in this area of Bath during the first half of the second century is therefore unclear. As with the Period III development at the Roman Baths, there may have been a short period of overlap in the later second-century constructions (Davenport 2008b) before tile stamping ceased.

Evidence from the extra-mural settlement at Walcot probably indicates small-scale but regular development throughout the Roman period (Davenport 1994, 2008b, 2021). Sites like Beehive Yard, for example, showed extensive sequences of first-century timber buildings followed by stone structures (Davenport 2008b: 415) with tiled roofs (Betts 2002a). Parts of the Walcot settlement have so far received only limited excavation (Davenport 2008b). If what has been explored so far (e.g. Davenport 2000, 2008b) is representative, then the settlement as a whole may have required a modest but continuous supply of ceramic building material during the second century. While this need may have been met locally, as indicated by a potential pottery or tile kiln found at Walcot Street (Davenport 2008b: 419), it could certainly have been fulfilled by a regional supply. The lack of any finds of stamped tile at Walcot is therefore surprising, especially given their frequency in comparative urban contexts in Cirencester (Darvill 1986) and Gloucester (Heighway and Parker 1982, Warry 2015).

Despite the density of suburban and rural villas around Bath (Scarth 1864, Davenport 1994), the vast majority appear to date from the mid third century onwards (Davenport 1994: 17). These have yielded considerable quantities of ceramic building materials, whether fragmentary (e.g. Betts 1999a, b) or as part of in-situ hypocausts, as at the Wellow (Phelps 1836: 164) or Combe Down (Scarth 1864: 117) villas. The late date of most of these structures means that finds of stamped brick or tile cannot typically be expected. Despite this, the excavation of a suburban villa at the Oldfield Boy’s School site, just by the Wells Road to the south of Bath, did yield a limited quantity of half-box flue tiles (Betts 1999b: 68). These are early forms, perhaps dating to the late first century or early second century (Brodribb 1987: 67, section 9.2.6), and if not simply recycled hardcore these may indicate that there was some activity prior to later phases. While an isolated example, most villa sites around Bath were excavated or recorded by antiquarians (e.g. Phelps 1836, Scrope 1862, Scarth 1864), and it may be that ephemeral early traces at these villas were simply not identified among masses of later construction material and artefacts. In any case, these sites have so far yielded no stamped brick or tile.

This review of Roman development in the Bath area has demonstrated few phases of activity during the early second century, i.e. during the main period of civilian stamping in the west of Britain (Warry 2017: 77, sections 2.1.4, 2.4.3). Nevertheless, there would probably have been a continuous but small-scale requirement for ceramic building materials for repairs and alterations, as suggested for estates and modest settlements (Darvill and McWhirr 1984: 242). Were Minety, for example, to supply Bath even in part during this period then stamped tile finds might be expected. Such sporadic supplementation of local products has been demonstrated at Silchester (Warry 2012, Machin 2018) and even Old Sarum (McWhirr and Viner 1978) through finds of LHS stamped tile produced at Minety (Darvill 1979: 328). The finds of two LHS stamped tiles from the villa at North Wraxall (Tomlin 2017: 482), in the Bath hinterland, may represent similar opportunistic supply outside the core Cirencester area. That such tiles have not yet been found in or closer to Bath confirms that the lack of stamps is not merely a quirk of sampling bias or phases of Roman activity.

### 7.2.4 Monopoly of Local Supply

The lack of Roman stamped tile finds from Bath and much of the hinterland area might be explained by the importance of local, non-stamping kiln sites in the supply of this region. However, no such local kiln sites have yet been confirmed (Betts 2015), partially because the provenance of the CBM fabrics of Roman Bath has not yet been investigated. Given the apparent prevalence of stamping around other regional settlements, particularly Wanborough (Mepham 2001), Cirencester (McWhirr and Viner 1978, Darvill 1986) and Gloucester (Heighway and Parker 1982, Warry 2015), any such kiln sites may have been located close to Bath and perhaps worked in a distinct tradition.

Stamping of CBM may have been an inherited practice (Warry 2017) or a response to client or organisational demands (see section 2.1.4), perhaps reflecting a specific system of oversight and quality control, if not merely marking products to prevent theft (Brodribb 1978). Given the wide array of different Roman stamp types found in Gloucestershire (McWhirr and Viner 1978), they may also have had a competitive function. Certain workshops could have gained a reputation for high quality products and may have stamped these to distinguish them from the brick and tiles of inferior competitors (Darvill 1980, Darvill and McWhirr 1984), especially if stock could be held at ancient builder's merchants in the region (e.g. Warry 2017), awaiting use. A lack of stamping at certain brickyards may therefore indicate a different, absent, or simply less archaeologically visible system of oversight. Alternatively, it may represent supply to different market conditions or perhaps directly to consumers with no intermediaries.

Another aspect which may have influenced the use of stamping was the literacy of those involved in brickmaking. While stamping a tile does not require the maker to be able to read, it may have been a factor in the very limited adoption of stamping in Roman Britain (e.g. *RIB* II(5): 56). This is reinforced at the regional level, to some extent, by finds of locally produced stamped *mortaria* ceramics from Shepton Mallet (Hartley 2001). These used a range of illiterate stamps (figure 7.5), potentially due to widespread illiteracy among the potters and consumers. Furthermore, there have so far been no finds of any non-numeric graffiti on CBM from Roman Bath and Somerset (e.g. *RIB* II(5)), despite alphabetic graffiti being recorded on tiles from other regions of Roman Britain (Tomlin 1979, Brodribb 1987), and significantly from Cirencester and Gloucestershire (e.g. *RIB* II(5): 92-158). While this is not definitive proof of illiteracy among brickmakers in this area, the evidence may fit with this interpretation.

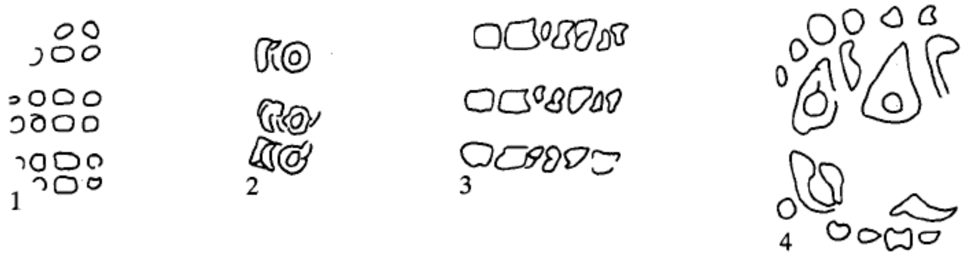


**Figure 7.5: Illustration of non-literate stamps from *mortaria* made at Shepton Mallet, Somerset. Not to scale. Modified from Hartley (2001: figure 39). Hartley, K., 2001. Shepton Mallet Mortaria. In: Leach, P., 2001. Excavation of a Romano-British Roadside Settlement in Somerset: Fosse Lane, Shepton Mallet 1990. © The Roman Society.**

There is a range of evidence that is perhaps inconsistent with the dominance of local non-stamping kiln sites as the sole explanation for the absence of stamped tile from Roman Bath. In particular, if local supply were dominated by such production sites, then there would presumably be little evidence for any form of regional or extra-regional transport of brick and tile to the area. In fact, one Roman CBM fabric has so far been identified as a definite long-distance import (Betts 2011: 1), although sherds of this fabric have been found to be present in assemblages in only small quantities (Betts 2015). While the duration of production of this Hampshire fabric group is not exact, Betts (2018: 1) has estimated it to be between AD 100-120, based on finds from London. If correct, this indicates limited long-distance imports of CBM into Bath during the early second century, i.e. when stamping was regionally prevalent.

If there was sufficient demand for tile and brick shipments to be brought nearly 90km from kiln sites in Hampshire to Bath during the early second century, then it appears unlikely that local supply and simple competition would have been able to prevent the much shorter movement of stamped CBM into the same area. The long-distance importation may admittedly be exceptional, perhaps reciprocal with the transport of Bath stone eastwards (e.g. Pearson 2006, Hayward 2009), rather than satisfying any insurmountable demand in the local area. The evidence is therefore far from clear-cut. It nevertheless appears unlikely that the absence of stamped tile in Roman Bath and the hinterland was solely due to cornering of the market by local non-stamping producers.

### 7.2.5 Stamp Distributions and Boundaries

If local, non-stamping production did not hold a monopoly on brick and tiles supplies to Roman Bath, then a logical alternative is that any shipments to the area were deliberately left unstamped. The only confirmed Roman CBM kiln sites from the region (McWhirr 1984), namely Minety (Scammell n.d.) and St Oswald’s Priory in Gloucester (Heighway and Parker 1982), produced stamped tile for at least part of their periods of operation. It therefore seems likely that Roman Bath could have been supplied in part with unstamped ceramic building materials from an otherwise stamping brickyard. This suggests that the stamps applied to Roman brick and tile in Britain had a discrete economic or administrative role tied to the organisation of production or the region of demand. In order to better understand these aspects, the known distributions of civilian stamped tile finds must first be reviewed.

A range of probably Minety-produced (Darvill 1979) LHS stamp dies have only been found on sherds exported a considerable distance (McWhirr and Viner 1978), in some cases up to 80km away (Darvill and McWhirr 1984: 253). This has led Warry (2017: 91-92) to make the assertion that certain die types at the kiln site were only applied to batches destined for transport outside the core Cirencester area. This does not necessarily mean that the stamps themselves were reserved for such a discrete distribution, rather that they happened to be applied only to material allocated for extra-regional use. Indeed, LHS stamped tiles of other die types are also found in and around Cirencester (McWhirr and Viner 1978, see figure 7.6). This implies that they may have belonged to a sub-unit or separate contractor at Minety which perhaps filled a local and, at times, extra-regional surplus role (Warry 2017, section 10.8.3).

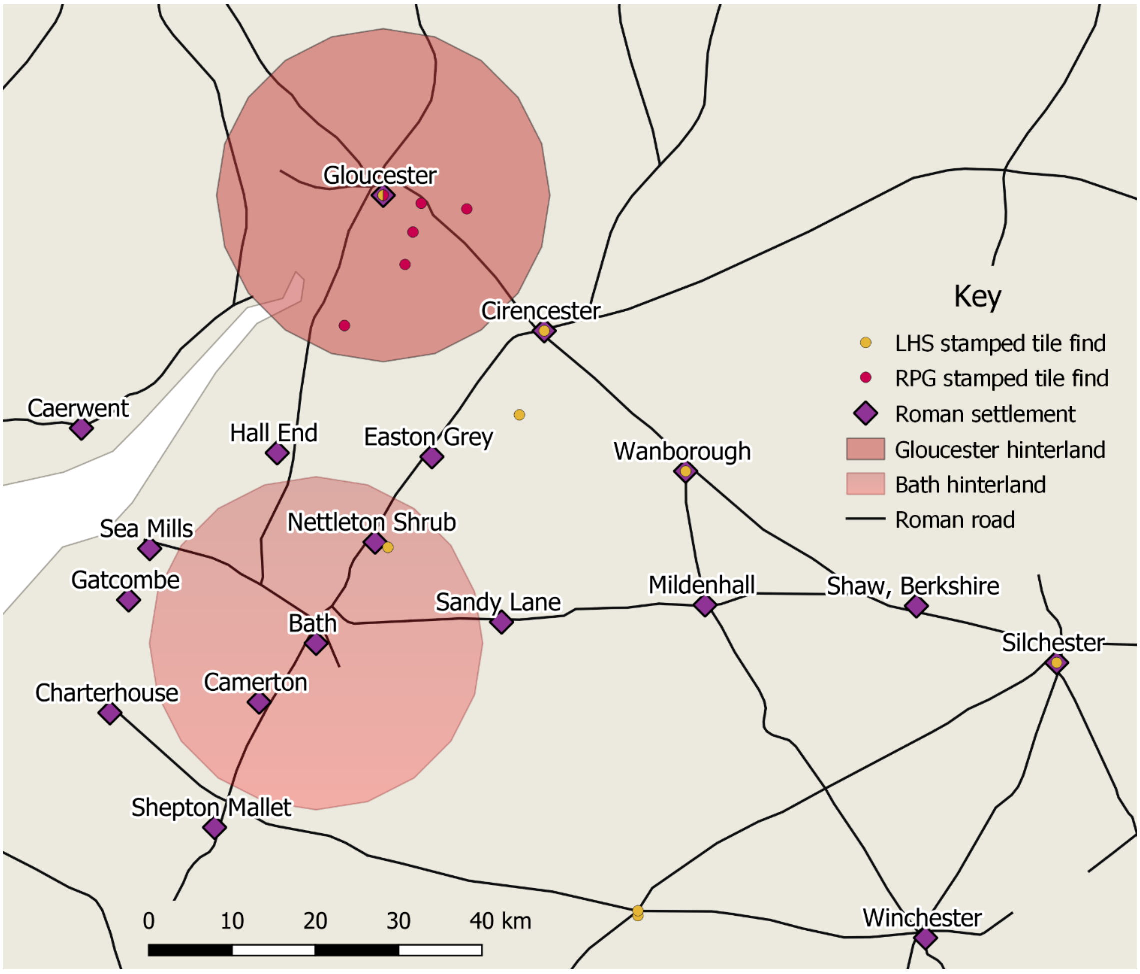


**Figure 7.6: Map showing the distribution of RPG and LHS stamped tile finds from Gloucestershire. The two-tone circle at Gloucester indicates finds of both types.**

There are other stamped finds from the west of England which demonstrate a relatively clear and restricted spatial distribution, namely the RPG series (figure 7.6). These stamps were almost certainly the result of municipal production at the St Oswald's Priory kiln site (Heighway and Parker 1982, see section 2.2.2). As might be expected for production aimed at supplying civic projects in and near Roman Gloucester (McWhirr and Viner 1978, Darvill and McWhirr 1984), all but one example of these stamps has so far been found within 20km of the settlement. The finds outside the immediate vicinity of the *coloniae* may represent publicly funded projects, but are perhaps more likely the result of small-scale commercial marketing of surplus civic brick and tile (e.g. Peacock 1979: 8). This seems especially probable for finds from Hucclecote Roman villa (Clifford 1933, 1961), a proposed ancient builder's merchants (Warry 2017). Part of this distribution may also be due to the movement of hardcore from Gloucester for later Roman building projects.

The IVC DIGNI stamped finds, although relatively few in number, show a somewhat restricted distribution primarily between Wanborough and Mildenhall (figure 7.7). No kiln sites have yet been identified for this stamped material, but on the basis of thin-section analysis Darvill (2001: 317) has suggested a possible origin near Calne, c.20km southwest of Wanborough near the Sandy Lane Roman settlement. Unlike the RPG stamps, there is some evidence for wider transport beyond the core area, with an IVC DIGNI stamped tile found at Silchester (McWhirr and Viner 1978: 369). This likely implies commercial production predominantly for the local area, but occasionally fulfilling wider demand when available. Indeed, the cluster of IVC DIGNI, LHS and TPF-series stamps at Wanborough (Mepham 2001) may indicate significant competition between the different regional kiln sites.

The distribution of the TPF series of stamped tile (including TPF, TPFA-C, TPFP and TPLF) is more intermediate (see figure 7.7). Much of this ceramic building material may have been manufactured at Minety (Darvill 1979), although certain finds have been suggested to be the products of as yet unidentified kiln sites (e.g. Darvill 1979, 1986).

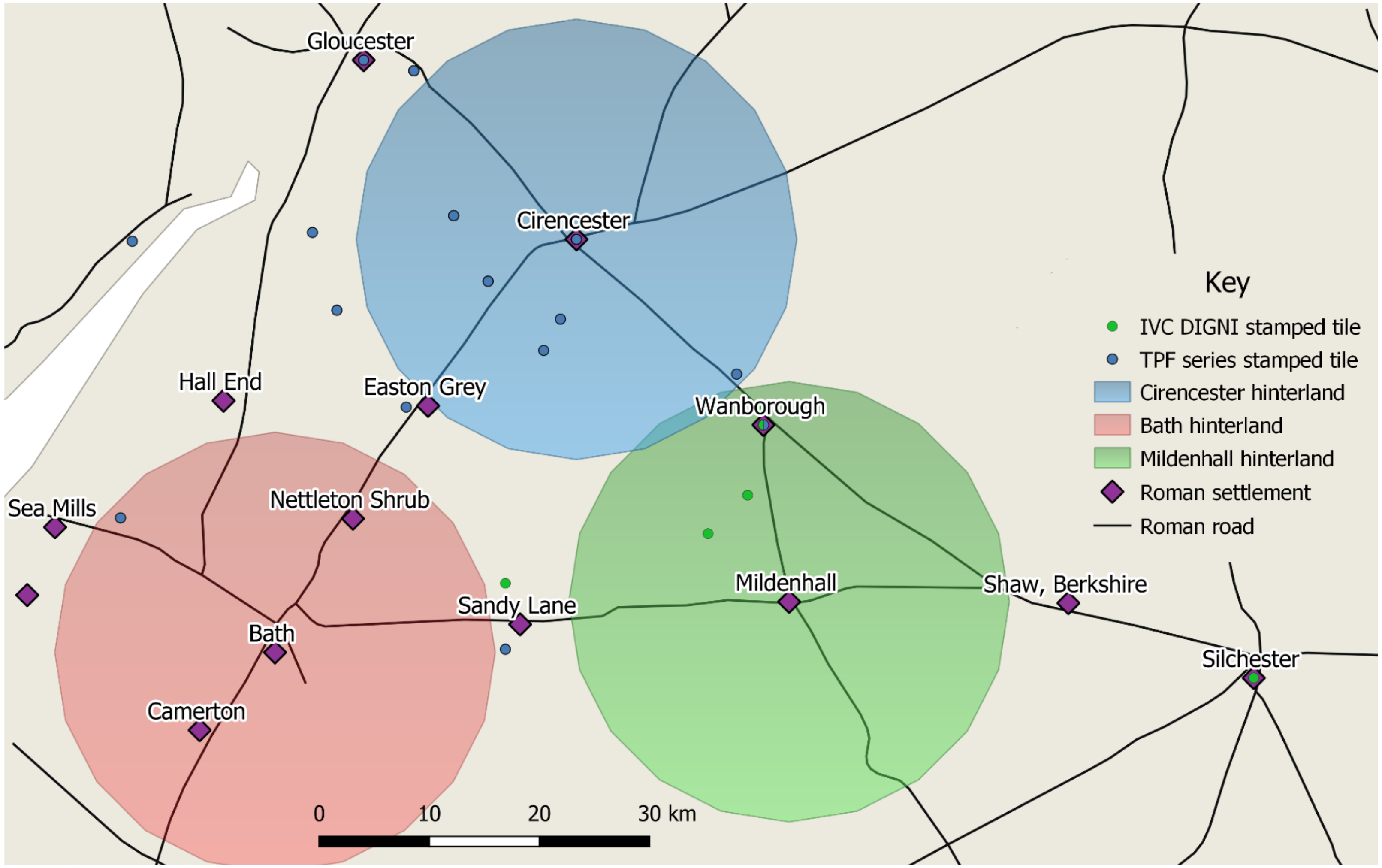


**Figure 7.7: Map showing the distribution of TPF series and IVC DIGNI stamped tile finds from Gloucestershire and adjacent counties. The two-tone circle at Wanborough indicates finds of both types.**

While Cirencester and its hinterland appears to have been a core area of supply for TPF-stamped brick and tile (Darvill and McWhirr 1984), finds of this series have also been recorded from Wanborough (Mepham 2001), from Gloucester (Warry 2017), around Sandy Lane (Tomlin 2017) and even in modern-day Bristol (Warry 2021 pers. comm.). Distribution beyond the Cirencester hinterland to the southwest is therefore fairly pronounced. While not signifying especially long-distance transport, especially in comparison to certain LHS finds (Darvill and McWhirr 1984), the distribution of the TPF series nevertheless demonstrates movement into areas that likely had their own CBM industries active at this time in the Roman period. An obvious example is Gloucester (Heighway and Parker 1982), but there are also a range of ARVERI and other stamped tiles recorded from the west bank area of the River Severn (McWhirr and Viner 1978, Warry 2017), perhaps representing contemporaneous local industries. An explanation for this distribution is perhaps commercial marketing of products regionally, with a significant but not absolute monopoly around Cirencester and more intense competition with other kiln sites further west, southwest and southeast.

While many smaller groups of stamped tile from the same region have been omitted here (e.g. McWhirr and Viner 1978, *RIB* II(5), Warry 2017), the examples above clearly demonstrate that the circulation of stamped brick and tile was complex and that there were a range of different scales and mechanisms of distribution. It must also be acknowledged that the find location of some stamps may be the result of ancient recycling and transport of hardcore, rather than due to original use in a Roman structure. Nevertheless, given the present known distributions of stamped tiles, it seems unlikely that there were strict administrative or territorial boundaries which prevented the movement of this material. The lack of stamped brick and tile finds from Bath is therefore challenging to interpret. Isolated finds at three different sites in the wider Bath hinterland (figure 7.8) indicate that stamped tile was likely entering the area in limited quantities, but was apparently not being consumed at the centre despite its greater potential for demand (e.g. Darvill and McWhirr 1984). The finds of TPF and TPFC stamped tile west and east of Bath may indicate that stamped CBM was actually being moved south along the Fosse Way to the road junction at Walcot and was then transported away from the city. Alternative, albeit more circuitous, routes were possible to avoid the settlement. However, if ceramic building materials were actually moved via Bath, then the lack of stamped finds from the city would be even more intriguing.

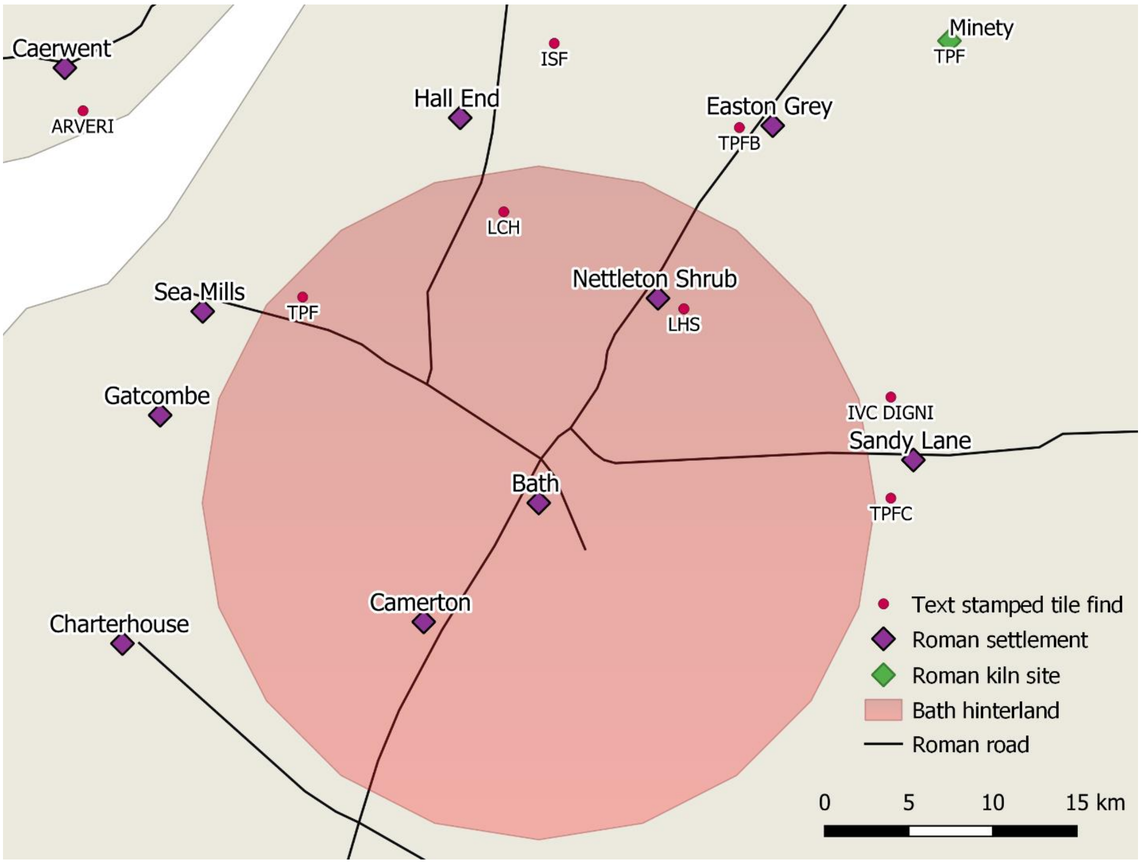


**Figure 7.8: Map showing the distribution of stamped tile finds in and around the Bath hinterland area.**

## 7.2.6 Organisation of Production, Taxation and Competition

If the lack of stamps on ceramic building materials from Roman Bath cannot be ascribed to a strict boundary of movement, then it perhaps implies a different organisation of production or a distinct relationship between producers and consumers in the area. What exactly this may have constituted is difficult to understand, especially when both public and private buildings in Gloucester (Warry 2015) and Cirencester (Darvill 1986) appear to have incorporated stamped material. It may be that a non-stamping non-local kiln site or perhaps a sub-unit at, say, Minety, was specifically tasked with supplying the needs of Roman Bath. If this were so, then perhaps finds of stamped tile from the hinterland area (figure 7.8) may be explained as supplementary batches outside the scope of this primary supply. This is supported to some extent by several of the stamps found, namely two LHS stamped tiles found at the Truckle Hill villa, North Wraxall (Tomlin 2017: 482), and an LCH stamped tile from Chipping Sodbury (Darvill and McWhirr 1984: 258). As noted above, the LHS workshop has already been proposed as fulfilling a surplus role locally and extra-regionally (Warry

2017: 91-92). The LCH stamp is unusual in that it has so far only been found on brick and tile in two other locations, namely at Gloucester (Warry 2017: 111) and at Wroxeter (*RIB* 2489.20). This may either indicate that these stamped tiles also filled a surplus role, or that it was the result of temporary itinerant production, with the maker transporting the stamp between the different locations. In either case, this LCH stamped material is unlikely to have constituted a significant local supply. This evidence therefore does not contradict the proposal that Roman Bath and the centre of the hinterland was primarily supplied with unstamped tile from a dedicated non-local source, though it cannot represent definite proof.

While it is challenging to identify the precise reason for the potential absence of stamping on CBM despatched to Roman Bath, a tempting explanation is perhaps a different tax or recording system for brick and tile shipments to that area. The Roman use of stamped tiles in the region bears a superficial resemblance to the excise stamping of brick during the Brick Tax in Britain between 1784 and 1850 (Watt 1990). During this period, green, i.e. unfired, bricks were taxed per thousand at brickyards and were subject to inspection by a local magistrate to record workshop output (Watt 1990: 34-5). A similar system in the Roman era might have seen a stamp applied per batch and, perhaps, per workshop if owned or sub-let by different individuals. The possibility of many three- or four-letter civilian stamps from Roman Britain constituting the initials of wealthy landowners or kiln site operators has previously been noted (McWhirr and Viner 1978: 366-7). Elite ownership and operation of Roman brickyards is also documented in Italy (Bloch 1941, Helen 1975), and this extended to Imperial families and, indeed, state control of kiln sites even in Britain (e.g. *RIB II*(5), Betts 1995, Fulford et al. 2019, see section 2.1.4). It is possible that the assessment of ancient brickyards and output could have constituted a revenue as part of wider taxation on the property of wealthy private individuals, though admittedly entirely speculative.

When considering civic levies, it is interesting that the specific area around Cirencester and Gloucester has yielded such a rich and varied array of civilian stamps (Clifford 1955, McWhirr and Viner 1978). These two settlements are unusual in the region for having possessed distinct Roman statuses which have survived down to the present, namely *civitas* (Frere 1978: 246) and *coloniae* (Holbrook 2006: 99-100) respectively. It appears reasonable that these could have conferred powers of taxation and enforcement unavailable to other, smaller settlements. While perhaps mere coincidence, it may be that the application of taxation to regional kiln sites and production by Magistrates from Cirencester and Gloucester enforced the adoption of stamping on brick and tile in the surrounding area. The sudden repealing of a levy in light of national changes of production and circulation in the mid second century (e.g. Betts 2016, 2017, sections 2.1.2 and 2.2.3), in some ways similar to the duration and Victorian abolition of the Brick Tax (Watt 1990), may also provide a feasible explanation for the sudden cessation of civilian stamping in the area (Warry 2017). As far as the ceramic building materials from Roman Bath are concerned, the lack of stamping on these batches may imply a system where specific projects were deemed tax free, or perhaps taxes of certain shipments were prepaid or passed onto the consumer.

Alternatively, and as outlined in section 7.2.4, the absence of stamps might simply represent a different or archaeologically invisible system of quality control, assessment and organisation at the brickyard. A further explanation is the contest of regional market share. The variety of stamps so far recorded from Gloucestershire (McWhirr and Viner 1978, Darvil and McWhirr 1984), and indeed the significant overlap in regions presumably supplied by different kiln sites (figures 7.6, 7.7), perhaps implies that competition was the most significant factor in the choice of whether to stamp products or not. A lack of stamping may therefore be a direct correlate with almost no local rivalry in production, and vice versa. To illustrate, the Roman roadside settlement at Wanborough (Anderson and Wacher 1980, Anderson et al. 2001) lay almost halfway between Cirencester and Mildenhall. Despite the site being small and receiving limited archaeological investigation (Anderson et al. 2001), especially compared to Bath (Davenport 1994, 2021, Cunliffe 2000), it has nonetheless yielded finds of IVC DIGNI, LHS, IAN and TPF-series stamped tile (Mepham 2001: 313-316). It appears likely that the deposition of these finds may be the result of fierce competition on the boundaries between areas usually supplied by different brickyards (see figure 7.7). Conversely, if Bath were supplied by a single source with a virtual monopoly, it may convincingly explain the lack of stamps from the city and the centre of the hinterland area.

## 7.3 Chapter Conclusion

A range of ceramic building material fabrics and forms have so far been identified from Roman Bath. While one fabric has been identified as a long-distance import from kilns in Hampshire, most fabrics are not provenanced but are assumed to be local. A range of relief-patterned tile has also been identified from Bath, and while all dies have links to the Minety kiln site, it is not clear if these finds are genuine imports or the result of itinerant production closer to Bath. A range of connections has been demonstrated between the ceramic building materials of Bath and those of the distinctive London-Sussex group workshop, perhaps indicating the despatch of a team or a craftsman from this workshop to Bath. Finally, the comparative absence of stamped CBM from the city and the hinterland area has been investigated and is likely the result of systematic ancient practices. While no firm conclusions can be made, it appears that the dearth of stamped tile at Bath may be the result of economic or administrative factors, perhaps linked to taxation or a lack of competition between kiln sites supplying the area. Future analysis may significantly refine this understanding.

# 8 Methods

This study utilises a combined approach of macroscopic survey, low-power microscopic fabric analysis, and compositional analysis via portable energy-dispersive X-ray fluorescence (pXRF) to investigate the ceramic building materials from the Roman Baths at Bath. While these techniques have already been used in the study of brick and tile from Roman Britain (e.g. Betts 2007, 2015, BRBP 2016, Machin 2021, Darvill 1979, 1980, 1982), a wide variety of other methods have also been applied and are reviewed in section 4.0. The combination of techniques used in this study has been chosen in response to the challenges presented by the brick and tile assemblages from the Roman Baths and in accordance with the aims and objectives of this project. Macroscopic recording and low power fabric analysis of fresh breaks were combined in a general survey of the brick and tile to quantify and determine the range of components and fabric groups present across the entire site for the first time. Further pXRF analyses were conducted to test fabric groups and compare to regional kiln-site material and Roman stamped tile groups in order to suggest provenance.

## 8.1 Ceramic Building Material Recording

A general survey of the ceramic building materials from the different assemblages of the Roman Baths was completed to identify the total range of components and the variety of ceramic building material fabrics present. This was conducted by identifying and recording each sherd chosen for inclusion and by creating a fresh break for fabric analysis with a x20 magnification microscope. This sampling included a selected proportion of every assemblage (table 8.1), in order to create a unified understanding of the full range of ceramic building materials present at the site for the first time (section 3.3).

### 8.1.1 Pilot Analysis

A trial survey was undertaken to quantify the volume of material in each uncatalogued assemblage and to develop and test a recording scheme. These estimates of sherd quantities and recording time per sherd (Appendix C) were then used to model the time required for different sampling proportions of the assemblages and informed selection of the sampling strategy for analysis of the ceramic building materials.

The opportunity was also taken to test the recording of a range of features in order to understand how they impacted the time taken to record each sherd and the value of the data generated. Combing marks were common, but fingerprints and a single relief-patterned impression (e.g. Cunliffe and Davenport 1985: plate LXVII) were also identified. The width of comb marks was measured and the number of teeth on each combing impression were counted in an attempt to profile and recognise the use of the same comb on sherds from different tiles. These ultimately resulted in very few matches between different fragments, but significantly added to the time required to analyse each sherd. The recording of comb widths and quantities of teeth were therefore not continued into the full survey.

The trial also included development of an initial fabric scheme using a x20 magnification microscope on old breaks present on brick and tile fragments from the assemblages. Ten different fabric groups were distinguished. While a range of important fabric types with typically fine quartz inclusions (e.g. F03, 05, 06, 08), or very few quartz inclusions of any kind (F04, 07), were identified, the absence of fabric groups with common large quartz inclusions in the pilot analysis was conspicuous, and contrasted strongly with the results of the full survey (section 9.2.1). No fabric reference collection was curated during this test analysis. While many common and easily recognisable fabric groups therefore continued in use with the same fabric numbers in the full recording, other fabric groups and numbers from the trial were abandoned, for example F02, F09 and F10. This was either because the type sherds of these fabrics could not be located or were found to be too similar to sherds of other fabric groups, especially with the introduction of analysis of fresh breaks (section 8.2).

The pilot analysis therefore proved successful and highly valuable. Each of the different assemblages at the Roman Baths were quantified. The recording of sherds and fabrics was trialled, and the time taken to analyse each sherd was measured, allowing the calculation of the total time required to sample different proportions of the material in each assemblage. Hollow voussoir, brick, voussoir brick, tegula and imbrex components were also identified, indicating some of the variety of components to be found in the assemblages. The range of marks and impressions to be recorded was also decided as a result of this trial. The pilot analysis therefore provided the foundation for the methodology of the recording of the ceramic building materials of the Roman Baths.

### 8.1.2 Recording Sampling Strategy

Once the uncatalogued assemblages had been quantified in the trial analysis it became clear that a total survey of all ceramic building materials excavated from the Roman Baths was not feasible within the timescale of the project. This was due to ongoing periods of pandemic restrictions and other demands on curatorial time limiting access to assemblages held at the Roman Baths Museum and Pixash and Combe Hay stores. The length of time available for the recording of the CBM was additionally restricted in order to have time to conduct further analysis of the brick and tile with complementary techniques.

**Table 8.1: Table showing the actual sherd count or estimate from average sherd weights (denoted by an asterisk) for each CBM assemblage from the Roman Baths, and the proportion of each assemblage sampled during this study.**

| Assemblage | Total Sherd Count | Sampling Proportion (%) |
|---|---|---|
| York Street | 720 | 33 |
| Temple Precinct (RB82-86) | 600* | 50 |
| East Baths (EB95-01) | 1060* | 50 |
| Spring Reservoir | 77 | 50 |
| Total Sherds Sampled | 1100 | - |

The sampling proportion selected for each assemblage needed to balance the time required for completion of this stage of analysis and inclusion of a large enough sample size to be representative of the full range of components and fabrics present. The sampling of 50% of the sherds of the Temple Precinct, East Baths and Spring Reservoir assemblages and 33% of sherds in the York Street assemblage was selected as a suitable compromise between a limited, achievable scope and inclusion of a wide enough range of material to generate a comprehensive and accurate understanding. This sampling strategy was developed in consultation with the staff of the Roman Baths and was approved by the manager of the Museum and Pump Room.

The reduced sampling proportion of the York Street material was also chosen because of the preservation of parts of the assemblage and the need to conserve this valuable archaeological resource. A range of catalogued fragments in the York Street assemblage consist of multiple partial or complete hollow voussoir tiles mortared together, sometimes with surviving areas of the mortar extrados, intrados, tile spine or ridge imbrices from the original position of these tiles in the vaulted roof of the Great Bath. Contiguous fragments and isolated intact examples of hollow voussoirs, box flue tiles or bricks were excluded from sampling as these could have suffered damage from handling or during the creation of fresh breaks for fabric analysis (section 8.2.1). The York Street material was also sampled at a lower proportion to reduce the impact to the areas of friable mortar and post-depositional grey-black protuberant surface formations (section 9.1.6) present on many of these sherds, both of which are susceptible to damage from the removal of material for fresh breaks.

### 8.1.3 Recording Methodology

The range of features measured and recorded for each sherd adhered to the minimum guidelines specified by the Archaeological Ceramic Building Materials Group (2002). This included quantification of each sherd by weight in grams, recording of sherd fabrics and identification of the form of each sherd using standardised terminology (defined in Appendix D). These guidelines also advocate (ACBMG 2002: 2.6.1d) recording supporting information such as particular form characteristics, evidence of reuse, manufacturing details and complete dimensions where present. Examples of ceramic building material recording sheets and criteria from other studies and reports (e.g. Betts 2002, Warry 2006: 398-409, Poole and Shaffrey 2008, McComish 2012: 122-125) and guides (Betts 1986, McComish 2015) were also consulted to inform selection of further recording features. The full recording system for each sherd is detailed in Appendix D.

Most features recorded were typical for research into Roman brick and tile assemblages, for example the presence of combing, animal prints, hobnail impressions, knife marks and scoring, tegula flange profiles and cutaways (e.g. Cram and Fulford 1979, Brodribb 1979, 1987, Betts 2002, Warry 2006, Poole and Shaffrey 2008). The maximum and minimum remaining complete widths and maximum remaining height of hollow voussoir sherds sampled were also recorded, as these measurements were vital to distinguishing between the many different types of hollow voussoir present (section 9.1.3).

## 8.2 Fabric Analysis

Fabric analysis of each sherd used a x20 magnification binocular microscope on fresh breaks, though a digital microscope with x20-x40 magnification was also used to capture images of fabrics or significant inclusions and features. Permission was given to create a fresh break on every sherd in the survey, which included the removal of a small flake of material.

### 8.2.1 The Creation of Fresh Breaks

Fresh breaks were situated to minimise damage to diagnostic features such as joints, edges, flanges, tegula cutaways or box flue cutouts. They were also placed to avoid surface marks, for example combing, knife cuts, animal prints and hobnail impressions. Sherds with no suitable locations for the creation of a fresh break were excluded from analyses. This included all intact components and any partial sherds with weak areas likely to fracture. Permission was given to create one fresh break per sherd, exposing an area approximately 25mm long by the entire thickness of the sherd. This was granted by the manager of the Roman Baths Museum and Pump Room. One fresh break was permitted per 500g of weight for large fragments. This was requested in order to examine several different areas and thus better understand variation within single tiles. However, in practice, multiple fresh breaks could only be made on bricks, as large sherds of other components rarely presented several suitable locations.

Sherds with diagnostic features were prioritised for inclusion in sampling in order to investigate any relationships between component forms and different fabric groups. Material removed during the creation of a fresh break was often bagged separately and retained when above a certain size or thickness. Many of these offcuts were later analysed using pXRF (sections 8.3, 9.3).

### 8.2.2 Development of a Fabric Scheme

The fabric of each sherd was recorded using a fabric scheme initially developed in the pilot analysis (section 8.1.1, Appendix E), though extended throughout the course of the full recording. A matching fabric reference collection of sherds was curated and used during analysis and will be deposited with the Roman Baths Museum upon project completion. Different fabric groups were distinguished on the basis of the presence or absence and size and frequency of quartz inclusions, cream/white streaks, iron oxide pellets, mica inclusions and shaped voids (see Appendix E for full fabric descriptions). This study has adopted the use of a decision tree matrix (figure 8.1), alongside traditional fabric descriptions in order to assist in the differentiation between fabric groups encountered in the Roman Baths assemblages. Images of sherd fabrics and significant features were also routinely captured using a digital microscope (e.g. section 9.2.2, Appendix E) for later reference.

The decision to create a new ceramic building material fabric scheme for this analysis ran contra to ACBMG (2002: 2.6.1b) guidelines, which recommends adherence to pre-existing regional fabric type series. In fact, there are two previous fabric schemes which could have been followed. Foster's (1985: 2: C4-5) series was developed during the analysis of CBM from the Temple Precinct but appears to have left no fabric reference collection to consult and was therefore discounted. Betts's (2011) scheme was developed from analysis of CBM from suburban villas (Betts 1999a, b), sites in Walcot (Betts 2002a, b) and from structures in the walled area of Roman Bath (Betts 2007, 2015). The fabric reference collection is held at the Museum of London Archaeological Archives and was visited during this project. Instead of using this scheme, it was decided to create a new one for this study for several reasons.

Firstly, considering the size and importance of the Roman Baths complex in the Roman period (e.g. Cunliffe 2000, Davenport 2021), it was not certain that the CBM being supplied would be the same as that used at much more typical villa or domestic settlement sites investigated elsewhere in Roman Bath. Secondly, the use of a new fabric series could be justified providing that these fabrics were then equated as much as possible with the material from the wider settlement (e.g. Betts 1999a, b, 2002, 2007, 2015) during the course of the project. The lack of collaboration between specialists and their respective fabric series is a key concern in the ACBMG (2002: 2.2.1, 2.6.1b, 2.9.1) guidelines, but the integration of academic and commercial research into the CBM from Roman Bath constitutes a key objective in this study (section 1.3). The equation of the two fabric systems and integration of the data from the Roman Baths with the material from the wider settlement appeared achievable within the scope of this project, so the use of a new fabric system could be justified.

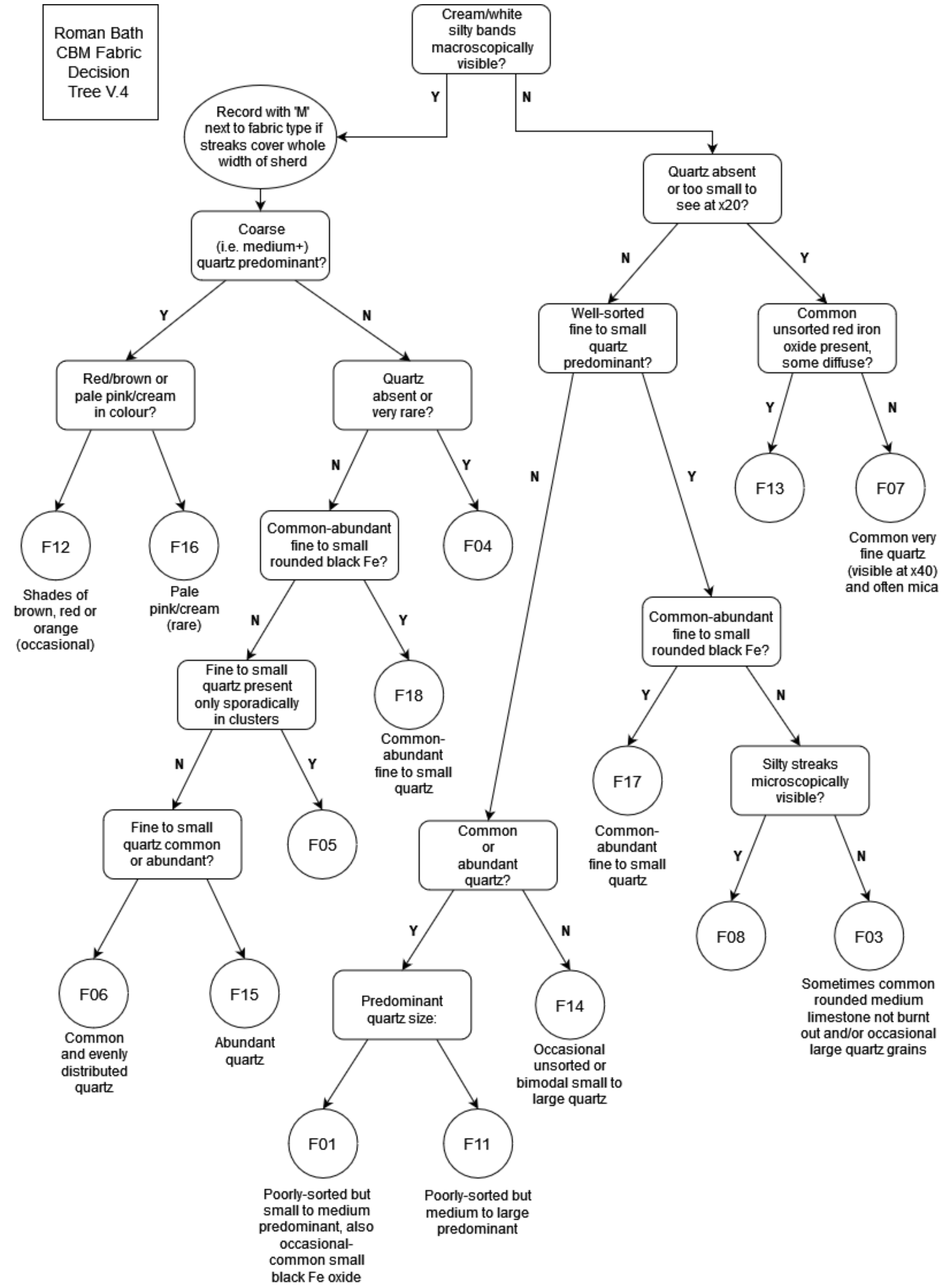


**Figure 8.1: Decision tree used to guide determination of fabric group during the fabric analysis of the ceramic building materials from the Roman Baths.**

## 8.3 Portable X-ray Fluorescence Sampling and Analysis

Portable X-ray fluorescence was used to analyse offcuts created during fabric analysis. 450 samples from the Roman Baths were analysed, with the proportions of offcuts of different fabric groups and tile types included being chosen to reflect the composition of the total assemblage from the site. More than 70 samples from regional and extra-regional sites and finds were also analysed to compare with the offcuts from the Roman Baths, in order to suggest provenance. Each sample was analysed using the same Niton XL3t GOLDD+ instrument, with the same point analysed three times and the results averaged.

### 8.3.1 Sample Preparation

A range of options existed for sample preparation ahead of pXRF analyses. These included surface analysis with no preparation, analysis of offcuts collected during fabric analysis, powdering and homogenisation for analysis in sample cups (Takahashi 2015: 29), and creation of pressed pellets (Takahashi 2015: 26-28) or glass fusion beads (Watanabe 2015). In-house facilities for the creation of pressed pellets and glass fusion beads were not available so these methods were discounted. The powdering of samples and analysis of material in sample cups with a microfilm lid was not adopted because the volume of material required to create a truly homogenised sample was likely to be prohibitive if removed from archaeological ceramics, where it is vital to minimise any damage.

Of the remaining sample preparation options, non-invasive surface analysis was considered but rejected. All previous applications of pXRF to CBM from Roman Britain have analysed surfaces (e.g. BRBP 2016, Machin 2018, 2021), though Warry (2021: 374) also trialled his instrument on a small number of sections cut with a saw. The Roman Baths material is unsuited to non-invasive analyses due to the condition of these assemblages. Many sherds preserve large areas of fragmentary or intact mortar upon the faces, bases and tops of these tiles. Thin green or black films on the surfaces of components from different assemblages are also not uncommon. Finally, many hollow voussoir tiles from the York Street assemblage display thick black platy and protuberant growths formed over surfaces and ancient breaks, particularly the materials from the Period III Great Bath roof. This range of features does not appear to be as prominent in other assemblages from the complex as in the York Street collection, yet they are still frequently present. As pXRF is fundamentally a surface technique, with extremely shallow penetration depths for many elements in relatively dense mediums such as rock (Potts et al. 1997: 32-33) and ceramic (Caesaereo et al. 2008: 208), the sampling of areas with even very minor deposits of accretions is likely to distort any compositional readings generated. Non-invasive surface analysis of the ceramic building materials from the Roman Baths was therefore discounted.

Offcuts taken from the CBM during the creation of fresh breaks (section 8.2.1) were instead analysed. The use of offcuts was preferential to analysis of the fresh breaks on the bricks and tiles themselves as it allowed the destructive shaping of samples to create flatter surfaces more suitable for analysis, which was not permissible on the parent sherds. Analysis of the fresh break surface on each offcut also had the advantage of avoiding any features or deposits present on the sherd surfaces, though proximity to the edge of the sherd may still have resulted in post-depositional chemical changes to elements such as Fe (Degryse and Braekmans 2014: 194). A consequence of the reliance upon offcuts was that only a single location upon each sherd could be sampled in contrast to previous studies that analysed three distinct surface locations per tile and averaged results (e.g. Machin 2021: 344, Warry 2021: 373). While not possible to directly mitigate this, it was hoped that the inclusion of a large sample population would nevertheless enable compositional variation within fabric groups and closely related material from the same structures to be evaluated and understood.

### 8.3.2 Sampling Strategy

The aim of the sampling strategy was to achieve a large population that closely approximated the composition of the Roman Baths assemblages in the proportions of different fabric groups and tile types included. Not all offcuts from the creation of fresh breaks were of a sufficient size for analysis, i.e. wide enough to fill the 10mm diameter of the pXRF analyser window, so were not retained. In order to achieve the calculated infinite sample thickness for the range of elements being analysed for (see Appendix F), the decision was taken to exclude all collected offcuts below 7mm in thickness. This left 539 suitable offcuts. While the total number was considerable, material from sherds of certain fabric groups or tile types were under-represented in comparison to their frequency in the recorded assemblages. Given these restrictions, a sample size of 450 was selected as this gave a good balance between a large sample number and inclusion of a diverse range of material that strongly reflected the composition of the assemblages, without any particular fabric groups or component types becoming extortionately over-represented.

**Table 8.2: Comparison of the proportions of different fabric groups identified in the recording of the assemblages from the Roman Baths (section 9.2.2) and the proportions and sample numbers of the population of offcuts selected for pXRF analysis.**

| Fabric Group | Proportion of Assemblages (%) | Sample Proportion (%) | Sample Number |
|---|---|---|---|
| F01 | 6.0 | 3.8 | 17 |
| F03 | 6.8 | 5.1 | 23 |
| F04 | 9.7 | 12.6 | 57 |
| F04M | 1.8 | 1.1 | 5 |
| F05 | 9.0 | 7.5 | 34 |
| F05M | 3.7 | 4.9 | 22 |
| F06 | 9.7 | 7.7 | 35 |
| F06M | 1.3 | 0.2 | 1 |
| F07 | 12.9 | 13.1 | 59 |
| F08 | 5.7 | 5.5 | 25 |
| F11 | 4.4 | 4.0 | 18 |
| F12 | 5.8 | 6.4 | 29 |
| F12M | 1.4 | 1.3 | 6 |
| F14 | 3.2 | 2.7 | 12 |
| F15 | 3.3 | 3.5 | 16 |
| F15M | 0.6 | 1.1 | 5 |
| F16 | 1.0 | 1.8 | 8 |
| F16M | 0.4 | 0.7 | 3 |
| F17 | 7.3 | 10.2 | 46 |
| F18 | 4.6 | 6.9 | 31 |
| Unidentified | 1.4 | 3.8 | 17 |

A range of material was also sampled in order to compare with the results from the Roman Baths ceramic building materials (Table 8.3). This predominantly derived from Tim Darvill's (1979, 1980, 1982, 1986, Darvill and McWhirr 1984) investigations of Roman CBM from Gloucestershire and Wiltshire, which included offcuts from a wide range of different stamped tile groups as well as fired clay and brick samples from the excavated kilns at Minety (e.g. Scammell n.d.). These were supplemented by a number of sherds from Fishbourne Roman Palace and other sites.

**Table 8.3: Table showing the number of samples analysed using pXRF for comparative materials from South Gloucestershire, Gloucestershire, West Sussex and Bournemouth.**

| Site | Stamp | Quantity |
|---|---|---|
| Cirencester | ARVERI | 8 |
| Kingscote Roman Settlement | ARVERI | 1 |
| Cirencester | TPF | 7 |
| Cirencester | TPFA | 5 |
| Cirencester | TPFB | 1 |
| Cirencester | TPFP | 6 |
| Cirencester | TPLF | 6 |
| Cirencester | LHS | 6 |
| Cirencester | TCM | 2 |
| Hucclecote Roman Villa | TCM | 1 |
| Minety Roman Kiln Site | - | 9 |
| St Oswald's Roman Kiln Site | - | 1 |
| Great Witcombe Roman Villa | - | 3 |
| Fishbourne Roman Palace | - | 7 |
| Wick Roman Villa/Possible Kiln Site | - | 2 |
| Aston Magna Post-Med Brickworks | - | 1 |
| Paxford Post-Med Brickworks | - | 1 |
| Clay Lane, Bitton, brick sample | - | 2 |
| Bournemouth brick sample | - | 1 |

The analysis of the comparative materials followed the conventions adopted for the Roman Baths samples, including only one offcut with a thickness of 7mm or more per sherd. The number of offcuts included from each stamped tile group was calculated to be reflective of the relative frequency of their finds across Gloucestershire, northwest Wiltshire, and northeast Somerset to date (table 8.4). This includes multiple samples for all of the most common stamps (section 7.2). While Darvill's collection also includes a number of samples from tiles with less common stamps, for example IVC DIGNI, these offcuts were all too thin or too small to be included.

**Table 8.4: Comparison of the proportions of number of finds of stamped tiles to date in Gloucestershire, Wiltshire, and northeast Somerset (see section 7.2) and the number and proportions of offcuts from each stamp group included in this analysis. Other stamps with no offcuts included in analysis were omitted from these calculations. Stamp occurrences compiled from *RIB* II(5), Tomlin 2017, Warry 2017 and Warry 2021 (personal communication).**

| Stamp | Regional Proportion (%) | Sample Proportion (%) | Sample Number |
|---|---|---|---|
| ARVERI | 17.1 | 20.9 | 9 |
| TPF | 19.8 | 16.3 | 7 |
| TPFA | 9.3 | 11.6 | 5 |
| TPFB | 1.2 | 2.3 | 1 |
| TPFP | 12.0 | 14.0 | 6 |
| TPLF | 10.5 | 14.0 | 6 |
| LHS | 12.8 | 14.0 | 6 |
| TCM | 17.4 | 7.0 | 3 |

## 8.3.3 Instrument, Mode and Analyses

The portable energy-dispersive X-ray fluorescence instrument used in this study was a Thermo Fisher Scientific Niton XL3t GOLDD+ analyser with a 50kV 200µA Ag anode. The same analyser (pXRF 2) at Bournemouth University was used throughout the duration of the analyses. The instrument's Mining (Cu/Zn) mode (Thermo Fisher Scientific 2010: 81) was employed with a 30:30:30:60s beam duration (table 8.5). Three measurements were made on the same point of each sample and the results averaged. This mode, beam time and number of repeat measurements were selected after a trial and comparison of different instrumental modes and beam times on certified reference materials and brick and tile samples (appendix G).

**Table 8.5: Table summarising the portable X-ray Fluorescence instrument, mode, beam time and number of repeat measurements per sample.**

| Instrument | Mode | Beam Duration (s) | | | | Total Time Per Measurement (s) | Measurements Per Sample |
|---|---|---|---|---|---|---|---|
| | | Main | Low | High | Light | | |
| Niton XL3t GOLDD+ | Mining (Cu/Zn) | 30 | 30 | 30 | 60 | 150 | 3 |

During analysis the CCRMP TILL-4 certified reference material supplied with the analyser was used to measure instrumental precision and accuracy and monitor any instrumental drift. This standard was chosen as it is closely comparable in composition to many of the ceramics analysed, particularly in regard to a suite of important elements such as Fe, Si and Al. Evaluation of instrumental performance was accomplished through triplicate repeat measurement of the TILL-4 standard before and after analysis of every 10 samples, i.e. 30 readings.

Bourke and Ross (2016: 150) have noted reduced precision for sample readings taken using pXRF shortly after the instrument has been turned on. This effect was also observed in the measurements of repeat analyses of the TILL-4 standard with the instrument used in this study. In order to negate any potential impact, the analyser was warmed up for approximately one hour through repeat standard measurements before any ceramic building material analyses were conducted. All analyses were performed with the instrument suspended upside down in a shielded test stand, with the offcut placed on top of the analyser nozzle and the same point on each sample analysed for each repeat measurement. Analysis used the entire area of the 10mm diameter window of the instrument, rather than a 3mm collimated spot (Thermo Fisher Scientific 2010: 234-5). Helium venting was not used with the analyser because trial analyses (Appendix G) indicated that the instrument was able to provide precise readings for light elements such as silicon, aluminium, potassium and calcium for both certified reference materials and CBM samples without it. While precision for measurements of magnesium and phosphorus was much worse, the value of improved precision for such elements did not appear proportional to the extra time or resources required to use helium venting with the instrument during analyses.

### 8.3.3 Statistical Methods

Three compositional readings were taken per sample using pXRF, and the results averaged. This data was then imported into the open-source R program (version 4.1.3) for statistical analysis and investigation. Principal component analyses (PCA) were completed and graphed in R using the factoextra package. Ten elements were selected for inclusion in these analyses, which were iron (Fe), calcium (Ca), silicon (Si), aluminium (Al), titanium (Ti), potassium (K), rubidium (Rb), strontium (Sr), zirconium (Zr) and niobium (Nb). These elements were chosen for PCA for two reasons. Firstly, evaluation of CRM and CBM measurements demonstrated that they were consistently measured with acceptable limits of accuracy and precision (appendix H). Secondly, these elements were present above limits of detection in every CBM sample (table H.3), which is a requirement for principal component analyses, for this technique cannot incorporate any missing values. The results for the chosen elements were converted from parts per million (ppm) to logarithmic values for PCA, in order to balance the contribution of major, minor and trace elements values to the variation in the dataset. During analyses the principal component of variation, i.e. PC 1, was discarded. This decision was made because, in studies of archaeological ceramics, this component of variation has been shown (e.g. Baxter and Freestone 2006: 524) to be the result of the dilution of the background matrix values by varying proportions of inclusions, the so-called 'temper effect'. The values for principal components of variation two and three calculated for each sample were therefore used instead during these analyses.

# 9 Analysis of the Ceramic Building Materials of the Roman Baths

This chapter will present the results of the novel analyses of the ceramic building materials from the Roman Baths. The findings from the recording of macroscopic features of sherds, including tile forms, marks, impressions and post-depositional accretions, are considered first. The results of the microscopic analysis of ceramic fabrics and inclusions are then presented, and any relationships between certain components or assemblages and fabric groups are highlighted. Finally, the results of portable X-ray fluorescence analysis of offcuts from the Roman Baths are examined, and these are compared to analyses of regional comparative samples in order to suggest sources for certain fabric groups and tile types.

## 9.1 Ceramic Building Material Recording Results

### 9.1.1 Overview of Assemblages

In total, 1100 sherds from the four assemblages of ceramic building materials from the Roman Baths were analysed and recorded.

**Table 9.1: Table showing the total sherd number, proportion of total sherds analysed, total mass and mean sherd weight and mean sherd size of ceramic building materials analysed from each assemblage.**

| Assemblage | Number of Sherds Analysed | Proportion of Total Sherds Analysed (%) | Total Mass (kg) | Mean Sherd Mass (g) | Mean Sherd Size (mm) |
|---|---|---|---|---|---|
| East Baths (EB) | 550 | 50 | 207 | 378 | 128 |
| Spring Reservoir (SR) | 49 | 4 | 55 | 1132 | 182 |
| Temple Precinct (TP) | 262 | 24 | 78 | 305 | 126 |
| York Street (YS) | 239 | 22 | 294 | 1465 | 256 |
| Total | 1100 | 100 | 635 | - | - |

There were clear disparities in the size and weights of sherds in the different assemblages (Table 9.1). While the East Baths and Temple Precinct bricks and tiles had very similar mean sherd masses and dimensions, those of the Spring Reservoir and York Street assemblages were on average longer and at least three times heavier. This suggests that the assemblages experienced differing degrees of movement, disturbance, and fragmentation prior to recovery, which is perhaps unsurprising given the different excavation histories and sources of these materials (section 3.4).

### 9.1.2 Component Range and Frequency

Sherds of 15 different tile types were identified from the ceramic building material assemblages of the Roman Baths (Table 9.2). The total assemblage was dominated by hollow voussoir sherds, fragments of brick and undiagnostic combed tiles, which could have come from hollow voussoirs, box flues or other combed components. Together with identified box flue sherds these four tile types comprised approximately 72% of the combined assemblages. This high proportion is unsurprising given the nature of the site, for these components would all have been employed in Roman hypocaust and/or vaulted structures. This value would of course increase if other, rarer tile types used in heating or in vaulted roofs were included, for example half-box flue tiles, Westhampnett hollow voussoirs (section 2.4.2) and identified voussoir bricks.

The limited numbers of sherds of tegulae (6.9%) and imbrices (6.0%) indicate that roof material comprised only a modest component of the assemblage. Warry (2020: 8) calculated an expected ratio of 2.4:1 for tegulae and imbrices fragments from a complete roof due to the larger volume of the tegulae. The broadly 1:1 ratio observed in each of the collections where these sherd types are present (Table 9.2) may therefore suggest preferential robbing of tegulae from these roofs or assemblages to reuse elsewhere as seen, for example, in the tegula drain in the southern corridor of the West Baths (e.g. Cunliffe 1976: figure 3).

Many remaining tile types are distinguished by their small sherd count (Table 9.2). Due to the fragmentation of the assemblages many sherds could not be identified beyond the brick or combed tile categories, so it is likely that a range of undiagnostic sherds from combed half-box flue tiles, tapering voussoir bricks and other tile types ended up under general classifications instead.

**Table 9.2: Table listing the number of sherds and mass of every tile type identified in the assemblage and the proportion of each tile type in the total assemblage.**

| Tile Type | Number of Sherds | Proportion of Total Sherds Analysed (%) | Sum of Sherd Mass (kg) | Proportion of Total Mass (%) |
|---|---|---|---|---|
| Hollow voussoir | 254 | 23 | 229 | 36 |
| Brick | 241 | 22 | 161 | 25 |
| Combed tile | 240 | 22 | 50 | 8 |
| Tegula | 76 | 7 | 36 | 6 |
| Imbrex | 66 | 6 | 12 | 2 |
| Box flue tile | 55 | 5 | 19 | 3 |
| Voussoir brick | 40 | 4 | 54 | 9 |
| Westhampnett hollow voussoir | 23 | 2 | 42 | 7 |
| Moulded brick | 7 | <1 | 9 | 1 |
| Half box flue | 6 | <1 | 2 | <1 |
| Flat tile | 3 | <1 | 2 | <1 |
| Curved Tegula | 1 | <1 | <1 | <1 |
| Mammata tile | 1 | <1 | 1 | <1 |
| Pilae brick | 1 | <1 | 4 | <1 |
| Wall tile | 1 | <1 | <1 | <1 |
| Unidentified | 85 | 8 | 13 | 2 |
| Total | 1100 | - | 635 | - |

There are disparities in the number of common components recorded in each assemblage. In particular, the York Street material yielded the highest number of hollow voussoir tiles (149), despite this assemblage comprising under 22% of the total sample population, versus the 50% of the East Baths contribution (table 9.1). The East Baths material was primarily and almost equally comprised of brick and combed tile fragments (table 9.3). The Temple Precinct assemblage had a large number of tegula and imbrex fragments, especially given that it constituted just under a quarter of the total assemblage. Though small, the Spring Reservoir assemblage is comprised almost solely of bricks, voussoir bricks and moulded bricks. These disparities confirm significant differences in the structural sources, post-depositional histories, and circumstances of recovery for material from each assemblage (section 3.4).

The occurrence of rare tile types in only certain assemblages is significant, with all Westhampnett hollow voussoir sherds from the York Street assemblage, half box flue tile sherds in the East Baths and Spring Reservoir assemblages, and moulded bricks only in the Spring Reservoir assemblage (Table 9.3). This indicates that certain components were only supplied to, or survived until recovery in, specific structures or areas.

**Table 9.3: Table showing the number of sherds of each tile type identified in each assemblage, and the proportion of sherds of each tile type in each assemblage from the East Baths (EB), the Spring Reservoir (SR), the Temple Precinct (TP) and York Street (YS).**

| | Number of Sherds | | | | Proportion (%) | | | |
|---|---|---|---|---|---|---|---|---|
| **Tile Type** | **EB** | **SR** | **TP** | **YS** | **EB** | **SR** | **TP** | **YS** |
| Hollow voussoir | 69 | 0 | 36 | 149 | 27 | 0 | 14 | 59 |
| Brick | 170 | 23 | 33 | 15 | 71 | 10 | 14 | 6 |
| Combed tile | 166 | 1 | 56 | 17 | 69 | 0 | 23 | 7 |
| Tegula | 20 | 0 | 45 | 11 | 26 | 0 | 59 | 14 |
| Imbrex | 17 | 0 | 41 | 8 | 26 | 0 | 62 | 12 |
| Box flue tile | 43 | 1 | 5 | 6 | 78 | 2 | 9 | 11 |
| Voussoir brick | 22 | 15 | 0 | 3 | 55 | 38 | 0 | 8 |
| Westhampnett hollow voussoir | 0 | 0 | 0 | 23 | 0 | 0 | 0 | 100 |
| Moulded brick | 0 | 7 | 0 | 0 | 0 | 100 | 0 | 0 |
| Half box flue | 5 | 1 | 0 | 0 | 83 | 17 | 0 | 0 |
| Flat tile | 0 | 0 | 3 | 0 | 0 | 0 | 100 | 0 |
| Curved Tegula | 0 | 0 | 1 | 0 | 0 | 0 | 100 | 0 |
| Mammata tile | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 100 |
| Pilae brick | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 100 |
| Wall tile | 0 | 0 | 1 | 0 | 0 | 0 | 100 | 0 |
| Unidentified | 38 | 1 | 41 | 5 | 45 | 1 | 48 | 6 |

### 9.1.3 Hollow Voussoirs and Westhampnett Hollow Voussoirs

A wide range of hollow voussoir types were found in the assemblages at the Roman Baths. In total, 11 different sizes were identified in addition to three sizes of Westhampnett hollow voussoir components, though further types of each may await discovery. Hollow voussoir sherds were distinguished from Westhampnett sherds through identification of semi-circular cutouts placed low on the face of the tile above the base (see figure 9.1). Where these were absent, sherds were recorded as hollow voussoir tiles instead, though a small number were later reclassified as Westhampnett hollow voussoirs on the basis of their maximum widths, extreme thickness, and coarse fabrics (section 9.2.4).

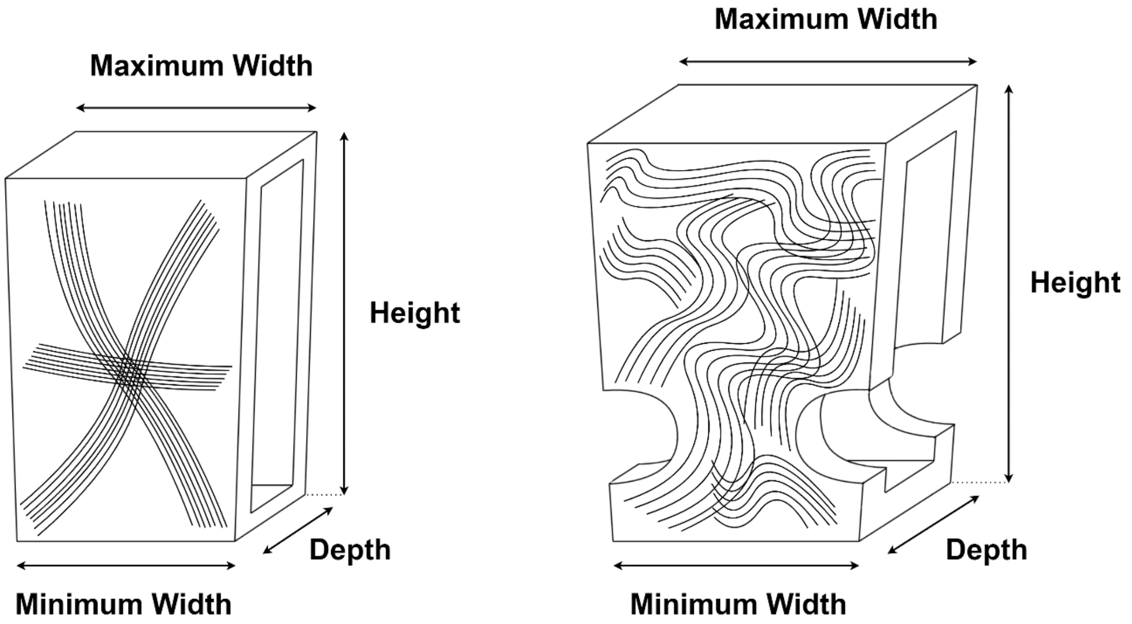


**Figure 9.1: Illustration of a hollow voussoir, left, and a Westhampnett hollow voussoir, right, with dimensions measured during recording specified.**

In order to better understand the range in hollow voussoir types and dimensions, the measurements of fragmentary sherds were supplemented with measurements taken from intact components from the York Street assemblage. Composite measurements were also taken from large sections of hollow voussoir roof fragments currently on display around the Great Bath. Type HV01 is the range in measurements for hollow voussoir tiles from the Period III roof of the Great Bath (figure 9.2, see Appendix I).

Distinctively tall and thin HV02 sherds (figure 9.2) were predominantly found in the Temple Precinct assemblage, though a small number were also identified in the York Street material. These fragmentary sherds matched Cunliffe and Davenport's descriptions (1985: 134-5) of the hollow voussoirs used in the roof of the Spring Reservoir Enclosure and must therefore have been from that structure, explaining the concentration of these sherds in the Temple Precinct.

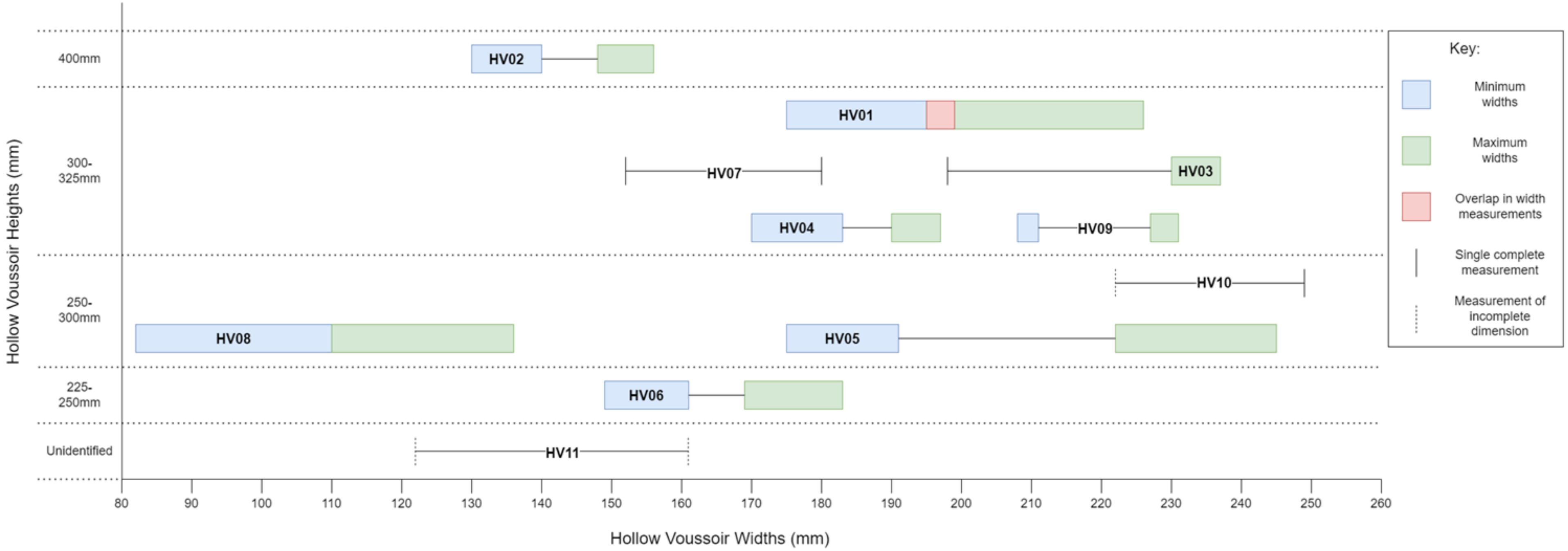


**Figure 9.2: Graph showing the range in maximum and minimum widths and the heights of different hollow voussoir types identified.**

No other types of hollow voussoir could be easily equated to a structure at the site. All examples of HV08 came from the East Baths assemblages, suggesting an origin in that part of the complex. The remaining hollow voussoir types were predominantly found in the York Street assemblage, though type HV07 did include a single sherd among the Temple Precinct material. The source buildings for many types of hollow voussoir tile from the site are therefore uncertain.

All Westhampnett hollow voussoir tile fragments were found in the York Street assemblage and were supplemented with the measurement of a single complete WH1 component on display and previously measured by Lancaster (2012). Three different types were identified and varied significantly in their dimensions, with two large types and one small (figure 9.3), though even the smallest type was far thicker than typical hollow voussoirs sherds (see Appendix I). The large maximum widths of WH1 and WH2, over 250mm wide, also contrasted strongly with those from the hollow voussoirs, with only the comparatively rare HV10 approaching a similar size. This suggests a clear distinction in production between the chunky Westhampnett style components and thinner typical hollow voussoirs, rather than a gradual evolution between the different styles of component at the site.

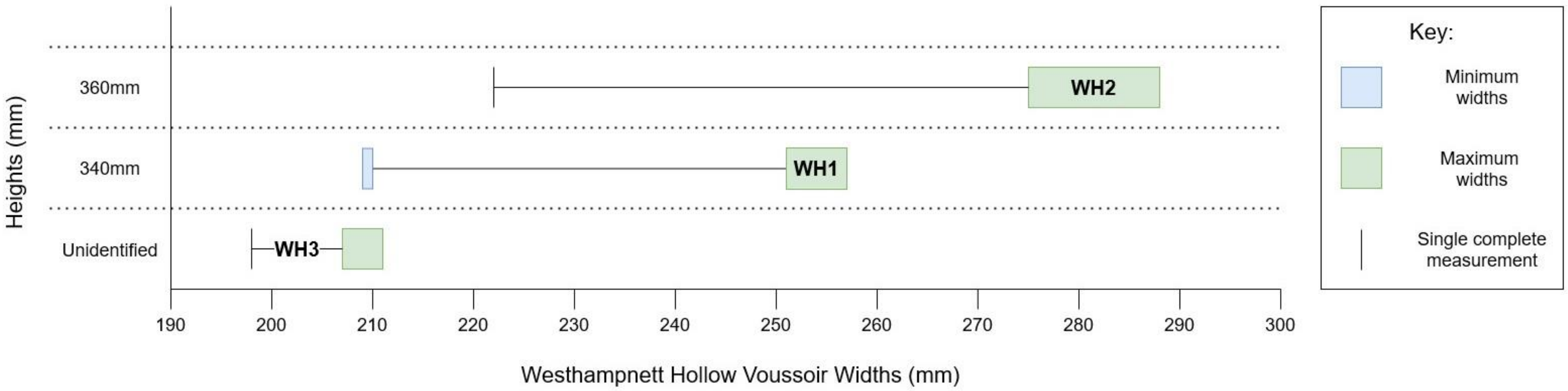


**Figure 9.3: Graph showing the range in maximum and minimum widths and the heights of different Westhampnett hollow voussoir types identified.**

### 9.1.4 Tegula Cutaways and Flanges

Four different tegula cutaway types were identified among the assemblages from the Roman Baths (figure 9.4), in addition to 12 different flange types.

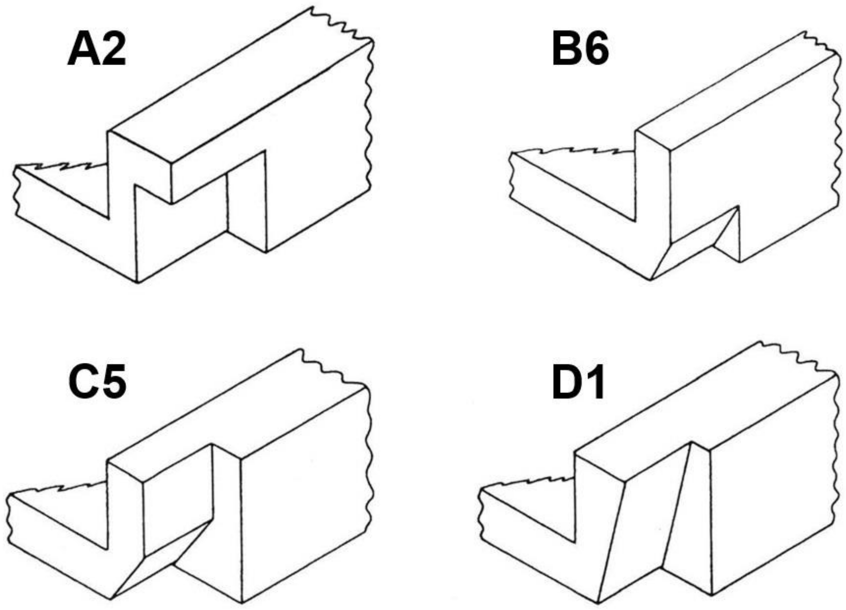


**Figure 9.4: Isometric illustration of the cutaways identified on Tegula tile sherds in the Roman Baths assemblages, following Warry's (2005: figure 1.2) cutaway types. Modified from Major and Tyrell (2015: figure 719). Major, H. and Tyrrell, R., 2015. The Roman Tile. Internet Archaeology, 40. [http://dx.doi.org/10.11141/ia.40.1.major7](http://dx.doi.org/10.11141/ia.40.1.major7) © Internet Archaeology.**

Types B6 and C5 were the most common cutaways identified among the assemblage (table 9.4). Types A2 and D1 were both rare, and one example of D1 from the East Baths (OTK 659) was only a possible assignation as the cutaway was not complete. There is a considerable range in sherd thicknesses for cutaways of each group, and substantial overlap between measured thicknesses of sherds of each type.

**Table 9.4: Table showing the range and frequency of different tegula cutaway types identified and the range of thicknesses for sherds of each type.**

| Cutaway Type | Frequency | Thicknesses (mm) |
|---|---|---|
| A2 | 1 | 19 |
| B6 | 10 | 20-28 |
| C5 | 8 | 16-28 |
| D1 | 2 | 15-21 |
| Total | 21 | - |

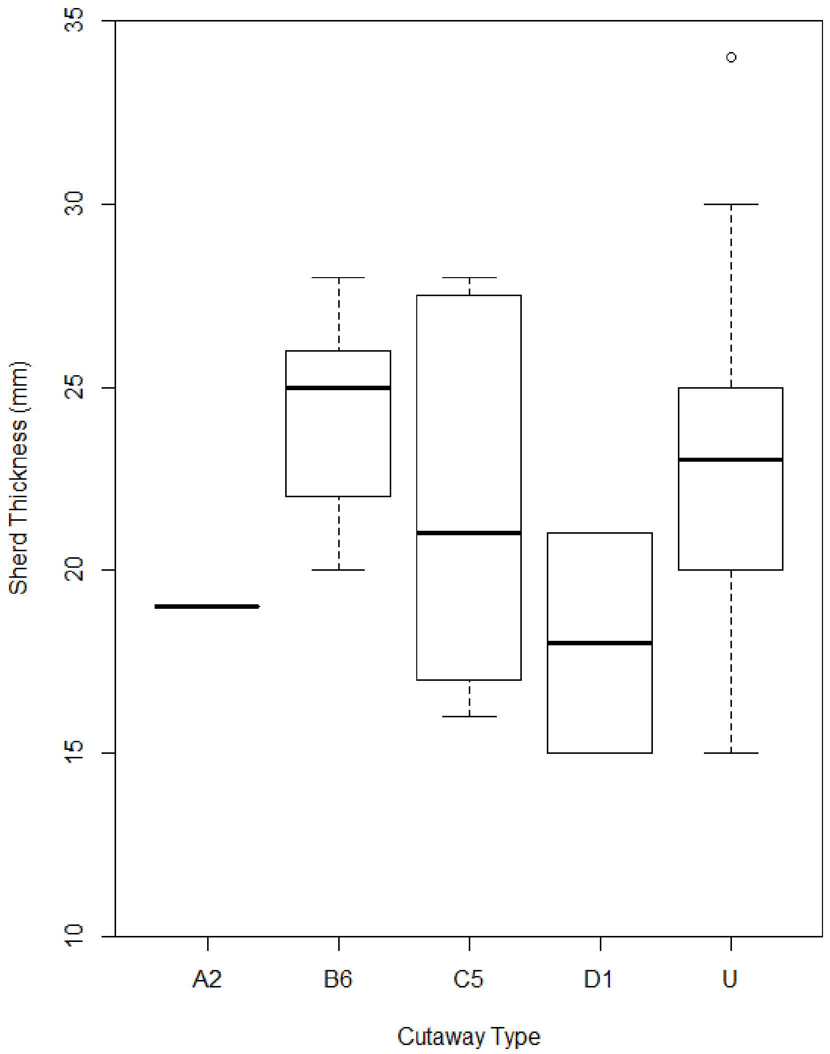


**Figure 9.5: Boxplot of tegula sherd thicknesses by cutaway type.**

Flange types L, S and V were the most common (see Appendix I). Most other flanges were recorded from multiple sherds, though potentially from as little as one complete tile. One sherd (OTK 757) had a flange profile that changed from type F to V along its length. As Warry (2005: 4) noted, tegula flanges appear to have often been made by hand and thus differed slightly along their length and presumably between the products of different tile makers. While identification of flange forms is therefore not as precise as cutaway types, it still has potential to shed light on production.

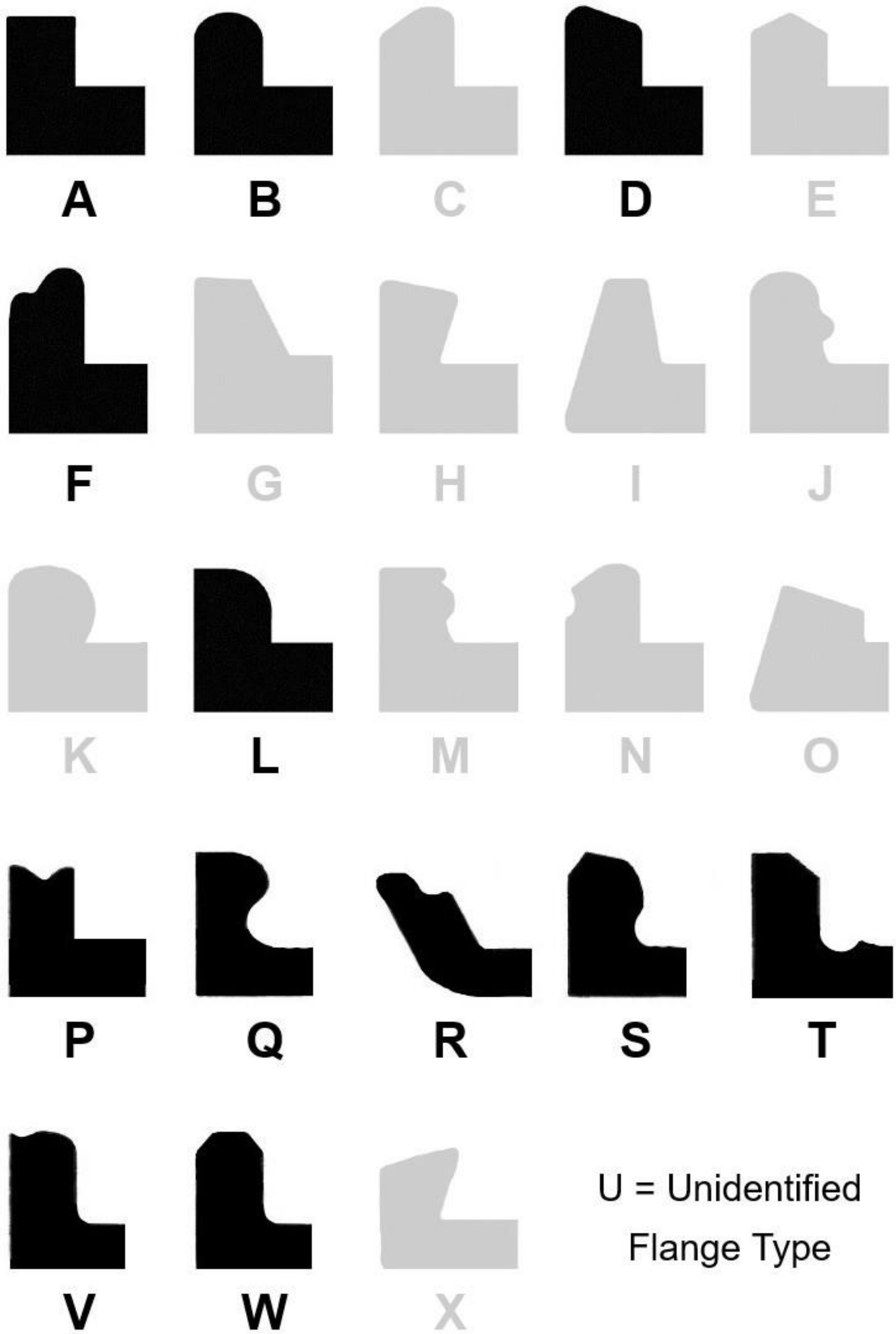


**Figure 9.6: Illustration of the different Tegula flange profiles identified from sherds of the Roman Baths assemblages. The flanges shaded out were not recorded on any tegula sherds. Drawings for flanges A-O after Payne (2016: figure 1), flange profiles P-X have been produced during this research.**

There are overlaps in thicknesses between a wide range of different flange types (figure 9.7), though certain types do stand out. Sherds with flanges L and S were typically thicker than sherds with other flange types, with median values both above 25mm. To this group might be added sherds of flange type V with a substantial median value of 24mm, though presenting wider overlap with other groups. As one sherd had a flange profile that changed from F to V over its length this suggests that these two flange types are also closely associated. Flanges L, S, V and F may therefore represent the remnants of a batch of thick tegulae.

**Table 9.5: Table showing the number of sherds with both identifiable tegula cutaway types and flange forms for each cutaway and flange group. Unidentified flange types and flange types with no cutaways identified have been omitted.**

| | Flange Form | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Cutaway Type** | **B** | **D** | **F** | **L** | **P** | **R** | **S** | **T** | **V** |
| A2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| B6 | 0 | 1 | 1 | 1 | 0 | 0 | 2 | 0 | 1 |
| C5 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 3 |
| D1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |

Cross-referencing the tegula cutaways and flange types produces limited conclusions. The groupings of thicker tegulae with flange types L, S, V and F all have examples of type B6 cutaways (table 9.5) which might be consistent with production in a batch. However, B6 cutaways were also present with other flange types, and conversely S and V flanges were also found with type C5 cutaways. This indicates that the relationship between flanges and cutaway types is complex. The small number of sherds (17) with identified cutaways and flange types suggests that any patterns identified are likely to be due to chance survival and recovery.

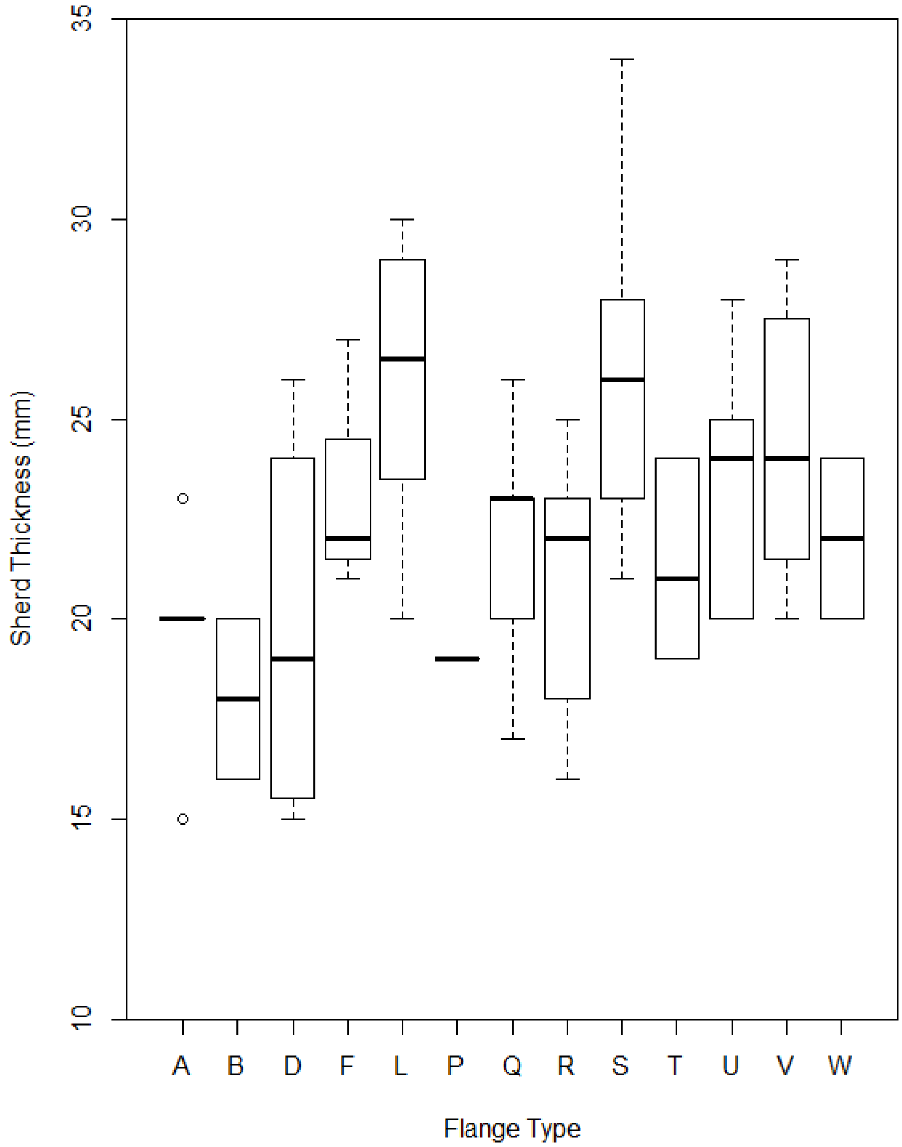


**Figure 9.7: Boxplot of tegula sherd thicknesses by flange type. U represents sherds with unidentified flange types.**

## 9.1.5 Marks and Impressions

A range of marks and impressions were observed on the ceramic building materials from the Roman Baths (table 9.6). Combing was the most common mark identified, which is unsurprising given the dominance of combed tile components in the overall assemblage.

**Table 9.6: Table showing the number of sherds recorded with different marks present and the range of tile types those impressions were found upon in the Roman Baths assemblages.**

| | Tile Type | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Marks and Impressions** | **Box flue tile** | **Brick** | **Combed tile** | **Flat tile** | **Half box flue** | **Hollow voussoir** | **Pilae brick** | **Tegula** | **Voussoir brick** | **Wall tile** | **Westhampnett hollow voussoir** | **Unidentified** |
| Combing | 43 | 2 | 225 | 0 | 3 | 227 | 0 | 0 | 0 | 0 | 19 | 2 |
| Signature mark | 0 | 7 | 0 | 0 | 0 | 0 | 1 | 4 | 3 | 0 | 0 | 1 |
| Knife scoring | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 2 |
| Animal print | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Nail hole | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Hobnail print | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Relief-patterning | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Knife blade imprint | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Tally mark | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

A range of signature marks, comprising arcs or loops drawn with varying numbers of fingers on clay prior to firing (e.g. Brodribb 1987: 99-105), were also present upon various types of bricks and several tegula sherds. Knife scoring was recorded on a small number of sherds, most of which were from tile types likely to have been used in heated and/or vaulted rooms. Other marks and impressions were extremely rare, which is surprising given the accidental nature of animal prints and possibly hobnail impressions. While the animal marks from sampled sherds all appeared to be paw prints of dogs, a single sheep or goat hoof impression was also noted in the face of a voussoir brick in the arch section of the Great Bath roof, currently on display next to the Great Bath.

No stamped tiles were identified from the assemblages of the Roman Baths. The single relief-patterned tile sherd excavated by Cunliffe and Davenport (1985: 134-5) from the Temple Precinct was recorded and was part of a hollow voussoir of type HV07 (section 9.1.3). As Betts et al. (1997: 118) noted, it has a type 53 die. No other definite relief-patterned tiles were identified, but a small number of sherds had a distinctive wavy impression which was both very deep and very wide (figures 9.8 and 9.9).


**Figure 9.8: Photograph of sherd OTK 1069 and the unusual deep and wide wavy keying present upon this sherd. Photographs taken with permission from the Roman Baths, Bath and North East Somerset Council.**

Two sherds, OTK 243 and 1069, are suggested to be the product of the application of a wavy patterned roller die. Both sherds are fragmentary and cannot be assigned to a specific tile type, but may be from hollow voussoir or box flue tiles. While the marks of one or both sherds may instead be the result of combing, the impressions appear broadly similar to those of a modern pottery roller-die and could well be the result of a larger, hand-carved Roman version. Moreover, Scammell (n.d.: 15) described fragments of apparently similar material being recovered from excavations at the Minety kiln site (figure 9.10), with the bottom right sherd being particularly reminiscent of the pattern on OTK 243 (see figure 9.9). This suggests the previously unidentified use of a wavy roller-die to key tiles from the Roman Baths.

**Figure 9.9: Photograph of sherd OTK 243, showing the distinctive deep and wide relief impressions. Longest sherd dimension is 82mm across. Photographs taken with permission from the Roman Baths, Bath and North East Somerset Council.**

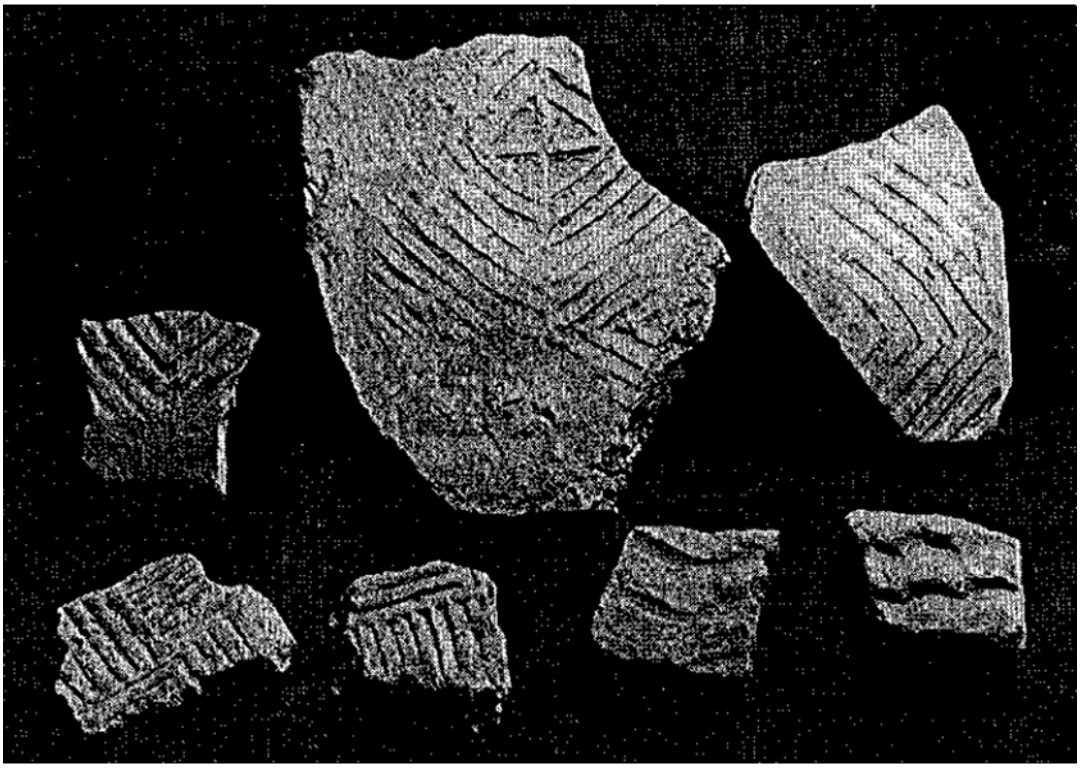

**Figure 9.10: Photograph of fragments of roller-die tiles recovered during excavations of the Minety kiln site. Two possible fragments of wavy relief-patterning can be seen to bottom right. From Scammell (n.d.: figure 11). Reproduced with kind permission from Wiltshire Museum.**

### 9.1.6 Post-depositional Concretions

A range of sherds in the York Street assemblage yielded distinctive dark-grey or black platy and/or protuberant surface formations ranging from 2mm to 60mm in thickness (figure 9.11). These are the subject of research by Sedimentologist Maurice Tucker, who has suggested that they formed when the ceramic building materials were immersed in the waters of the Great Bath after the collapse of the roof (Tucker 2021 pers. Comm.). Similar deposits can be seen forming around the ledges at the edges of the bath even today. These deposits were not present on any material recovered from the Spring Reservoir, where the water is at its hottest before it cools down as it travels to the Great Bath. They were also not present on any sherds from the East Baths or Temple Precinct assemblages. This suggests that these accretions are a sole phenomenon of the conditions and temperature of the Great Bath water.

Areas of thick concretions are almost solely present among hollow voussoir sherds in the York Street assemblage, especially types HV01 and HV05. While the HV01 dimensions included measurements taken from sections of roof fragments from the Great Bath, including that shown in figure 9.11, HV05 is very distinct in terms of size (figure 9.12) and fabrics (section 9.2.4) and no link to the Great Bath had otherwise been suggested.

**Figure 9.11: Photograph of a fragment of the Great Bath roof on display, with grey concretions present on the hollow voussoir tiles and coating two box flue tiles attached to the structure. Photographs taken with permission from the Roman Baths, Bath and North East Somerset Council.**

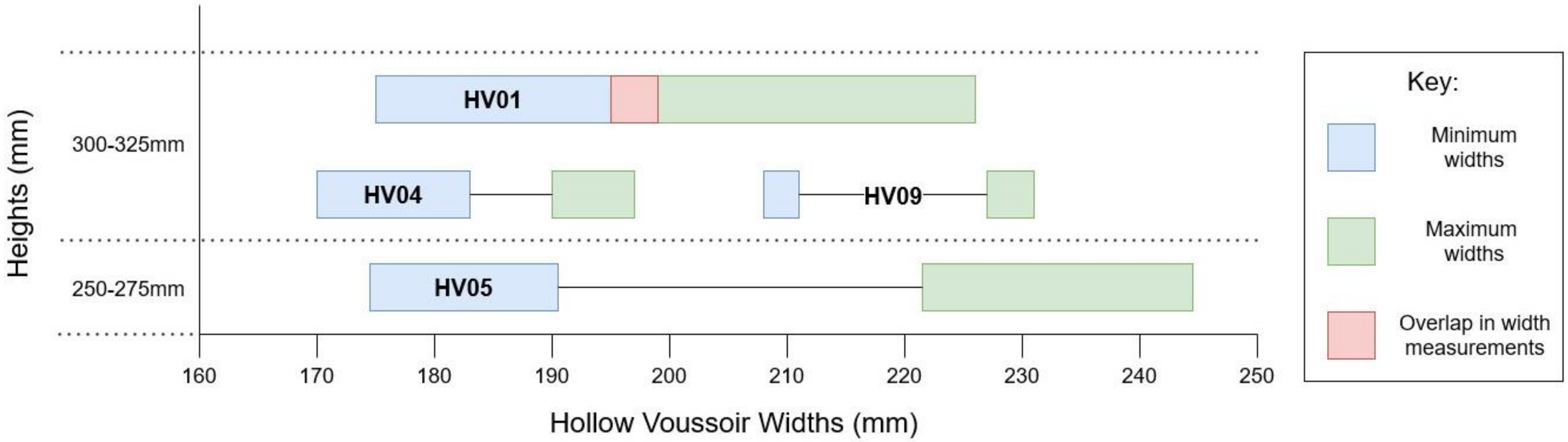


**Figure 9.12: Graph showing the minimum and maximum widths and heights of hollow voussoir types with sherds that displayed concretions typical of the Great Bath.**

Two sherds of type HV09 and one sherd of HV04 also displayed substantial concretions. Given the much more limited number of sherds identified from these groups, this could suggest that stray sherds from each eventually scattered into the Great Bath. Alternatively, the similar heights and overlap in maximum or minimum widths with those of HV01 sherds (figure 9.12) could suggest that both types are mere batch variations of HV01. A third possibility is that these hollow voussoirs could have been used to roof other bath structures and may have fallen into the water of one of those. While hollow voussoirs from roofing have been found in most other areas of the site, including the tepidarium of the West Baths during Davis's excavations (Cunliffe 1969: 133, see figure 9.13), it appears unlikely that conditions so precisely mirrored those in the Great Bath as to reproduce these deposits. As the assemblage from Cunliffe's (1976) excavations in the West Baths cannot be located, important evidence from an area of the site with multiple large bath structures is therefore absent. While these concretions are thus most likely the sole product of the Great Bath, it is impossible to be sure.

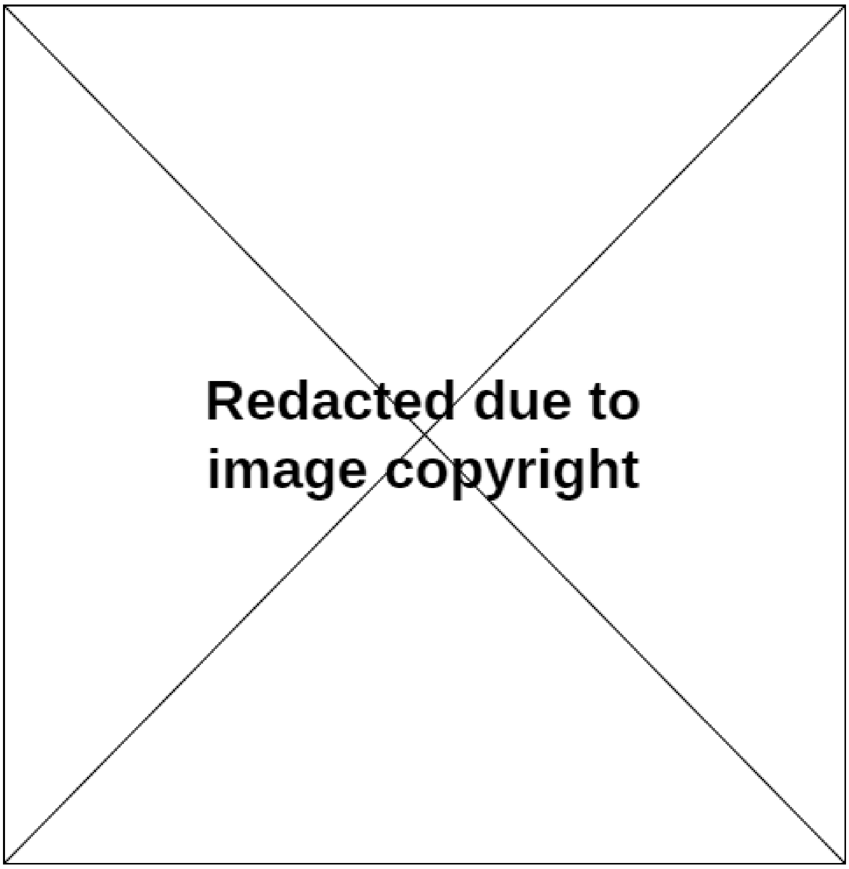


**Figure 9.13: Illustrated section of Davis's 1869 excavations in the tepidarium of the West Baths looking north, showing contiguous hollow voussoir tiles from the fallen vaulted roof of the structure. From Cunliffe (1969: figure 48), redrawn from Irvine (n.d.). © Society of Antiquaries of London.**

# 9.2 Ceramic Building Material Fabric Results

## 9.2.1 Fabric Frequencies

A range of different fabric groups were identified in the Roman Baths assemblages, using the fabric decision tree (see section 6.2.2). Four fabric groups comprised nearly half (49%) of the total assemblage by both sherd number and sherd mass. These were fabrics 04, 05, 06, 07 and massively streaky equivalents (04M-06M), see table 9.7 and Appendix I.

**Table 9.7: Table showing the number of sherds and proportion of each fabric group in the total assemblage, with streaky and massively streaky (M) fabric equivalents grouped together, e.g. 05 and 05M.**

| Fabric | Number of Sherds | Proportion of Sherds (%) | Sum of Sherd Mass (kg) | Proportion of Total Mass (%) |
|---|---|---|---|---|
| 07 | 142 | 13 | 50 | 8 |
| 05 + 05M | 140 | 13 | 103 | 16 |
| 04 + 04M | 127 | 12 | 76 | 12 |
| 06 + 06M | 121 | 11 | 79 | 12 |
| 17 | 80 | 7 | 22 | 3 |
| 12 + 12M | 79 | 7 | 84 | 13 |
| 03 | 75 | 7 | 27 | 4 |
| 01 | 66 | 6 | 37 | 6 |
| 08 | 63 | 6 | 29 | 5 |
| 18 | 51 | 5 | 25 | 4 |
| 11 | 50 | 5 | 32 | 5 |
| 15 | 43 | 4 | 19 | 3 |
| 14 | 35 | 3 | 25 | 4 |
| 16 + 16M | 15 | 1 | 22 | 3 |
| Unidentified | 13 | 1 | 5 | 1 |
| Totals | 1100 | - | 635 | - |

The remaining fabrics all comprised at least 1% of the total population. Nevertheless, the actual number of sherds recorded for F16 was very limited, as were the total number of sherds for very streaky fabric versions like F06M, F12M and F15M. These latter fabrics consistently comprised only a small fraction of their direct equivalents, with a ratio of approximately 1:5 between sherds of all massively streaky (M) fabrics and typically streaky fabrics as shown in table 9.8. This suggests that these deposits were generally only a part of those being exploited, rather than comprising distinct sediments. This is confirmed in the co-occurrence of F05 and F05M moulded bricks in the Spring Reservoir Enclosure roof (table 9.12) and F04/05/06 and massive equivalents in type HV01 hollow voussoirs from the Great Bath roof (section 9.2.4).

**Table 9.8: Table reporting the number of sherds, mass of sherds and proportions of fabrics grouped together on the presence/absence and extent of macroscopically visible cream-white streaky bands in the CBM.**

| Streaky? | Number of Sherds | Proportion of Sherds (%) | Sum of Sherd Mass (kg) | Proportion of Total Mass (%) |
|---|---|---|---|---|
| No | 511 | 47 | 222 | 35 |
| Yes | 475 | 43 | 336 | 53 |
| Massive | 101 | 9 | 72 | 11 |
| Unidentified | 13 | 1 | 5 | 1 |

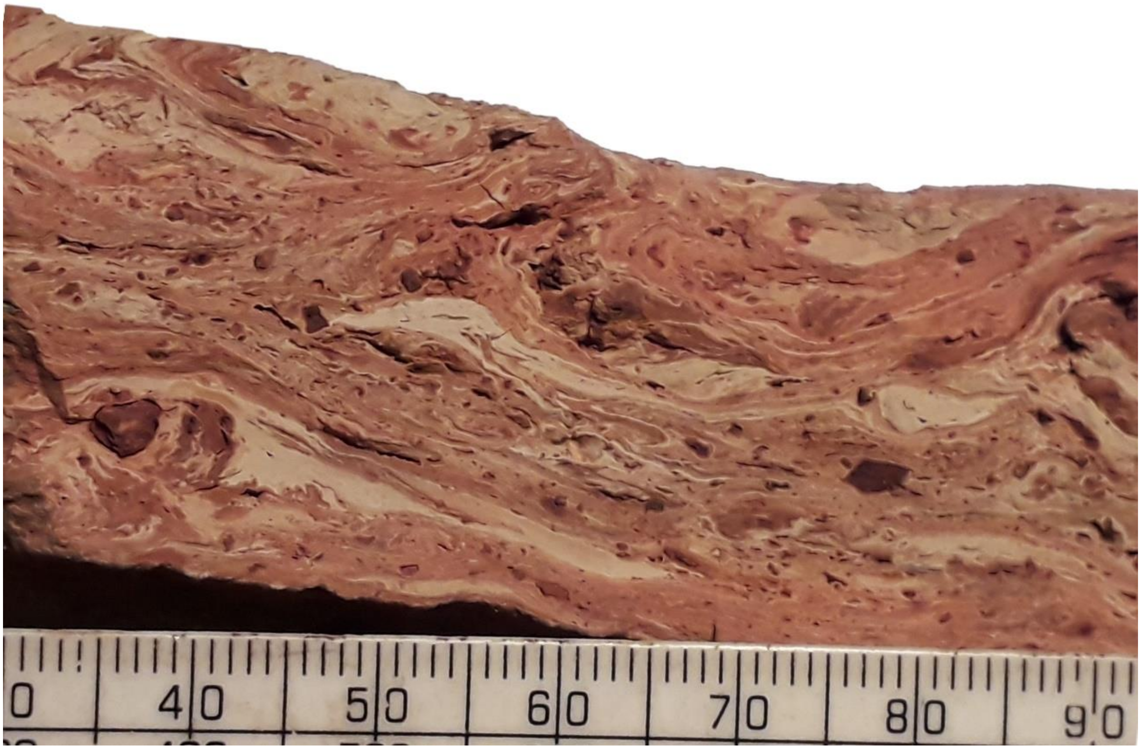


**Figure 9.14: Photograph of a voussoir brick from the ribs of the Spring Reservoir Enclosure roof, demonstrating the heterogeneous streaky appearance of 05M and similar fabrics. Photographs taken with permission from the Roman Baths, Bath and North East Somerset Council.**

Fabrics with fine quartz inclusions (i.e. predominantly c. 0.3mm in size) dominated the total assemblage (table 9.9). What is surprising is that the remainder is divided somewhat equally between very fine (quartz absent or c. 0.15mm or less) and coarse (quartz predominantly 0.5mm or larger) groups, despite the small individual contributions of many of the coarse fabrics such as F11, 14 or 16 (table 9.7). This suggests that the supply of coarse fabrics was important, though perhaps not obvious on a purely fabric by fabric basis.

**Table 9.9: Table showing the number of sherds and proportion of fabrics grouped together on the size of predominant quartz inclusions present.**

| Fabric Fineness | Number of Sherds | Proportion of Sherds (%) | Sum of Sherd Mass (kg) | Proportion of Total Mass (%) |
|---|---|---|---|---|
| Fine | 574 | 52 | 305 | 48 |
| Very fine | 268 | 24 | 125 | 20 |
| Coarse | 245 | 22 | 200 | 32 |
| Unidentified | 13 | 1 | 5 | 1 |

Most fabrics were present across multiple assemblages (table 9.10). The exceptions were F17 and 18, which despite comprising 12% of the entire assemblage by sherd count (table 9.7) were only identified among the East Baths material. While these fabrics were the last to be added to the fabric scheme, offcuts from all assemblages were re-examined using a microscope during pXRF analyses, and this confirmed that these fabrics did not occur among sherds from the Spring Reservoir, Temple Precinct or York Street assemblages. This suggests a supply of these fabrics solely to structures or phases in the East Baths.

A wide range of fabric types were also absent from the Spring Reservoir assemblage. This is likely due to the small number of sherds sampled from the assemblage, only 49, and the limited range of tile forms present (table 9.3). The lack of both F04 and F06 sherds from this material is nevertheless significant given that each comprises nearly 10% of the total assemblage (see table 9.7). This suggests that certain fabrics are likely to be associated with the production of specific components for certain structures, representing discrete batches of material moving into the site.

**Table 9.10: Table showing the number of sherds of each fabric identified from each of the Roman Baths assemblages.**

| | Assemblage | | | |
|---|---|---|---|---|
| **Fabric** | **EB** | **SR** | **TP** | **YS** |
| 01 | 31 | 1 | 21 | 13 |
| 03 | 45 | 0 | 15 | 15 |
| 04 | 69 | 0 | 29 | 9 |
| 04M | 6 | 4 | 8 | 2 |
| 05 | 24 | 7 | 34 | 34 |
| 05M | 11 | 8 | 11 | 11 |
| 06 | 13 | 0 | 43 | 51 |
| 06M | 0 | 0 | 8 | 6 |
| 07 | 99 | 15 | 25 | 3 |
| 08 | 34 | 0 | 10 | 19 |
| 11 | 16 | 0 | 22 | 12 |
| 12 | 16 | 11 | 10 | 27 |
| 12M | 8 | 1 | 0 | 6 |
| 14 | 10 | 0 | 12 | 13 |
| 15 | 25 | 2 | 6 | 3 |
| 15M | 4 | 0 | 3 | 0 |
| 16 | 1 | 0 | 1 | 9 |
| 16M | 2 | 0 | 0 | 2 |
| 17 | 80 | 0 | 0 | 0 |
| 18 | 51 | 0 | 0 | 0 |
| Unidentified | 5 | 0 | 4 | 4 |

## 9.2.2 Fabric Observations

*Fabric Colours*

Most of the fabrics identified occurred in sherds that were generally orange, pinkish-red, red or dark red-brown in colour, rarely with a reduced blue-grey core. A small number of sherds were entirely dark blue-grey, and these were often fired to the point of vitrification. Sherds of F14, F17 and F18 were often a greyish-brown colour that contrasted with other material observed. As noted above, F16 sherds were buff or pale yellow-brown but similar colours were observed in a small number of sherds of different fabrics, particularly F04. This suggests that the same materials could be fired to produce a range of colours, though shades of red and orange were predominant. Post-depositional conditions may also have changed the colour of sherds (e.g. Warry 2021:

372), but as much material from different areas of the site appears similar such alteration may have been limited.

*Fabric Hardness*

The hardness of different fabrics were observed when creating fresh breaks for fabric analysis with a small chisel and hammer. Most sherds were generally well-fired and robust, with the exception that all of the material from the Spring Reservoir proved fragile. A range of fabrics occurred in the bricks from this structure (section 10.1.3) and the common condition of all of this material indicates that the conditions in the Spring were extremely hostile, rather than the bricks having been underfired as Cunliffe and Davenport (1985: 134-135) suggested. Sherds of F01 and F11 were highly fired and extremely hard, to the point where it was often challenging to create a fresh break upon this material. Sherds from fabrics 03, 04, 05, 06, 07 and 08 were typically well-fired and some material from these fabric groups was fired to the point of vitrification, being very hard but also brittle. The remaining fabrics, for example F12, 14, 15 and 16, were also generally well-fired and resilient but rarely appeared to be vitrified. Fabrics 17 and 18 appeared to be the least well fired of all, and offcuts from these sherds could be easily shaped with a chisel in direct contrast to material from most of the other fabrics. This suggests a range of different firing temperatures employed on the CBM from the Roman Baths though, as the material from the Spring Reservoir demonstrates, post-depositional conditions may have affected the preservation of sherds.

*Voids*

Large voids were present across all fabrics, but were especially common in sherds of fabrics F04, 07, 03 and 14. These voids were generally linear and amorphous but a few distinct profiles could be discerned between fabrics, with sherds of F05, 06 and 12, for example, all having distinctive hexagon shaped voids present (figures 9.15, E.15). Irregular Y-shaped voids were also occasionally observed (e.g. figure E.29), as were roughly triangular voids with elongated tails (figures E.16, E.21). Linear voids with a five-pointed star shape (see figures E.25 and E.27) were seen across a number of fabrics, including F04, 07, 11 and 12. These voids are unlikely to be from the use of cereal chaff or other organic tempers as there were no traces of carbonaceous matter or highly localised reduction zones sometimes seen in organic tempered ceramics. Instead, they may be the result of fragments of bivalve shell and microfossils burning out during firing, for many preserved fragments of calcareous structures (e.g. figure 9.16).

Furthermore, in reduced sherds preservation was greater and these voids were still entirely filled with calcium carbonate. These preserved traces differed substantially from the crystalline secondary calcite formations which were occasionally observed in the empty voids. Though not diagnostic in themselves, the presence of voids from bivalve shell and microfossils may suggest the use of marine-derived clays from the region, many of which are notably fossiliferous (section 7.2).

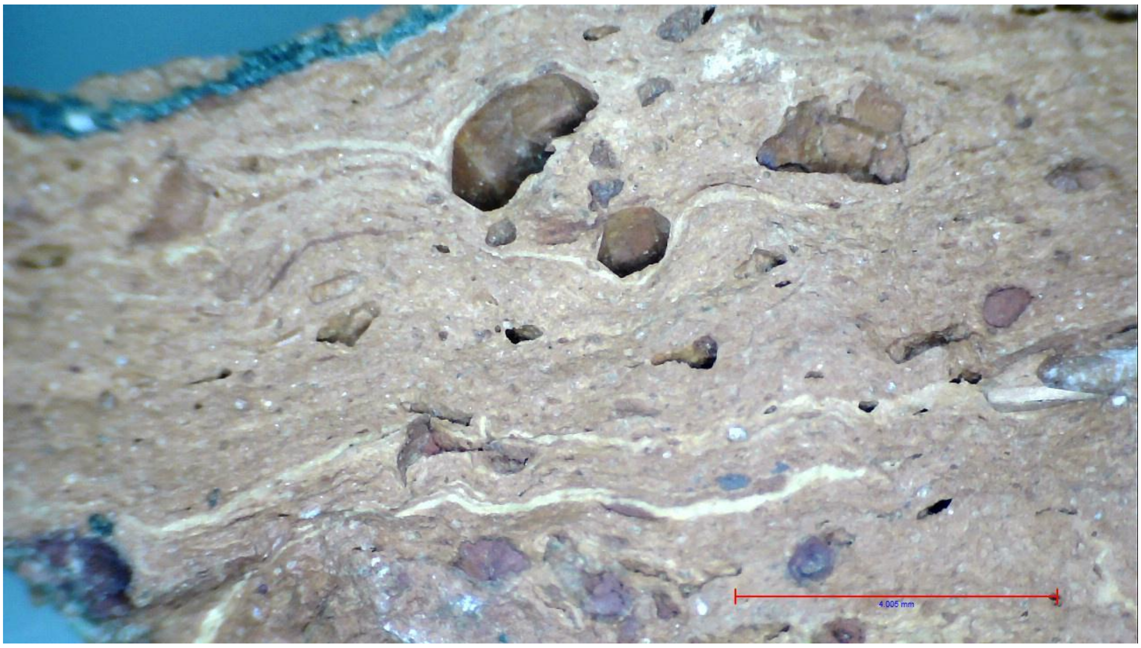

**Figure 9.15: Photograph of sherd OTK 057 in fabric 05, showing two distinctive hexagon shaped voids also seen in fabrics 06 and 12. Scale bar is 4mm long.**

**Figure 9.16: Photograph of a fresh break on sherd OTK 269, showing traces of a part-preserved shell, perhaps from a small snail or ammonite, c.4mm in diameter.**

### 9.2.3 Fabric Groups by Components

Sherds of the dominant tile types in the Roman Baths assemblages, including hollow voussoirs, combed tiles, bricks, and box flues (section 9.1.2) all occurred in a wide range of fabrics. There were nevertheless clear differences between the range of fabrics recorded for different tile types (table 9.11). Few sherds of bricks or voussoir bricks were noted in the otherwise common fabric 06, while conversely few hollow voussoir tiles were identified in fabric 07. Box flue tiles in coarse fabrics such as F11 or F12 were also rare. This suggests that discrete clay resources were commonly used in the production of certain components, but only rarely for others.

**Table 9.11: Table showing the number of sherds of common tile types recorded per fabric.**

| Fabric | Hollow voussoir | Brick | Combed tile | Tegula | Imbrex | Box flue tile | Voussoir brick |
|---|---|---|---|---|---|---|---|
| 01 | 11 | 17 | 11 | 8 | 7 | 0 | 1 |
| 03 | 20 | 9 | 21 | 3 | 9 | 2 | 0 |
| 04 | 16 | 45 | 19 | 2 | 2 | 7 | 7 |
| 04M | 3 | 7 | 4 | 0 | 0 | 0 | 4 |
| 05 | 40 | 17 | 18 | 1 | 2 | 6 | 2 |
| 05M | 12 | 17 | 6 | 0 | 0 | 0 | 2 |
| 06 | 42 | 7 | 23 | 15 | 10 | 5 | 1 |
| 06M | 6 | 3 | 4 | 0 | 0 | 0 | 1 |
| 07 | 7 | 30 | 33 | 22 | 17 | 6 | 4 |
| 08 | 19 | 8 | 19 | 3 | 3 | 5 | 1 |
| 11 | 7 | 5 | 10 | 9 | 9 | 0 | 0 |
| 12 | 6 | 13 | 12 | 4 | 2 | 2 | 8 |
| 12M | 3 | 7 | 2 | 0 | 0 | 0 | 2 |
| 14 | 9 | 5 | 4 | 8 | 5 | 1 | 0 |
| 15 | 6 | 7 | 10 | 0 | 0 | 9 | 1 |
| 15M | 0 | 3 | 3 | 0 | 0 | 1 | 0 |
| 16 | 9 | 0 | 1 | 0 | 0 | 0 | 0 |
| 16M | 2 | 0 | 1 | 0 | 0 | 0 | 1 |
| 17 | 22 | 20 | 26 | 1 | 0 | 5 | 0 |
| 18 | 11 | 17 | 12 | 0 | 0 | 5 | 5 |
| Unidentified | 3 | 4 | 1 | 0 | 0 | 1 | 0 |
| Total | 254 | 241 | 240 | 76 | 66 | 55 | 40 |

The range of fabrics that sherds of tegulae and imbrices were recorded in is extremely similar (table 9.11), with only a single tegula sherd in F17 lacking equivalent imbrex fragments. The close relationship in the numbers of these sherds in the total assemblage and per assemblage was noted in section 9.1.2, and the correspondence in fabrics further suggests that these components are likely to have come from the roofs of the same structures and were probably supplied together.

Many other tile types were identified from only a small number of sherds (table 9.12), and the significance of isolated finds in certain fabrics is difficult to interpret (though see 9.2.6). In contrast, the Westhampnett hollow voussoirs formed a coherent group with a small range of coarse and/or streaky fabrics including F12, F12M, F11, F6 and F15 (table 9.12). With their unique thickness and large sizes (see section 9.1.3), this suggests that these tiles are likely the result of a single production event at the same site.

**Table 9.12: Table showing the number of sherds of rare tile types recorded per fabric.**

| Fabric | Westhampnett hollow voussoir | Moulded brick | Half box flue | Flat tile | Curved Tegula | Mammata tile | Pilae brick | Wall tile |
|---|---|---|---|---|---|---|---|---|
| 01 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 03 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| 04 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 05 | 0 | 6 | 0 | 0 | 1 | 0 | 0 | 0 |
| 05M | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 06 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 07 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 1 |
| 11 | 4 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 12 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12M | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 15 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 23 | 7 | 6 | 3 | 1 | 1 | 1 | 1 |

Further evidence of a production batch can perhaps be seen in the fabrics of the moulded bricks. Though only a small number of these sherds were recorded, all were of fabrics 05 and 05M. These are very unusual tiles only known from one structure at the site (section 9.2.6), and the consistent fabrics suggest that they were all produced at the same time using the same deposits.

The six sherds of half-box flue tiles identified were mostly in fabric 07, with one sherd in fabric 04. Six combed tile fragments (OTK 46, 76, 551, 945, 988, 1014) from the East Baths were the same unusual thickness (c.27-30mm) as the identified half-box flue tiles from this assemblage, were in several of the same contexts and occurred solely in fabrics 07 and 04, suggesting that these are further examples of half box flue tile sherds that lacked diagnostic features. While this may indicate another coherent production batch in these very fine fabrics, most sherds were found in reworked contexts in the East Baths (Davenport 2021a, b) and may represent a chance sample from an originally far wider range of materials and fabrics, especially given that the half-box flue form is early (section 9.2.6), and few examples seem to have survived from the site.

### 9.2.4 Hollow Voussoir Fabric Groups

Most types of hollow voussoir identified included sherds of predominantly fine fabrics, especially some of the most numerous such as HV01 and HV08 (table 9.13). There were also hollow voussoir types whose sherds were predominantly coarse, including HV05 as well as the Westhampnett forms identified. While HV07 and HV11 included sherds of very fine fabric F07, both types included fabric analysis on only a single sherd, so it is unclear how characteristic these were of the wider forms.

There were clear patterns identified between certain hollow voussoir types and fabric groups (table 9.13). These relationships were not tested statistically as many types of hollow voussoirs had too few sherds identified to yield valid results. Moreover, the hollow voussoir types that did have a large range of sherds tended to produce a characteristic range of fabrics. Statistical testing of these relationships was therefore not completed as it seemed unlikely to yield new findings proportional to the time required to complete the analyses, given that clear patterns could already be observed simply by listing the number of sherds of different fabrics for each hollow voussoir type. To illustrate, fabrics 04, 05, 05M, 06, 06M and 08 were consistently recorded together in a range of sherds from hollow voussoir types HV01, HV02, HV06 and HV09 (table 9.13), suggesting that these fabrics were very closely related. The co-occurrence of many of these fabrics in sherds from different hollow voussoir types indicates that the same kiln site and clay deposits supplied multiple roofing projects at the Roman Baths, though not necessarily at the same time.

Sherds of HV04 formed a discrete batch in terms of fabrics, with nine sherds being identified as fabric 14. This fabric was not identified from sherds of any other hollow voussoir types. It is unclear if HV04 was a subgroup of HV01 (see sections 9.1.3 and 9.1.6) or not, and this concentration of fabric 14 sherds may indicate a discrete episode of production. Sherds from HV04 did also include a range of other fabrics, which could suggest production at the same site as other hollow voussoir types. As the lower measurements of type HV01 overlap slightly with HV04 (see section 9.1.3), it may be that these sherds in other fabrics are extreme examples of HV01 instead. It therefore remains unclear if HV04 was used to roof a separate structure, or merely comprised a batch within the tiles of the Great Bath roof.

HV09 may also be a batch of hollow voussoirs from the Great Bath roof. Unlike HV04, the fabrics of sherds of HV09 are entirely consistent with those of HV01, including sherds of F04, 05M and 06. Though somewhat similar in dimensions to HV10 as well, the only fabric identified from these sherds was F11, i.e. coarse and without streaks, and thus entirely distinct. Given the overlap in dimensions, the similar fabrics and presence of Great Bath-like concretions on HV09 sherds (section 9.1.6), it is therefore likely that these are just a sub-group within HV01.

Hollow voussoir type HV05 occurred in a distinctive pale yellow-brown and coarse fabric 16 and very streaky variant 16M. In fact, it also occurred in several other coarse and fine fabrics, many sherds of which had also been fired to the same distinctive colour despite presenting all other typical features of their fabrics. This perhaps suggests production in a different firing atmosphere to the norm, rather than the use of a different clay source entirely.

**Table 9.13: Table showing the number of sherds of each fabric group recorded for each hollow voussoir type identified.**

| Fabric | HV01 | HV02 | HV03 | HV04 | HV05 | HV06 | HV07 | HV08 | HV09 | HV10 | HV11 | HVU |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 0 | 0 | 0 | 2 | 4 | 0 | 0 | 1 | 0 | 0 | 0 | 3 |
| 03 | 4 | 0 | 0 | 3 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 2 |
| 04 | 2 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 6 |
| 04M | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 05 | 19 | 6 | 0 | 0 | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 11 |
| 05M | 3 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 4 |
| 06 | 16 | 4 | 0 | 1 | 0 | 3 | 0 | 2 | 1 | 0 | 0 | 15 |
| 06M | 1 | 1 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 07 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 2 |
| 08 | 7 | 2 | 0 | 1 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 5 |
| 11 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 3 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 12M | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 14 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 1 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 16M | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 2 |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 1 |
| Unidentified | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Unsampled | 13 | 2 | 1 | 1 | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 3 |

Sherds of hollow voussoir type HV08 were only identified from the East Baths, and like those assemblages (section 9.2.1), this was the only hollow voussoir type where fabrics 17 and 18 were identified. The sherds of F03 and F15 also identified (table 9.13) were noted to be very like F17 and F18 in the size, range, and frequency of quartz inclusions, yet they lacked the distinctive common small black or dark red iron oxide inclusions. HV08 was therefore very different in dimensions and fabrics from other hollow voussoir types identified, and likely represents a discrete phase of supply to the East Baths.

Other hollow voussoir types included very few sampled sherds and it is unclear to what extent the recorded fabrics were representative of the wider groups. It is nevertheless interesting that a sherd of HV07 and another in HV11 both occurred in fabric 07, which was rare for hollow voussoirs with only 6 examples in total. The sampled HV07 sherd was the relief-patterned example from the Temple Precinct (Cunliffe and Davenport 1985: 134-135), OTK 140, and might suggest that this fabric was characteristic of residual early material. This does not necessarily have to be the case, for a sherd of F07 occurred in both the HV01 and HV06 groups.

**Table 9.14: Table showing the number of sherds of each fabric group recorded for each Westhampnett hollow voussoir type identified. HVU/WHU stands for unidentified hollow voussoir or Westhampnett hollow voussoir type sherd.**

| Fabric | WH1 | WH2 | WH3 | WHU | HVU/WHU |
|---|---|---|---|---|---|
| 01 | 0 | 1 | 0 | 0 | 0 |
| 06 | 0 | 0 | 0 | 1 | 0 |
| 11 | 1 | 1 | 0 | 2 | 1 |
| 12 | 1 | 2 | 5 | 9 | 0 |
| 12M | 0 | 1 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 1 | 0 |
| Unsampled | 2 | 0 | 0 | 0 | 0 |
| Total | 4 | 5 | 5 | 13 | 1 |

Sherds from Westhampnett hollow voussoirs appear to form a discrete group of predominantly coarse fabrics such as F12, 12M, 11 and 01, with only two sherds from fine fabrics such as F06 and F15. The evidence for division of fabrics by Westhampnett hollow voussoir type beyond this is ambiguous (table 9.14). While F01 and 12M are specific to WH2, the small number of identified sherds per Westhampnett type means that such patterns are highly likely to be due to chance survival and recovery, rather than reflecting differences in production. The present evidence is therefore consistent with the manufacture of all three types of Westhampnett hollow voussoirs together. The dimensions, thicknesses and range of fabrics recorded for these components all present clear differences to the most abundant hollow voussoir types recorded, suggesting a discrete episode of production and use.

### 9.2.5 Tegula Fabrics

Tegula sherds were identified in a range of fabrics (table 9.11). Unlike flange types (section 9.1.4), there was little difference in sherd thicknesses by fabric, with all but F01 having a median value between 20mm and 25mm (figure 9.17). F01 therefore appeared distinct, although a small number of other fabrics were identified in similarly thin sherds, e.g. F06 and F07. This suggests that most fabrics were present over a wide array of sherd thicknesses, with little evidence for discrete batches of components. The most common cutaway types, B6 and C5, were each present on sherds of four different fabrics (table 9.15), which both included all grades of quartz inclusions. Furthermore, several fabric types included sherds with more than one type of cutaway, with fabric 07 including at least one sherd from each type. Given that only 21 sherds had identifiable cutaway types, the spread of different types across fabrics is therefore considerable.

**Table 9.15: Table showing the frequency of tegula sherds with different cutaway types by fabric group.**

| | Cutaway Type | | | |
|---|---|---|---|---|
| **Fabric** | **A2** | **B6** | **C5** | **D1** |
| 01 | 0 | 0 | 0 | 1 |
| 06 | 0 | 1 | 4 | 0 |
| 07 | 1 | 7 | 1 | 1 |
| 11 | 0 | 1 | 1 | 0 |
| 12 | 0 | 1 | 0 | 0 |
| 14 | 0 | 0 | 2 | 0 |

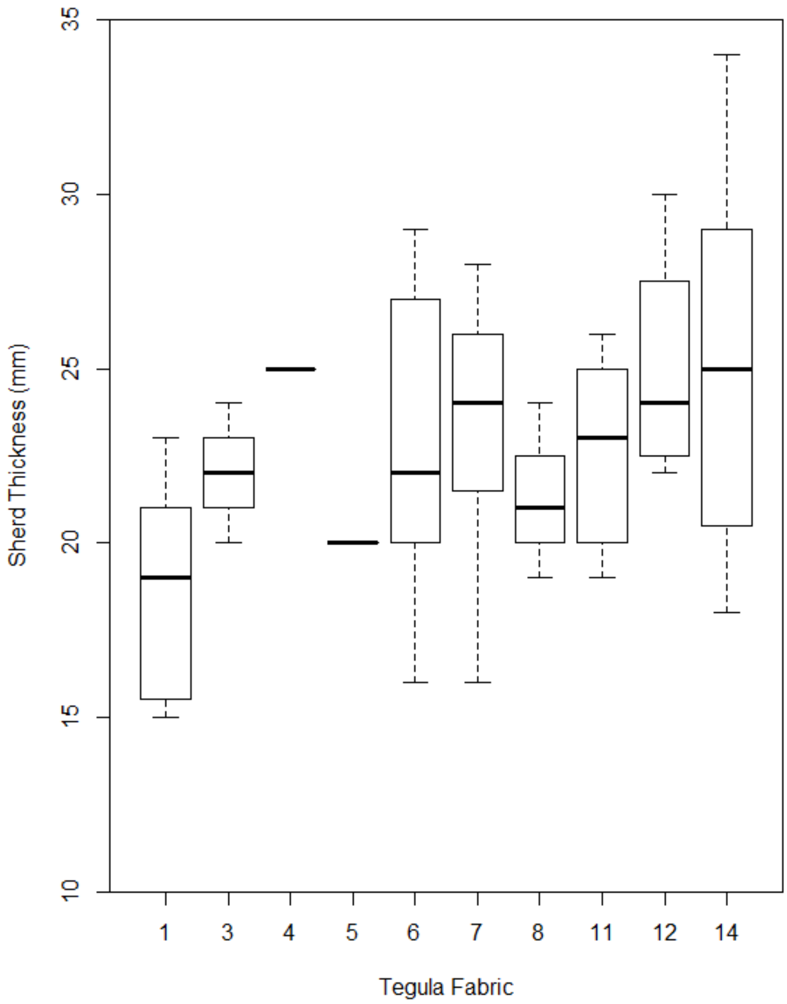


**Figure 9.17: Boxplot of tegula sherd thicknesses by fabric group.**

Consideration of the flange types and fabric groups shows similar variation. Most fabric types occur with more than one flange profile, and most flanges occur with at least two different types of fabrics. Some variation between flanges and fabrics might be expected due to natural heterogeneity in clays of the same deposits, but it is clear that the same profiles frequently occur on sherds with very different fabrics.

Few coherent patterns are noticeable between flanges, cutaways, thicknesses and fabrics. Tegulae with flange type A and P were all in coarse fabrics F01 and 11, which are closely related (Appendix E), and all examples were found together in the Temple Precinct assemblage, perhaps suggesting a group of material. While flange types F, L, S, and V were grouped together on the basis of sherd thicknesses (section 9.1.4), all occur in a range of fabrics with limited overlap between them (table 9.16). This suggests that clay deposits exploited for tegulae were either heterogeneous or that different workshops using different resources employed the same flange profiles, perhaps at different times.

**Table 9.16: Table showing the frequency of tegula sherds with different flange profile by fabric group.**

| | Fabrics | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Flange** | **01** | **03** | **04** | **05** | **06** | **07** | **08** | **11** | **12** | **14** | **17** |
| A | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| B | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| D | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 |
| F | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| F + V | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| L | 0 | 1 | 0 | 0 | 0 | 7 | 0 | 0 | 1 | 1 | 0 |
| P | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Q | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 1 | 0 | 0 |
| R | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 1 | 0 |
| S | 0 | 0 | 1 | 0 | 2 | 2 | 0 | 2 | 0 | 3 | 1 |
| T | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 0 |
| V | 0 | 0 | 1 | 0 | 5 | 0 | 1 | 0 | 1 | 0 | 0 |
| W | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Unidentified | 2 | 0 | 0 | 1 | 2 | 4 | 0 | 1 | 1 | 2 | 0 |

## 9.2.6 Dating Evidence for Morphology, Impressions and Fabrics

There were a range of dateable forms and features present among the ceramic building materials from the Roman Baths (table 9.17). Most were dated to before the middle of the second century, with a range of features likely to be from sherds of early phases of construction at the baths in the first century AD.

**Table 9.17: Table showing the range, number and date of significant morphologies, marks and impressions recorded from the CBM of the Roman Baths.**

| Evidence | Frequency | Possible Date |
|---|---|---|
| Westhampnett hollow voussoirs | 23 | Later first century |
| Half box flue tiles | 6 | Later first century |
| Knife scoring | 7 | Later first century |
| Wall tiles | 1 | Late first-early second century |
| Moulded bricks | 7 | Late first-early second century |
| Relief-patterned tile | 1 | Late first-early second century |
| Tegula cutaways | 21 | First-second century |
| Nail holes | 3 | Unidentified |

*Westhampnett Hollow Voussoirs*

Lancaster (2012: 420) dates the invention of hollow voussoirs prior to the Vespasianic period, i.e. before the mid to late 70s AD, partly on the basis (Lancaster 2012: 420) that widespread employment of this invention must have post-dated the erection of large first-century bath buildings that used standard box flue tiles, for example Exeter (Bidwell 1979: 151) and Caerleon (Zienkiewicz 1986: 327). While a reasonable assumption, there was considerable complexity and concurrent use of multiple different tile types for heated structures in Britain in the mid first century, for example in London (Pringle 2006, 2007), so there may be grounds for dating this innovation back further. Westhampnett hollow voussoirs have been found at relatively early first-century AD sites in West Sussex such as Fishbourne (e.g. Cunliffe 1971: 43) and Angmering (e.g. Scott 1938: figure 10). These examples could date from later phases of activity at either site, as Lancaster (2012: 424) suggests. Fulford and Machin (2021: 217) have instead argued convincingly that relief-patterned tile finds from these sites are likely to be Neronian or Neronian-early Flavian in date. The examples of relief-patterning dies from these sites have been ascribed by Betts et al. (1997: 19-20) to production by a Sussex workshop with a distinctive range of fabrics (section 2.4.2), as have many Westhampnett hollow voussoirs in that region (Lancaster 2012: 421). There are also examples of Westhampnett style tiles keyed with the dies of this workshop (e.g. Betts et al. 1997: 11). Together, this evidence suggests that the invention of Westhampnett hollow voussoirs could have occurred sometime in the AD 60s.

Sherds of this tile type were predominantly identified as F12, with a small number of sherds in F11, F12M, F06 and F15 (section 9.2.4). This suggests that F12 and its associated fabrics were reaching the site from an early date. This was very likely during the first century AD and maybe as early as Period I of the complex in the late 60s or early 70s AD (e.g. Davenport 2000: 8), though perhaps unlikely given the short interval between invention and use.

*Half Box Flue Tiles*

Half box flue tiles have been dated to pre- and post-Boudiccan contexts in Roman London (Pringle 2007: 207), i.e. either side of AD 60. They were present in early demolition layers from the Legionary Baths at Exeter (Bidwell 1979: 149), dated to approximately 60-80AD (Bidwell 1979: 15-17) and an unstratified example similar in form to those at Exeter was found at the Caerleon Fortress Baths (Zienkiewicz 1986: 327) likely dating to the same period. Half-box flue tiles, Scammell's (n.d.: 14) type five, were also excavated from the kiln debris at Minety in association with a range of fragments of relief-patterned tiles (Scammell n.d.: 13-15), further suggesting a late first-century or early second-century date (e.g. Lowther 1948: 10, Betts et al. 1997: 23). Scammell himself suggested (n.d.: 15) a date of approximately 80 AD for the site, though Fulford and Machin (2021: 212) have argued for an earlier date on the basis of a re-evaluation of the pottery excavated. While not exhaustive, the range of evidence considered strongly suggests a first century date for the half-box flue tiles identified from the Roman Baths, though a very early second-century date may also be possible. They may therefore belong to initial periods of construction at the site or subsequent, but still early, phases.

Six sherds from half box flue tiles were identified from the Roman Baths assemblages. Five sherds were present in F07 and a single sherd in F04, though six probable examples of these components (section 9.2.3) were also identified in the same fabrics. The early date of half box flue tiles indicates that fabrics F07 and F04 were being supplied to the site during the later first century or very early in the second century AD.

*Knife Scoring*

Knife scoring was an early method used to key surfaces for mortar and plaster, being largely superseded by combing. Knife scored box flue tiles have been dated to pre-Flavian contexts in London, Canterbury and Fishbourne (Pringle 2006: 128) and similar tiles have been identified at Exeter (Bidwell 1979: 151) and Caerleon (Zienkiewicz 1986: 327), all suggesting a first century date for this practice on bathhouse components. Though the number of occurrences in the Roman Baths assemblages are small (table 9.18), knife scoring was noted on a notched wall tile sherd (OTK 256) and on one Westhampnett hollow voussoir fragment (OTK 387), both consistent with an early date for this practice.

The range of fabrics across all sherds with knife scoring included F03, 05, 07, 11 and 12M. This suggests that these fabrics were reaching the site during the later first century.

**Table 9.18: Table listing the OTK sherd numbers, tile types and fabrics of sherds recorded with knife scoring.**

| Sherd | Site Code | Tile type | Fabric |
|---|---|---|---|
| 208 | RB82 | Flat tile | 03 |
| 256 | RB82 | Wall tile | 07 |
| 315 | YS CBM | Combed tile | 05 |
| 364 | YS CBM | Hollow voussoir | 11 |
| 387 | YS CBM | Westhampnett Hollow voussoir | 12M |
| 819 | YS CBM | Unidentified | 03 |
| 824 | EB01 | Unidentified | 07 |

*Wall Tiles*

Only a single example of a notched wall tile was identified from the Roman Baths assemblages. There are certainly many other examples from the site, for these tiles were bedded into the mortar sealing the lead sheets at the base of the Spring Reservoir (figure 9.18). These tiles were therefore being supplied to the site in the very earliest period of construction for, as Cunliffe and Davenport (1985: 38-40) noted, the rest of the site could only have been consolidated after the waters of the Spring had been brought under control. Sadly, no fragments of the tiles from the Reservoir could be located in the Spring assemblage. Wall tiles have been found in mid first-century to early second-century contexts in London (Pringle 2007: 206), and a single relief-patterned example was found at the settlement at Lower Wanborough in Wiltshire (Betts et al. 1997: 11, 118) and was associated with other dies dated to approximately 80-150 AD (Betts et al. 1997: 23). This suggests that the solitary example from the Temple Precinct could date to the first period of construction at the baths, in common with those from the reservoir, but may be from a later phase.

The single notched wall tile sherd was in fabric 07, suggesting a later first- or early second-century start date for F07 at the Roman Baths, potentially including the very first phase of construction.

**Figure 9.18: Photograph of the notched wall tiles laid in the mortar at the base of the Spring Reservoir. Modified from Cunliffe and Davenport (1985: plate VIIIa). Image courtesy of the School of Archaeology, Oxford University. Photographer Robert Wilkins.**

*Moulded Bricks*

A limited number of moulded bricks were found as part of the Spring Reservoir Enclosure ribs during the excavations of Cunliffe and Davenport (1985: 134-135). No examples were found in any other assemblage from the site. Zienkiewicz (1986: 325) noted that such bricks are rare in Britain, with finds predominantly from Caerleon (e.g. Lee 1862: pl. XXII) and the Legionary Baths there (Zienkiewicz 1986: 325), though Brodribb (1987: 57) notes a number of solitary examples of somewhat similar oblong bricks from 13 other sites, though it is not clear if the end was shaped in the distinctive multi-stepped manner of the Bath and Caerleon examples. It is also unclear if more of these bricks have since come to light. There is a single example from a sealed context in a paved-over drain corner at the Caerleon Baths, dating prior to AD 100-110 (Zienkiewicz 1986: 325). Given the rarity of these moulded bricks in Britain and within the Roman Baths assemblages it appears that their production was likely short and restricted, and a similar date therefore seems reasonable. A late first- or very early second-century date strongly conflicts with Cunliffe and Davenport's (1985: 65) suggestion for a late second- to early third-century period of construction for the Spring Reservoir Enclosure, but further evidence for the redating of this structure is presented in section 10.2.

Of the seven sherds of moulded bricks recorded from the Roman Baths, six were of fabric 05 and one sherd was in F05M. These moulded brick finds suggest a late first-century or early second-century date for the earliest supply of fabrics F05 and F05M to the site.

*Relief-patterned Tile*

Fulford and Machin (2021: 217) have suggested that all relief-patterned tiles be redated to pre-Flavian periods (see section 2.1.2), partly on the basis of finds of multiple die types among sherds at the Neronian Little London kiln site near Silchester (e.g. Fulford et al. 2017). While this appears logical for the specific die types found, the Bath and Gloucestershire area has yielded a range of other die types, many of which are strongly linked to the Minety kiln site instead (see section 7.1.1). Certain die types found both at Bath and Little London, for example die 54 (Betts 2007: 53), do suggest very early supply. However, the dating of the Minety kiln site is still not fully understood (see section 2.2.2), and there does not yet appear to be enough clear evidence to unanimously redate other relief-patterned tile dies from this area to pre-Flavian phases. This is in direct contrast to those that have clear links to exceptional and short-lived early Roman sites in West Sussex, such as the dies from Fishbourne Roman Palace (e.g. Cunliffe 1971, Manley and Rudkin 2003). A late first-century or very early second-century date is therefore preferred for the relief-patterned tile from the Roman Baths until further new evidence emerges (though see section 10.7.2).

A single definite relief-patterned tile is known from the site (Cunliffe and Davenport 1985: 134-135), though see section 9.1.5 for two possible examples identified during this study. The example excavated by Cunliffe and Davenport (1985), sherd OTK 140, was in fabric 07. The two potential examples of relief-patterning, OTK sherds 243 and 1069, were identified in fabrics 08 and 06 respectively. This indicates a late first-century or very early second-century date for F07 at the Roman Baths, and may suggest a similar date for F06 and F08.

*Tegula Cutaways*

*Contra* Warry (2005), tegula cutaways were not used to estimate precise dates for flange types or fabrics because he has since acknowledged (Warry 2017: 94) that Type C cutaways are widely present in early phases across all southern *Civitas* centres in Roman Britain, and thus that this evolutionary dating schema of tegula cutaways is not accurate for a range of major settlement sites. This confirms objections by Mills (2013: 459), see also section 4.2.3. Having said that, finds of type C cutaway tiles have been found in early contexts in Leicester and London (Mills 2013: 458), type A in Boudiccan contexts in Colchester (Warry 2005: 115) and type B is widely associated with second-century military stamping (Warry 2005: 106-136), suggesting that these three types were in use from a relatively early date, though uncertain when production ceased. As all but two cutaways identified from the Roman Baths assemblages are types A2, B6 or C5 (section 9.1.4), it therefore seems likely that most of the tegula sherds identified are from either the first or second centuries, especially given the later abundance of stone roofing tiles in the region (Williams 1971a: 106-107, Darvill and McWhirr 1984: 31). This is reinforced by the identification of the earliest local use of Pennant sandstone tiles at a bathhouse at Truckle Hill in northwest Wiltshire, dating to at least the early-second century (Andrews 2013: 117, 127). Furthermore, Davis (1884: 14) found large numbers of hexagonal stone roof tiles during his excavations of the Great Bath and he suggested (Davis 1884: 14) that they had been been used to roof the semi-circular exedrae to the north and south of the bath, confirming later use of stone tiles at the Roman Baths itself.

Tegula fabrics are discussed in section 9.2.5 and include sherds of fabrics 01, 03, 04, 05, 06, 07, 08, 11, 12, 14, though sherds of F07, 06, 11, 01 and 14 were the most common. This suggests that many of these fabrics may be first- or second-century in date.

*Nail holes*

Nail holes have been identified as being present on tegulae from London dating from after the middle of the second century (Betts 2017: 370) and would therefore appear to be a late feature. However, Warry (2005: 226-228) notes that pre-formed nail holes have been found in very small quantities on tegulae from earlier sites such as Fishbourne (Cunliffe 1971, Manley and Rudkin 2003) and on earlier stamped tile from York (Warry 2005: 137). Only one tegula sherd of 76 identified from the Roman Baths actually had a nail hole, so as a group these sherds still appear more consistent with an earlier rather than later date.

Three sherds from the Roman Baths had nail holes, and these included a tegula (OTK 207), a flat tile (OTK 188) and an unidentified tile type (OTK 255). The tegula sherd was identified as being fabric 11, and the other two sherds were in fabric 01. These two fabrics appear to be closely related (Appendix E), and the presence of nail holes only with these fabrics, together with a typically late (e.g. Mills 2013: 459-460) type D1 cutaway on a sherd of fabric 01, may indicate a small late supply of tegulae to Roman Bath in these coarse non-streaky fabrics.

### 9.2.7 Fabric Groups and Regional Equivalents

The fabric scheme devised for analysis of the CBM from the Roman Baths during this study (section 6.2.2) is here equated with Ian Betts's (2011) fabric scheme for Roman CBM from sites in the wider area of Roman Bath, facilitated through a visit to the reference collection held at MoLAA. A collection of offcuts from Darvill's (1979, 1982, Darvill and McWhirr 1984) analyses of the Roman stamped tile from Gloucestershire were also examined and assigned to the fabric groups of this study.

Many of the fabric groups from the Roman Baths could be directly equated to Ian Betts's (2011) fabrics. Two fabric groups, IB6 and IB8, had no equivalents to material from the Roman Baths. F16 had no direct equivalent in Ian Betts's fabric groups. As this fabric may just represent a single batch of CBM fired to a non-typical colour, as noted in section 9.2.2, it may therefore be equivalent to coarse streaky IB4.

Two fabrics present features somewhat difficult to equate directly. Both IB1 and IB9 presented fine calcareous mottling dispersed throughout the body of the sherd, and common voids with partially burnt-out calcareous inclusions. Similar calcareous speckles were rarely, but definitely, observed within the CBM from the Roman Baths, for example in sherds OTK 499, 671 and 874 of fabric 07. Large voids with fully or partially burnt-out calcareous inclusions were also observed across a wide range of fabrics (section 9.2.2), particularly F07 and F04, but also in sherd OTK 741 of fabric 14 (figure 9.19). While fabrics IB1 and IB9 are therefore consistent with CBM features observed from the Roman Baths, the quantity of such sherds and the exact spread of fabrics that they occur in are not fully understood.

**Table 9.19: Table equating the fabrics defined in this study with Ian Betts's (2011) existing fabric scheme for CBM from Roman sites in the wider area of Bath. See notes below for fabrics with an asterisk. MoLA fabric numbers for IB17, 18 and 23 represent generic fabrics seen in most locations, not definite imports from kiln sites in London (Betts 2022 personal communication).**

| IB Fabric | OTK Fabric | Notes |
|---|---|---|
| 1 | F07* | Very fine calcareous mottling and common voids, as in IB9 |
| 2 | F04, F04M | |
| 3 | F15 | |
| 4 | F12 | |
| 5 | F17, F18 | IB5 has more frequent large quartz than typical F17 or F18, but still very similar |
| 6 | No equivalent | Perhaps pottery rather than CBM (Betts 2011: 1) |
| 7 | F06, F08, F05, F03 | |
| 8 | No equivalent | Common large or very large rounded or elongate flat platelet inclusions absent from any CBM from the Roman Baths. MoLA fabric 3019 (Betts 2011: 1) |
| 9 | F07, F04* | Very fine calcareous mottling and common voids, as in IB1 |
| 16 | F07 | |
| 17 | F01, F14 | Undiagnostic fairly sandy fabric, MoLA 3006 |
| 18 | F07 | Undiagnostic little or absent quartz fabric, MoLA 2452 |
| 23 | F11 | Undiagnostic coarse fabric, MoLA 3004 |
| No equivalent | F16 | Fabric distinctive due to firing conditions rather than inclusions, thus otherwise equivalent to IB4 |

**Figure 9.19: Photograph of OTK sherd 741 of fabric 14, demonstrating the common partially burnt-out voids, very fine white mottling, and pale fabric colours of IB1 and IB9. Scale is 4mm long.**

*Stamped Tile Fabrics*

A range of offcuts from Roman stamped tile from Gloucestershire, predominantly finds from sites in Cirencester, were examined under a x20 magnification microscope. Many of these offcuts were extremely small in comparison to the fresh breaks typically inspected, and only a small number of offcuts were available for each stamp group. These fabric identifications are therefore less secure than those of sherds from the Roman Baths. Stamps were grouped at a broad level as individual stamp types have been reclassified since Darvill's (1979, 1980, 1982) analyses, e.g. *RIB* II(5), Warry 2017. Fired clay samples and tile fragments previously collected from the surface at the Minety Roman kiln site (NGR ST992920) by Darvill were also included.

A wide range of fabrics present among the ceramic building materials of the Roman Baths were identified in the stamped and Minety material, table 9.20. Though the numbers of sherds per stamped tile group are small, several fabrics, for example F04, 06, and 08, frequently occur together just as they do in hollow voussoir sherds from the Roman Baths, for example HV01 and HV02 (section 9.2.4). Other fabrics noted together in certain components, for example F07 and F04 in half box flue tiles from the East Baths assemblages (section 9.2.3), also occur together in the ARVERI and TPLF stamped groups. This contributes further independent evidence for a range of fabric associations identified in tile types at the site, and may suggest a common source for much of the CBM from the Roman Baths and from Roman Cirencester.

**Table 9.20: Table showing the number of sherds of different fabric groups identified from offcuts of Roman stamped tiles from Gloucestershire. Minety samples include clay samples and fragments of CBM collected from the Minety Roman kiln site in northwest Wiltshire as part of Darvill's (1979, 1980, 1982) analyses.**

| | Fabric | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Stamp** | **01** | **03** | **04** | **05** | **05M** | **06** | **06M** | **07** | **08** | **12** | **14** | **15** |
| ARVERI | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 2 |
| LHS | 0 | 0 | 0 | 2 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| TCM | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| TPF | 0 | 5 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 2 |
| TPFA | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 |
| TPFB | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| TPFP | 0 | 3 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| TPLF | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 |
| Minety Samples | 0 | 2 | 0 | 0 | 0 | 4 | 0 | 0 | 1 | 2 | 0 | 0 |

# 9.3 Results of X-ray Fluorescence Analysis

Portable energy-dispersive X-ray fluorescence analysis was completed on 450 offcuts of ceramic building materials from the Roman Baths, 50 samples of Roman stamped tile and kiln site material from Gloucestershire and a small number of other samples from the region and from Fishbourne Roman Palace in West Sussex. An investigation of the accuracy and precision of the elemental results produced using this technique is presented in Appendix H. As a result of those analyses, compositional readings for ten elements, including silicon (Si), iron (Fe), titanium (Ti), potassium (K), aluminium (Al), rubidium (Rb), zirconium (Zr), strontium (Sr), calcium (Ca), and niobium (Nb), were selected for inclusion in statistical analyses in this study, the results of which are presented below.

## 9.3.1 X-ray Fluorescence Analysis of Samples from the Roman Baths

There were significant elemental disparities between materials from the different assemblages at the Roman Baths and between sherds of different fabric groups.

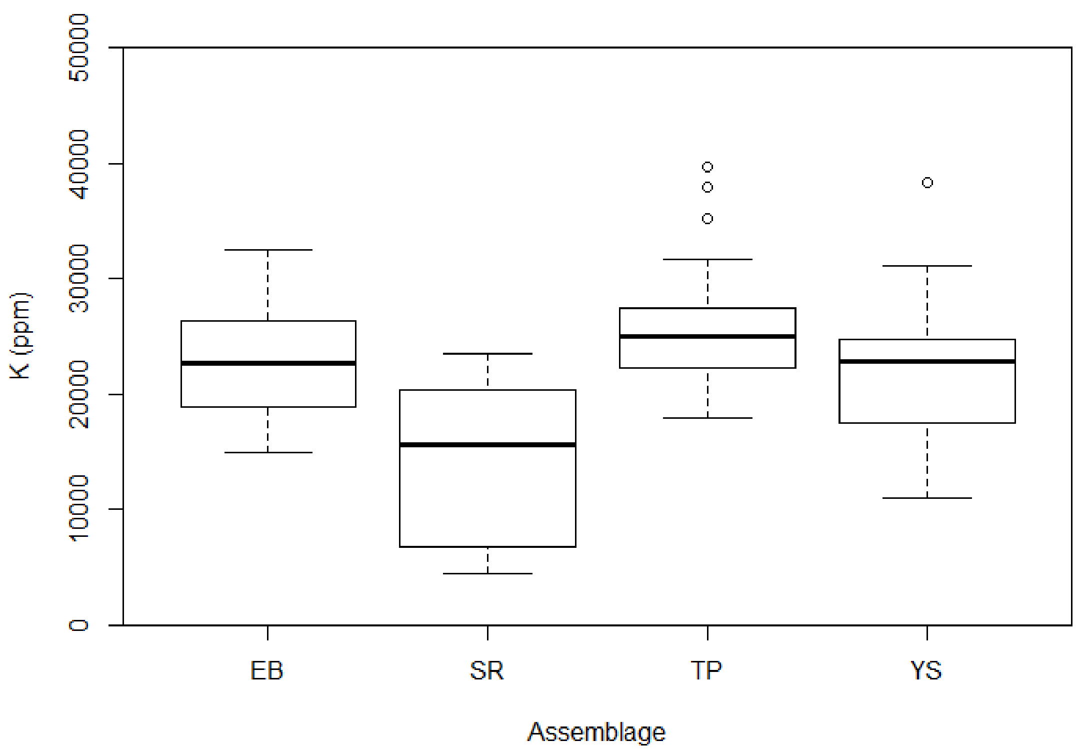


**Figure 9.20: Graph showing the different quartile values for K recorded from CBM offcuts in each different assemblage from the Roman Baths.**

Offcuts from the Spring Reservoir assemblage were depleted in elements including K, Rb and Si (figures 9.20-9.21). While this material included a small number of fabrics in comparison to other assemblages (section 9.2.1), these were relatively diverse, spanning very fine non-streaky sherds (F07) to coarse streaky material (F12). Offcuts of these fabrics occurred in other assemblages, yet these samples lacked similarly reduced values for K, Rb and Si. This suggests that the low readings observed in the Spring Reservoir material are the result of systematic post-depositional changes that affected this assemblage alone, i.e. immersion in the hot waters of the Spring Reservoir.

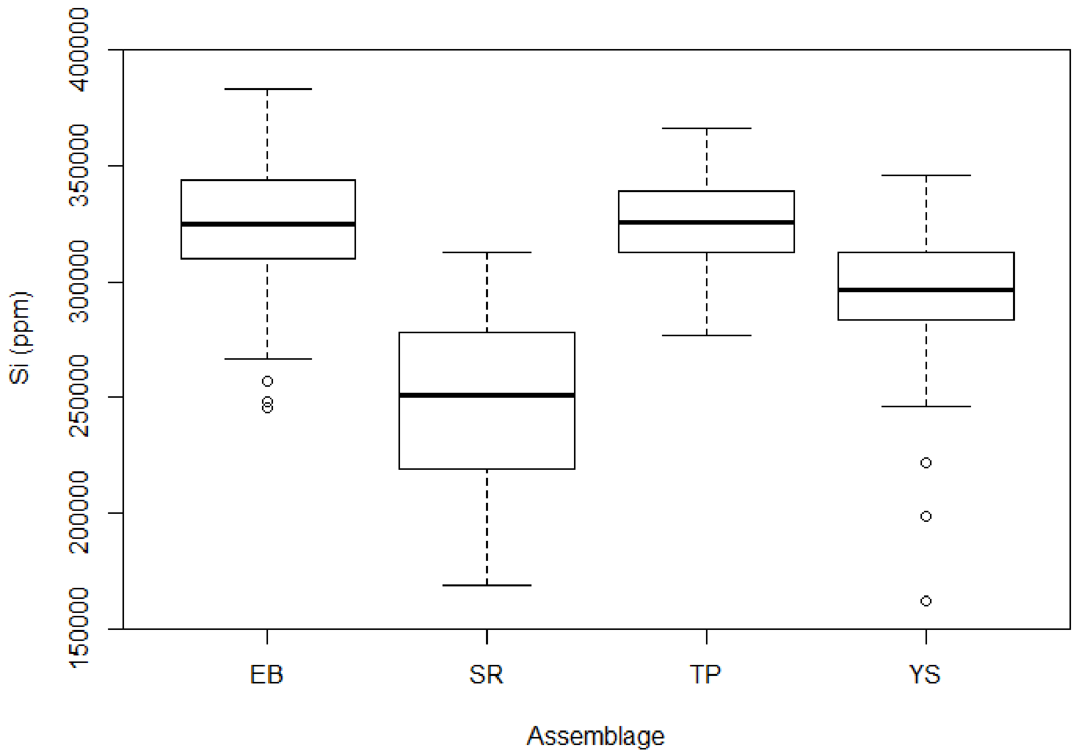


**Figure 9.21: Graph showing the different quartile values for Si recorded from CBM offcuts from each assemblage from the Roman Baths.**

There were also a number of significant elemental differences between fabric groups. Values for Si and Ca, in particular, correlated well with fabric observations. Sherds of fabrics 15, 17 and 18 were all noted to be especially sandy (Appendix E), and offcuts from these fabric groups consistently presented elevated Si readings (see figure 9.22). High Si values for samples from fabrics 03 and 08 likely represent similar sherds to F17 and F18 that lacked the distinctive small iron oxide inclusions of these fabrics, and such sherds were recorded from the East Baths and co-occurred in hollow voussoir type 08 (section 9.2.4).

Sherds from fabrics 07, 04 and 14 were identified as having the most common voids of all fabrics (section 9.2.2), and offcuts of F07 and 14 presented the highest population values for Ca (see figure 9.23). While the quartile values for Ca in F04 were much lower, there were a significant number of high outlier values for offcuts of this fabric, consistent with the values recorded in F07 and 14. Conversely, sherds of F17 and F18 were noted to have very few voids, and offcuts of these fabrics presented low Ca values. The origin of high Ca content is perhaps less obvious than with Si and may represent the contribution of partially preserved calcareous microfossils and shell fragments (section 9.2.2) or the infilling of voids with secondary calcite or aragonite. Given the particularly high values observed in F07, 14 and 04, and low values in F17 and F18, it nevertheless appears that the recorded Ca values positively correlate with the observed abundance of voids.

Other features observed during fabric analysis appeared to have limited impact on elemental values generated. Iron oxide inclusions were typically observed across all fabrics, though it was not possible to estimate if these inclusions were more or less prevalent among certain groups, except for the distinctive well-sorted small-medium inclusions of F17 and F18 (Appendix E). The Fe readings from offcuts of different fabric groups appeared largely consistent, with most groups having a median value of around 40000-52000ppm (figure 9.24), though the maximum values recorded for each fabric group ranged significantly. While part of these values are likely to be contributed by visible discrete or diffuse iron oxide inclusions, much is likely due to the Fe content dispersed in the clay itself (e.g. Stucki 2006), though post-depositional alteration may also have contributed to these values (Degryse and Braekmans 2014)

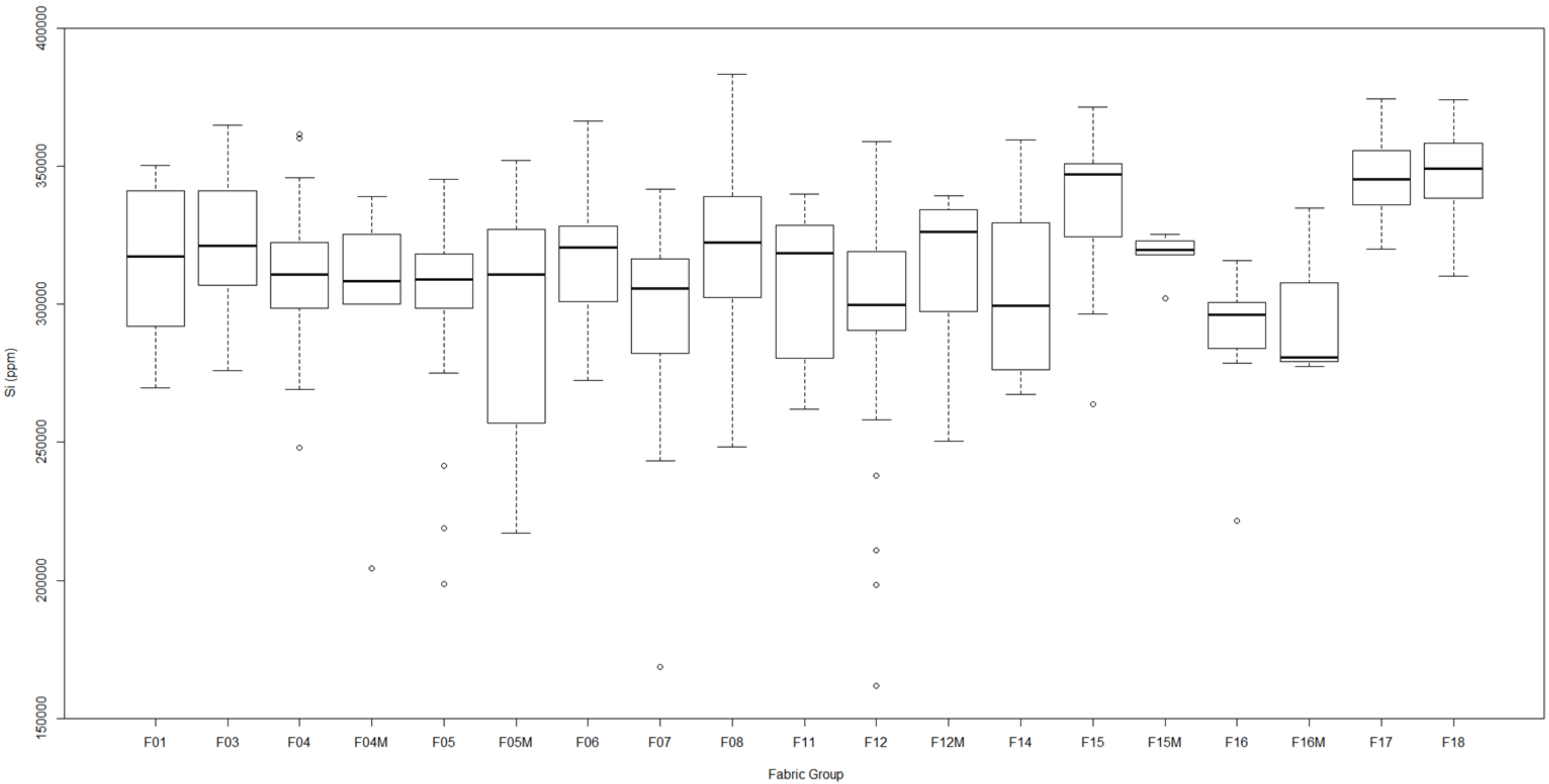


**Figure 9.22: Graph showing the quartile values for Si recorded from CBM offcuts from each different fabric group.**

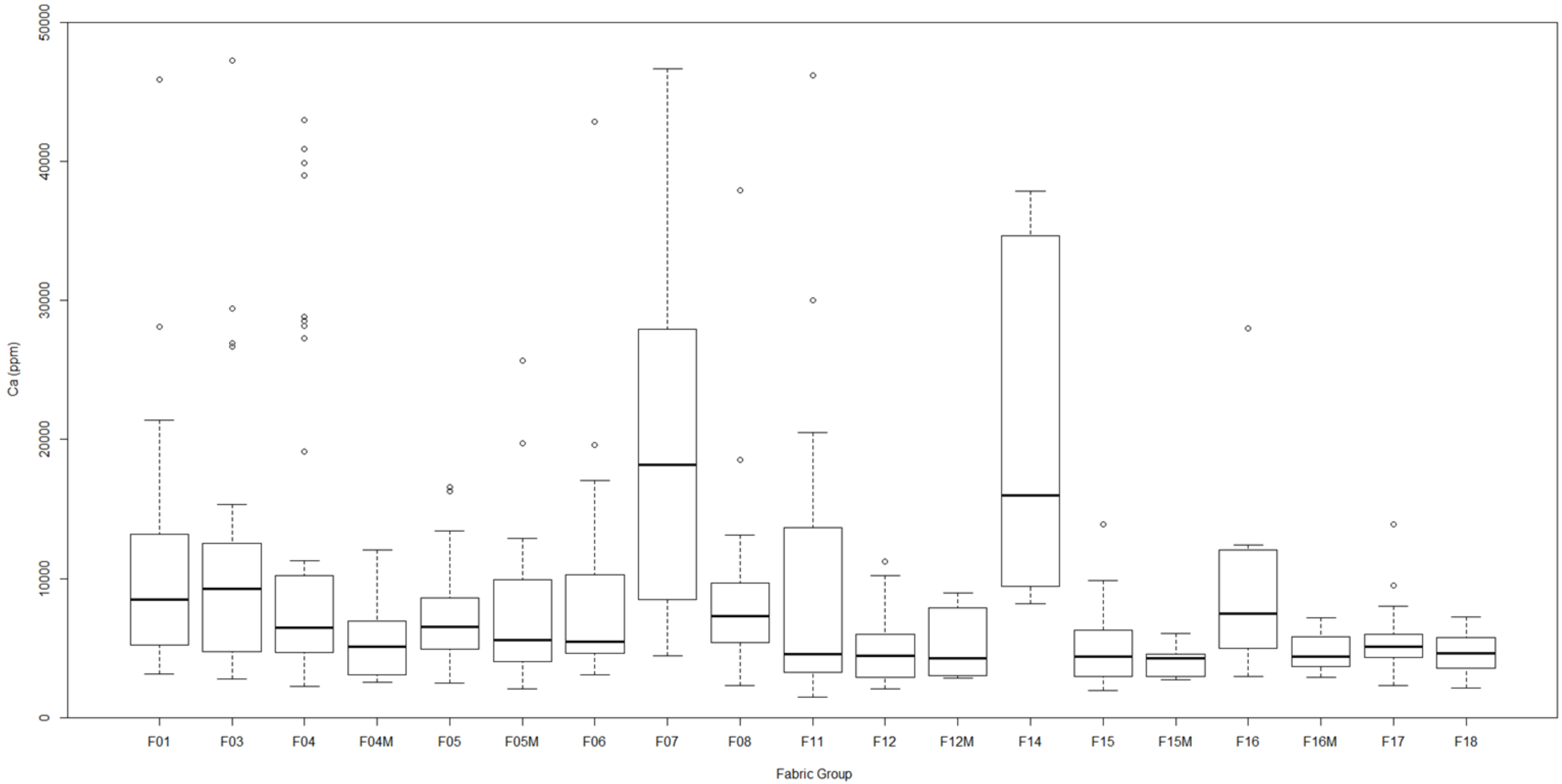


**Figure 9.23: Graph showing the quartile values for Ca recorded in CBM offcuts from each different fabric group.**

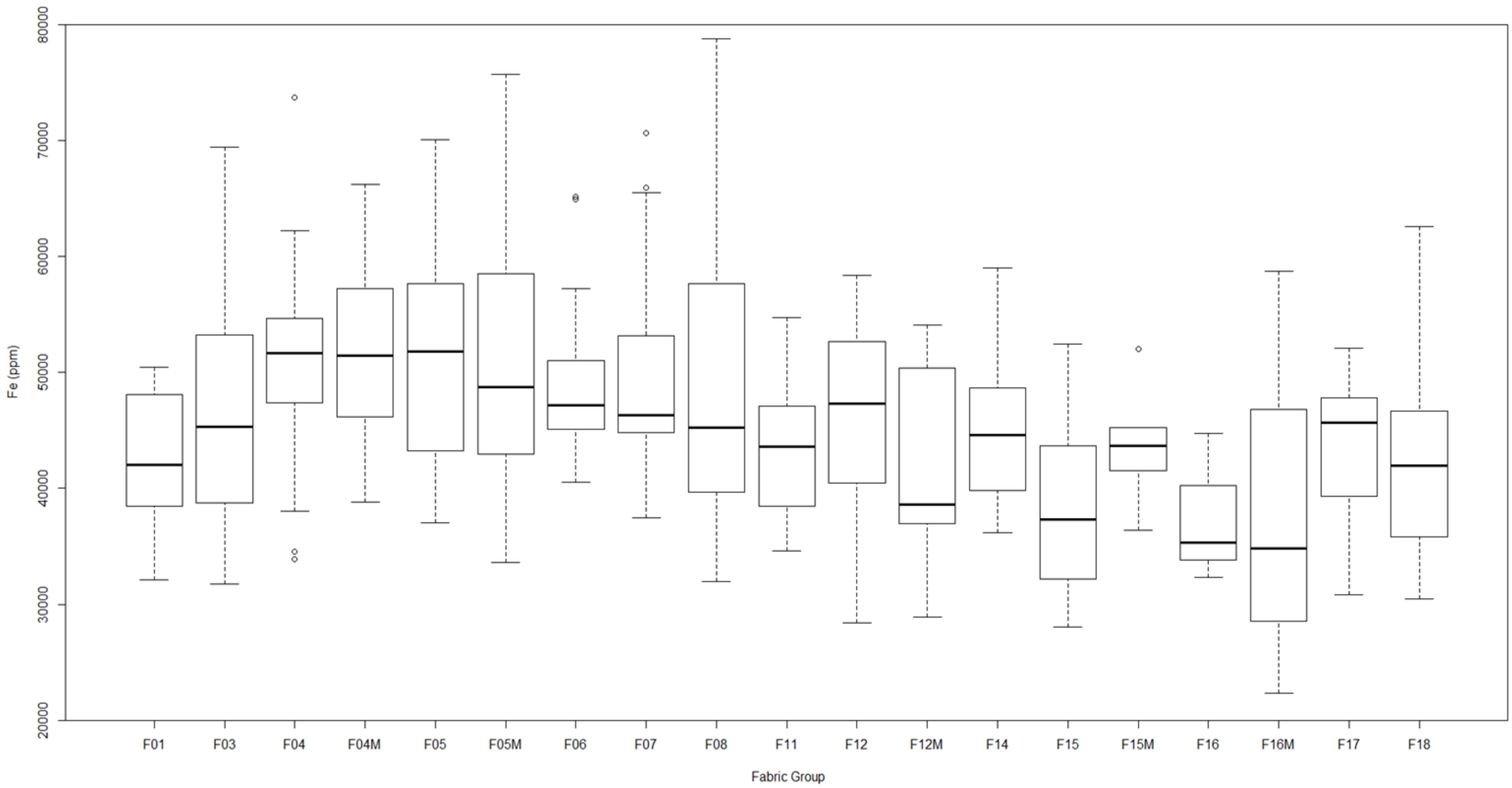


**Figure 9.24: Graph showing the quartile values for Fe recorded in CBM offcuts from each different fabric group.**

Macroscopic cream or white streaks were identified in sherds of many fabrics, yet the presence of such streaks appears to have had little impact upon the results generated. These streaks are unlikely to be calcareous as the highest Ca values recorded were for offcuts of two non-streaky fabrics, F07 and 14, and because offcuts of massively streaky fabrics such as F04M, F05M, F12M and F16M all produced low Ca readings (figure 9.23). When all non-streaky, streaky, and massively streaky fabrics are grouped together there are minor differences in Ti and Al values between non-streaky and other samples, with the latter having higher quartile values than non-streaky offcuts (figure 9.25). This suggests that these features may be comprised of those elements, though further targeted chemical analyses would be required to resolve their composition.

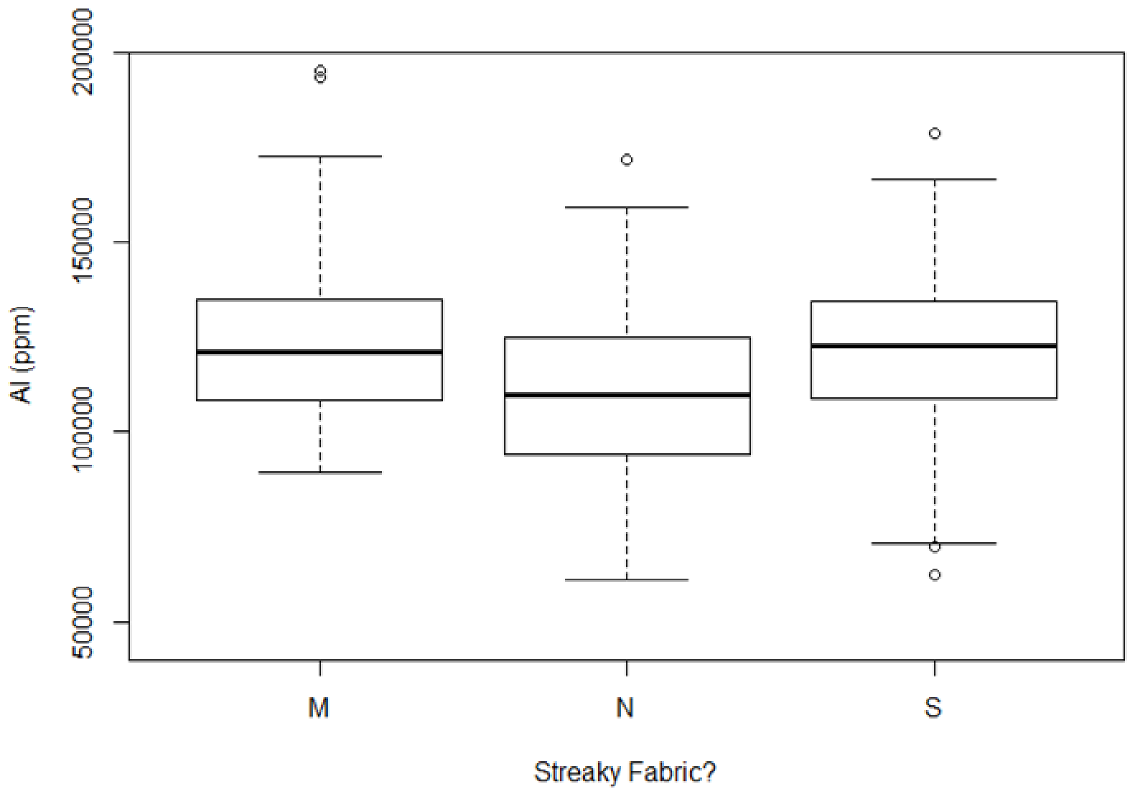


**Figure 9.25: Graph showing the quartile values for Al recorded from CBM offcuts from different streaky (S), non-streaky (N) and massively streaky (M) fabric groups.**

While a range of features observed in fabric analyses can therefore be correlated somewhat with chemical results from Si, Ca and Al, a range of fabric groups presented exceptional values for other elements. The results from Sr produced a similar distribution to that of Ca in figure 9.23, with the highest population values observed in offcuts of F07 and 14, and low values for F04 yet with a significant number of high outliers in that fabric. Sr should therefore correlate with Ca, though this is actually only a moderate positive correlation (figure 9.26), with a Pearson correlation coefficient calculated to be 0.61. The correspondence of both elements may suggest a common source, perhaps through co-occurrence in remnant fossil shell inclusions (e.g. Sucheras-Marx et al. 2021), or in post-depositional mineral formations in empty voids.

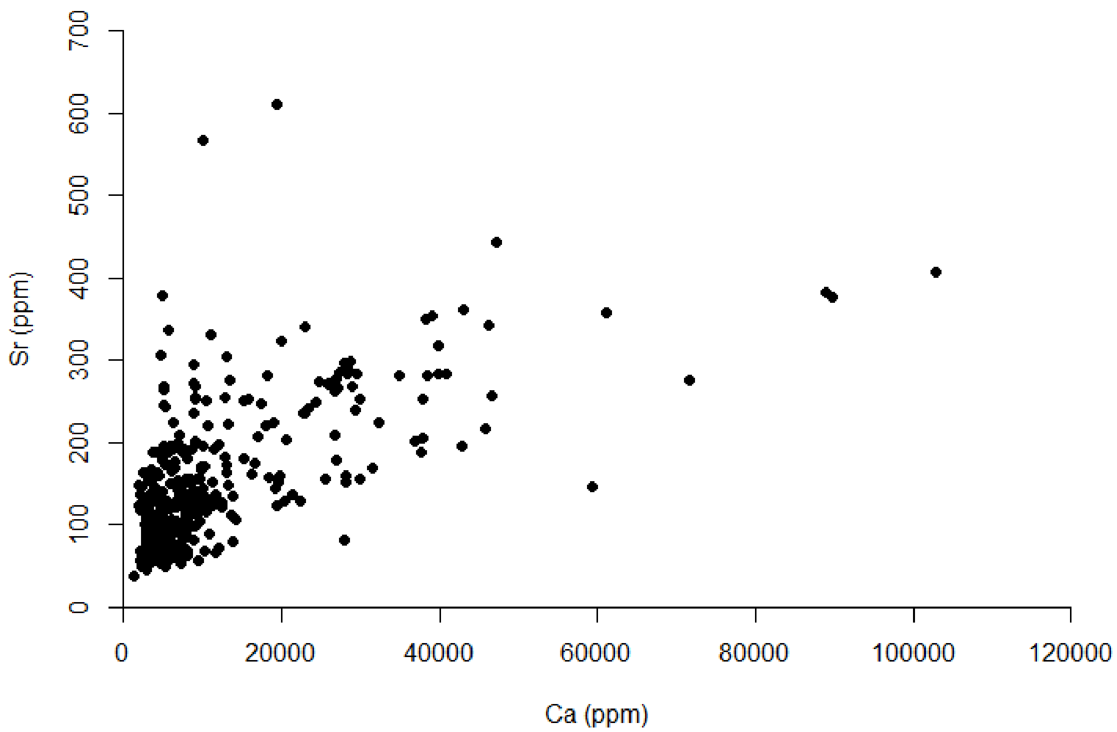


**Figure 9.26: Graph plotting the recorded values of Ca and Sr from samples from the Roman Baths assemblages.**

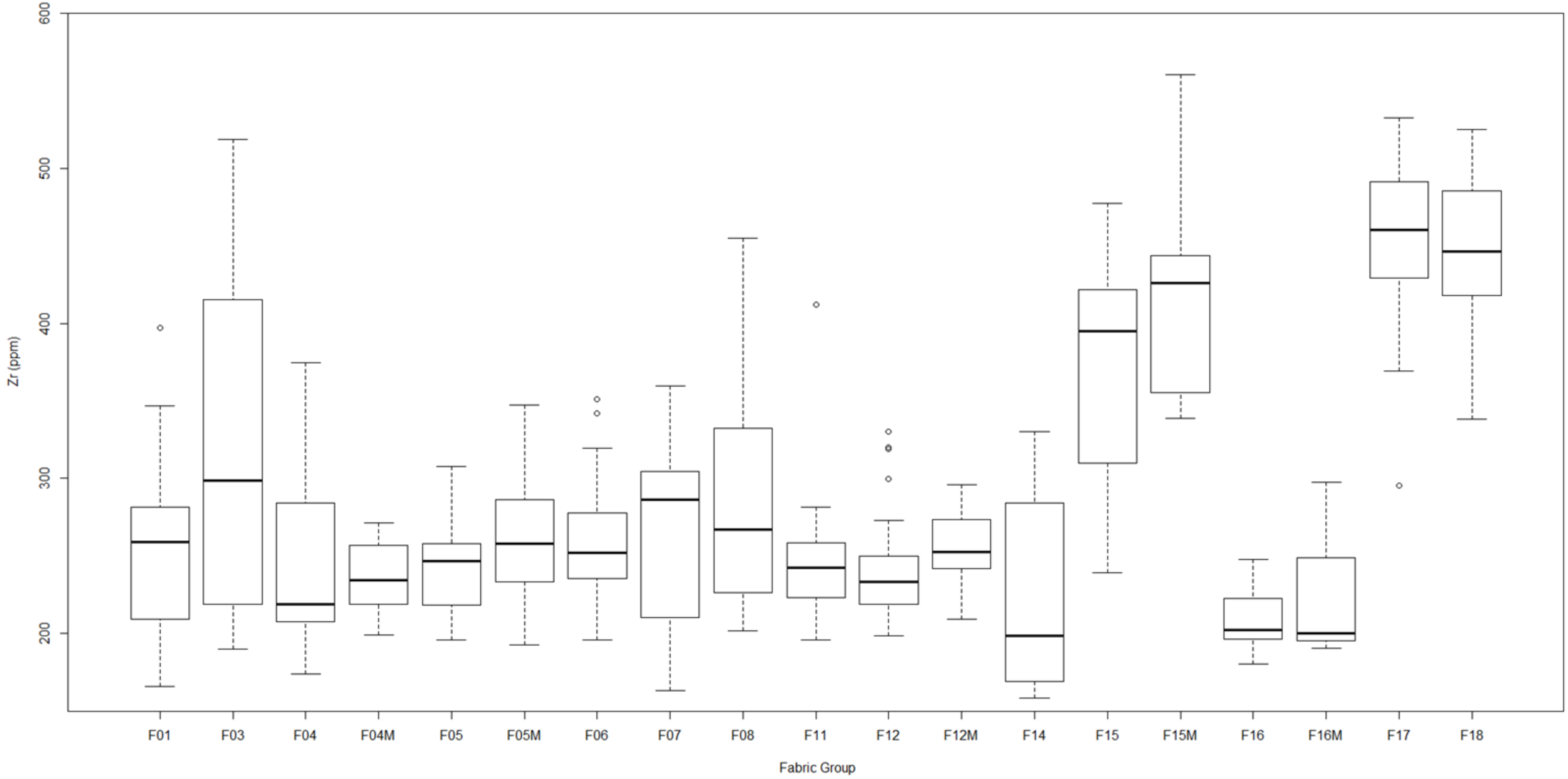


**Figure 9.27: Graph showing the quartile values for Zr recorded from CBM offcuts from each different fabric group.**

The values for Zr demonstrated an even more pronounced correlation towards sandy fabrics than that observed for Si (figure 9.22), with the same fabric groups of F15, 15M, 17, 18 and a smaller number of examples of F03 and 08 demonstrating significantly elevated values (figure 9.27). While a small number of offcuts from the Temple Precinct assemblages produced readings of over 400ppm (figure 9.28), enhanced Zr values appear to be distinctive of material from the East Baths and may represent a discrete phase of supply to the site.

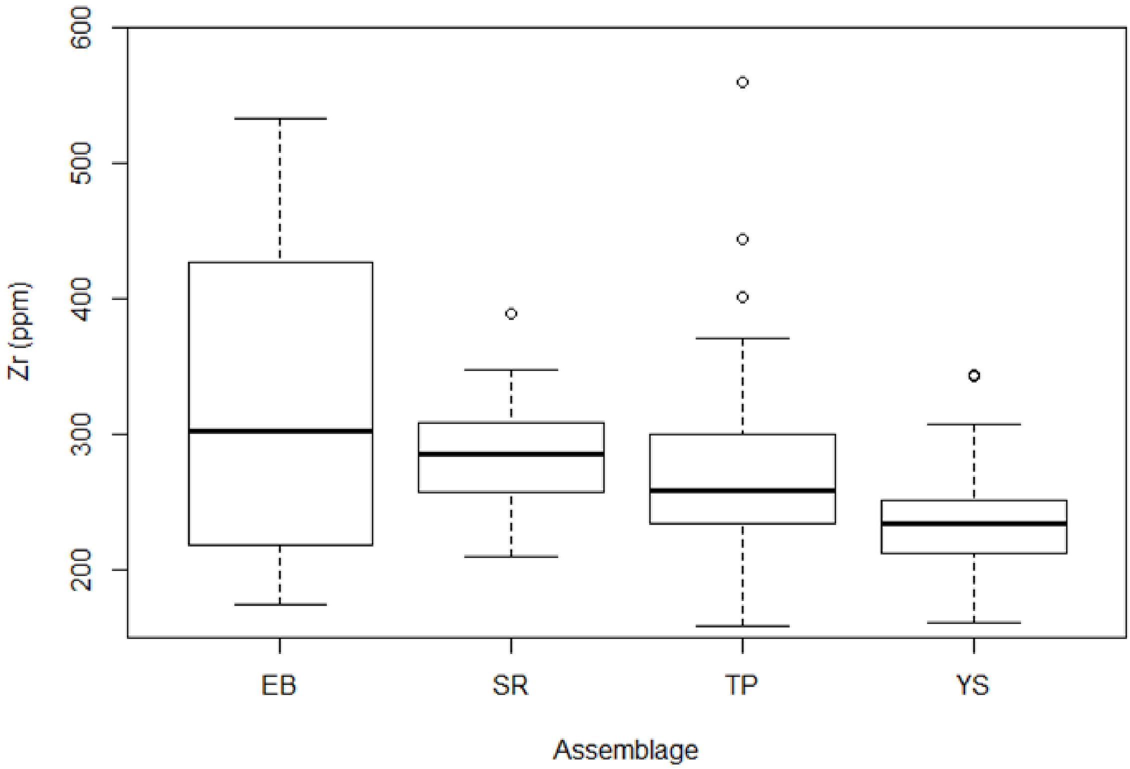


**Figure 9.28: Graph showing the quartile values for Zr recorded from CBM offcuts from each assemblage from the Roman Baths.**

Offcuts of fabrics 01, 11, 12, 12M, 14, 16 and 16M all produced a range of low values of Nb in comparison to other fabrics (figure 9.29), though F01, 11 and 14 also yielded high values. The low readings of offcuts from F16 and 16M are particularly conspicuous, however the absolute difference between these and readings from other fabrics is only in the order of 20ppm. These differences may therefore be the result of nothing more than natural variation in a single clay source, though may suggest a common affinity for several coarse fabrics.

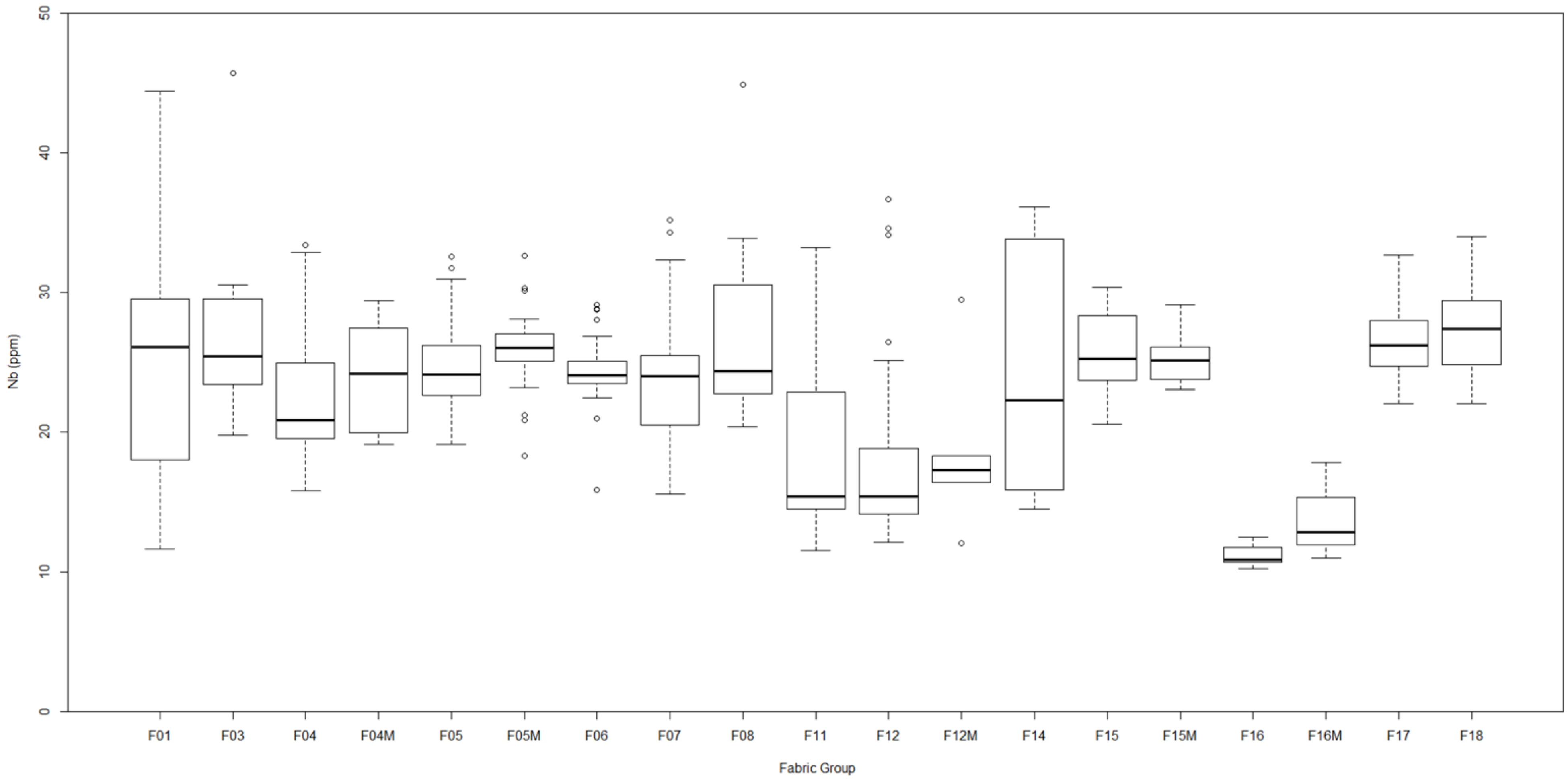


**Figure 9.29: Graph showing the quartile values for Nb recorded from CBM offcuts for each different fabric group.**

### 9.3.2 Principal Component Analyses of Samples from the Roman Baths

Principal component analyses were completed in order to investigate relationships between offcuts. All readings were transformed from parts per million (ppm) into logarithmic values prior to analysis in order to balance the contribution of major, minor and trace elements values to the variation in the dataset. Ten elements that could be measured with reasonable precision and accuracy (Appendix H) were selected for inclusion, namely Fe, Ca, Si, Al, Ti, K, Rb, Sr, Zr and Nb. Baxter and Freestone (2006: 524) demonstrated that the principal component of variation in chemical analyses of archaeological ceramics is typically a result of 'temper effects', i.e. dilution of background clay composition as a result of increased quartz or other inclusion content.

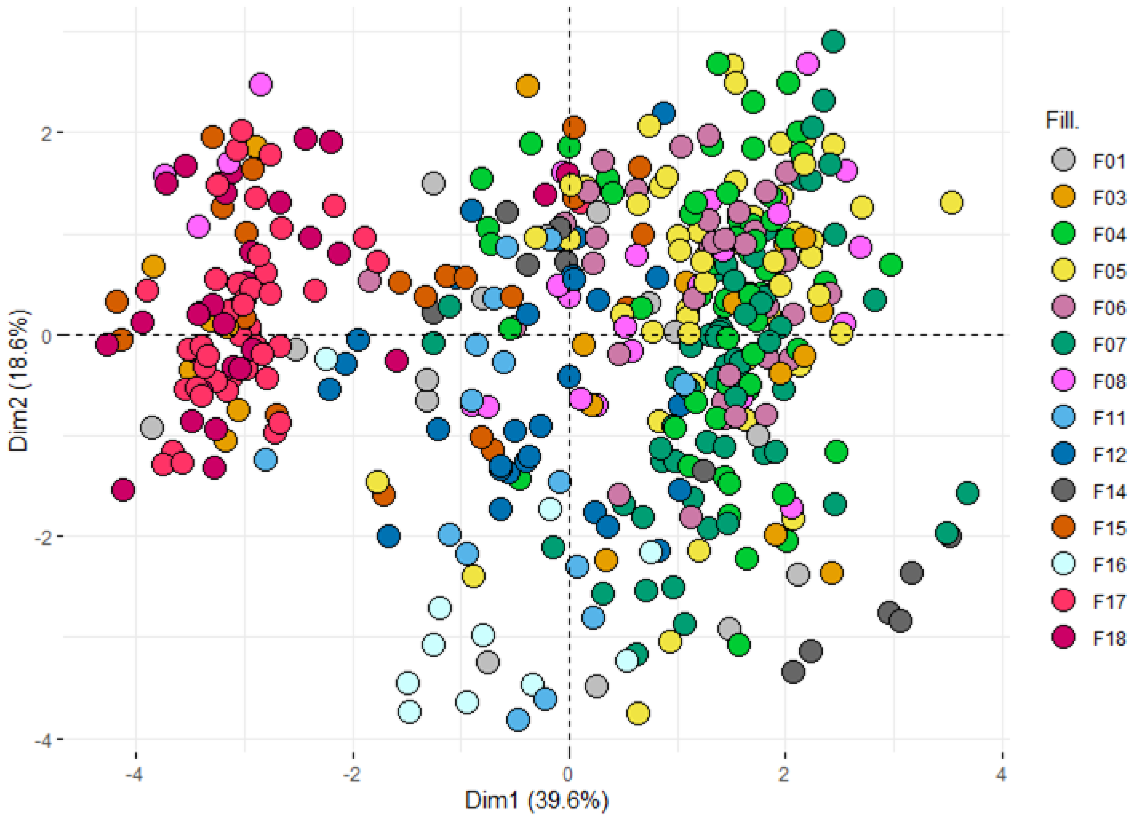


**Figure 9.30: Graph plotting values for principal components 1 and 2 for samples analysed from the Roman Baths, excluding outlier values from the Spring Reservoir and York Street assemblage.**

This appeared true of the data from the Roman Bath samples, with a clear negative correlation between the amount of quartz visually identified in samples and the values observed for the principal component of variation (figure 9.30). Offcuts identified as being quartz rich, particularly samples from fabrics 15, 17 and 18, consistently presented extremely low values for PC 1. Conversely, those fabrics that were identified as being quartz poor, for example many sherds of fabrics 04 and 07, often showed high values for PC 1. The principal component of variation in this dataset was therefore not used to further investigate the relationships between different samples.

The remaining principal components of variation investigated, two and three, should yield groupings based on the underlying chemistry of the ceramics (Baxter and Freestone 2006), though what PC 3 represents in real terms is uncertain. As the principal component of variation was omitted, the second and third components were therefore responsible for only a moderate range of variation in the dataset, generally between 30-40%. Following Kaiser (1960), these values were only used if they presented eigenvalues greater than 1.0 in order to better ensure the reliability of these results.

Initial plotting of the data (figure 9.31) demonstrated that a range of offcuts from the Spring Reservoir assemblage presented very low values for principal components 2 and 3 in comparison to the rest of the assemblage. Examination of the loading plot (figure 9.31, right) suggests that these values are largely a result of reduced Rb, K and Si, and to a lesser extent Nb, values in the material from the Spring, for these elements correlate strongly with principal component 2. This confirms elemental disparities noted in section 9.3.1, which are likely to be a result of submersion in the hot Spring Reservoir waters.

A small number of sherds from the York Street assemblage also presented low values for PC 2 and high values for PC 3, suggesting reduced Si, Al, and Ti but high Ca. All of these outlier values from the Spring Reservoir and York Street assemblages were removed and the principal components of variation recalculated.

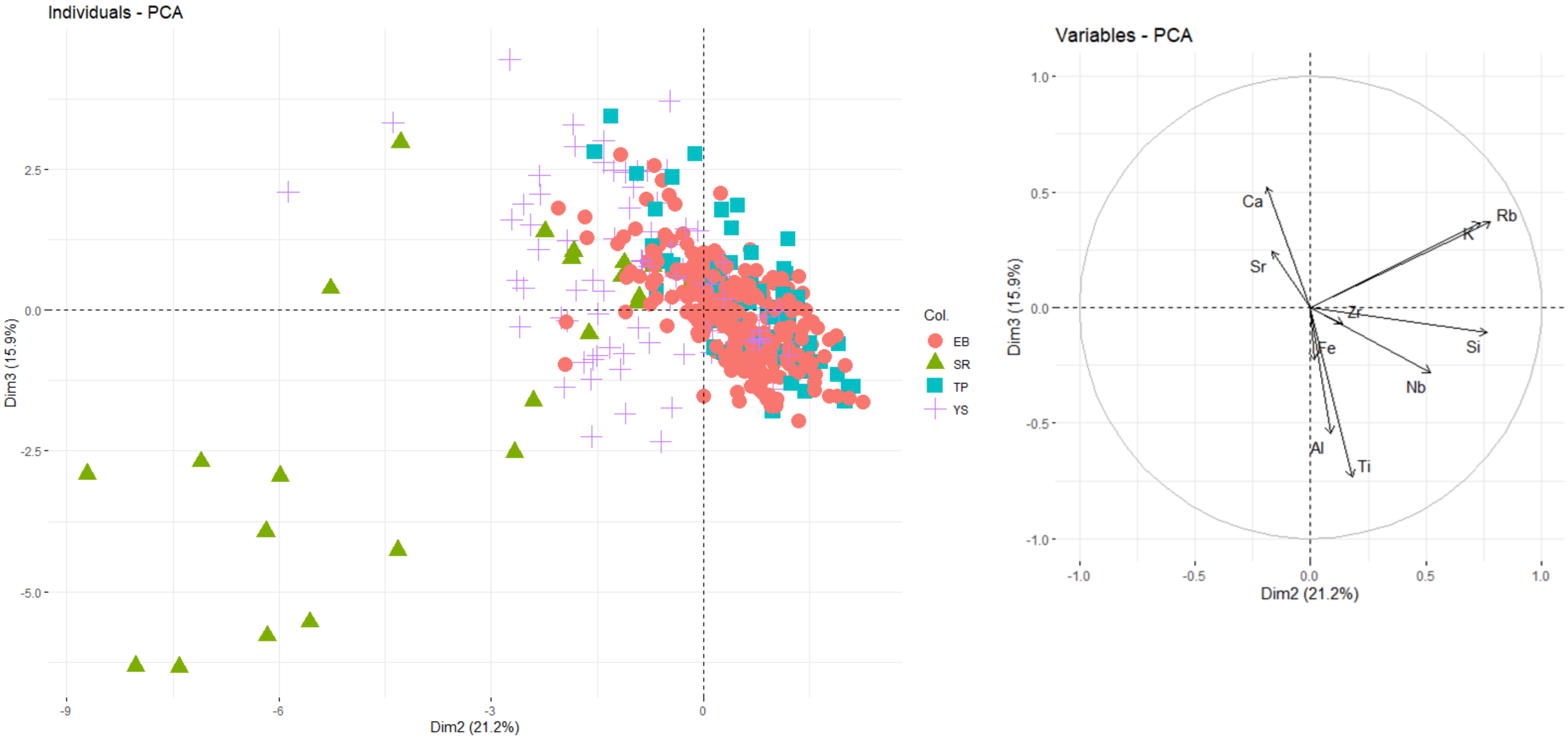


**Figure 9.31: Graph plotting values for principal components 2 and 3 for all samples analysed from the Roman Baths, coloured by assemblage. The loading plot for this graph is shown to the right.**

Reanalysis after removal of outliers showed substantial overlap between samples assigned to different fabric groups. Nevertheless, offcuts of several fabrics do appear to group apart to some extent. Many samples of F11 and F12 group together (figure 9.32), with moderate or low values for PC 2 and high values for PC 3, though a number of sherds of these fabrics present a much wider range of values. This suggests low Ca, Sr and Nb values for many of these offcuts, as all of these elements are negatively correlated with PC 3 (figure 9.32, right). Both fabric 11 and 12 co-occur in Westhampnett hollow voussoir types (section 9.2.4), so the close relationship demonstrated here is not particularly surprising.

Sherds of the distinctive pale and coarse fabric 16 (very pale blue in figure 9.32), presented low values for PC 2 and high values for PC3. From the loading plot, this suggests that these offcuts were relatively poor in elements such as Si, Ti and Nb, which all correlate with PC 2, and Ca and Sr, which negatively correlate with PC 3. There is some overlap between F16 and offcuts of other coarse fabrics, for example F01, 11 and 12. These fabrics were found to co-occur in hollow voussoir type 05 (section 9.2.4), so may represent variants from the same batch that presented slightly different textural features, if not suggesting a common source for many samples of these fabrics.

Many other fabrics included particularly wide spreads of samples. Offcuts from fabric 14, for example, consistently presented moderate negative values for PC 3, but spanned much of the breadth of PC 2 (figure 9.32). Offcuts of fabric 07 appear closely related to many of fabric 04, yet both appear in two broad clusters around coordinates (-1, -2) and (0.5, 1.5). A relationship between fabrics 07 and 04 was suggested by their co-occurrence in half-box flue tiles from the same contexts in the East Baths (section 9.2.3). Indeed, one F04 and one F07 offcut from the half-box flue tiles were included and plotted closely together in the lower cluster of F04/07 samples. The two different groupings observed here may suggest different batches supplied to the site that appeared texturally indistinguishable, though whether the product of different deposits at the same kiln site or of multiple different sites is unclear.

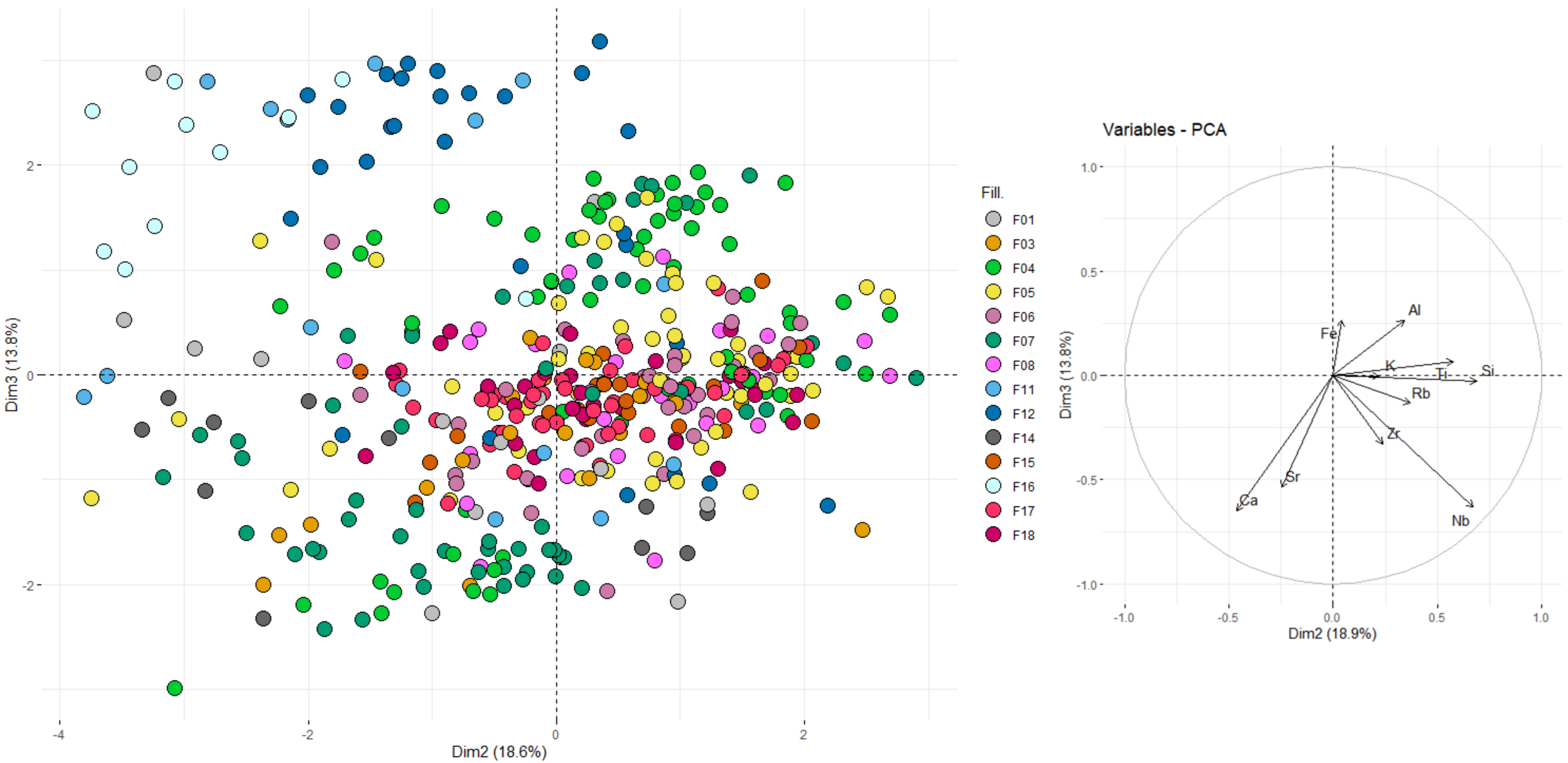


**Figure 9.32: Graph plotting principal component values two and three of offcuts analysed from the Roman Baths with outlier values removed, coloured by fabric group. Normal and massive (M) streaky variants are grouped, e.g. F05 and F05M. Loading plot shown to the right.**

There was much more extensive overlap between offcuts of fine fabrics 03, 05, 06, 08, 15, 17 and 18. While disparities in Si and Zr concentrations had been noted between samples of these fabrics (section 9.3.1), they plot closely together on the basis of PC 2 and PC 3, suggesting that any differences observed were largely a product of varying quartz contents. The mean values for offcuts from these groups are also very similar (see figure 9.33), indicating that these fabrics are likely to be related. The mean values for offcuts of fabrics 07 and 04 also plot closely to some of these values, yet this is perhaps misleading for both F04 and F07 have a range of samples distributed to either side of the main group of fine sandy offcuts (figure 9.32), making averaging towards the origin inevitable. Fabrics 04, 05 and 06 were noted to co-occur together in hollow voussoir types HV01, 02, 06 and 09 (section 9.2.4), and a range of samples from both F04 and F07 actually plot directly amongst the dense concentration of samples of fine fabrics (see figure 9.32). Many of the F04 offcuts, and indeed certain F07 samples, are therefore consistent with an origin at the same source(s) as the fine fabrics.

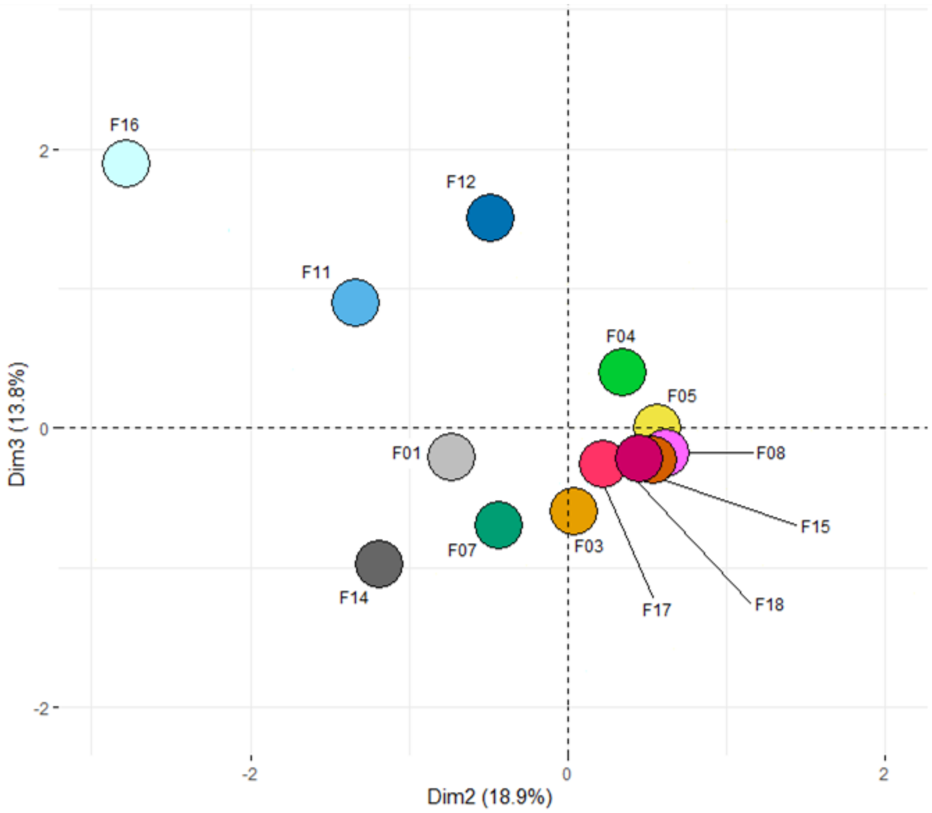


**Figure 9.33: Graph plotting the fabric group mean values for PC 2 and 3 for offcuts analysed from the Roman Baths with outlier values removed. The group mean for F06 is obscured by the means of fabrics 05, 08, 15 and 18. See figure 9.32 for the loading plot.**

Principal component analyses were undertaken separately on offcuts from hollow voussoir and Westhampnett hollow voussoir sherds in order to investigate whether samples from suggested different types (section 9.1.3) formed distinct groupings. As can be seen (figure 9.34), three distinct clusters emerged. The first concentration consisted solely of sherds of type HV08, which were only found in the East Baths assemblages. The loading plot for this data (figure 9.34)) suggests that these were differentiated on the basis of high Si, Zr and Nb values, which presented strong negative correlations to PC 2.

The middle cluster consists of a range of material, including sherds of HV01, 02, 06, 09 and two offcuts from Westhampnett hollow voussoir sherds. All four of these hollow voussoir types occurred in the same range of fabrics (section 9.2.4), predominantly including F04, 05, 06, 08 and massive equivalents, and the close relationship demonstrated here suggests that they are consistent with production at the same site. The occurrence of two Westhampnett hollow voussoir offcuts in this group is perhaps surprising (figure 9.34), but in fact these two samples were the only two sherds from Westhampnett hollow voussoirs identified in fine fabrics 06 (OTK 813) and 15 (OTK 1035). Although the exact type of Westhampnett component these sherds came from could not be identified, their grouping alongside texturally similar fine fabrics, as opposed to the typical coarse fabrics of this tile type, is significant. It may suggest that these sherds came from a batch of Westhampnett hollow voussoirs produced at a different site to the rest, perhaps the same as that producing hollow voussoir types HV01, 02, 06 and 09. Alternatively, and if from the same kiln site as the other Westhampnett sherds, it could suggest considerable variation within the clays being used and a possible link between the production of fine and coarse fabrics not otherwise evident.

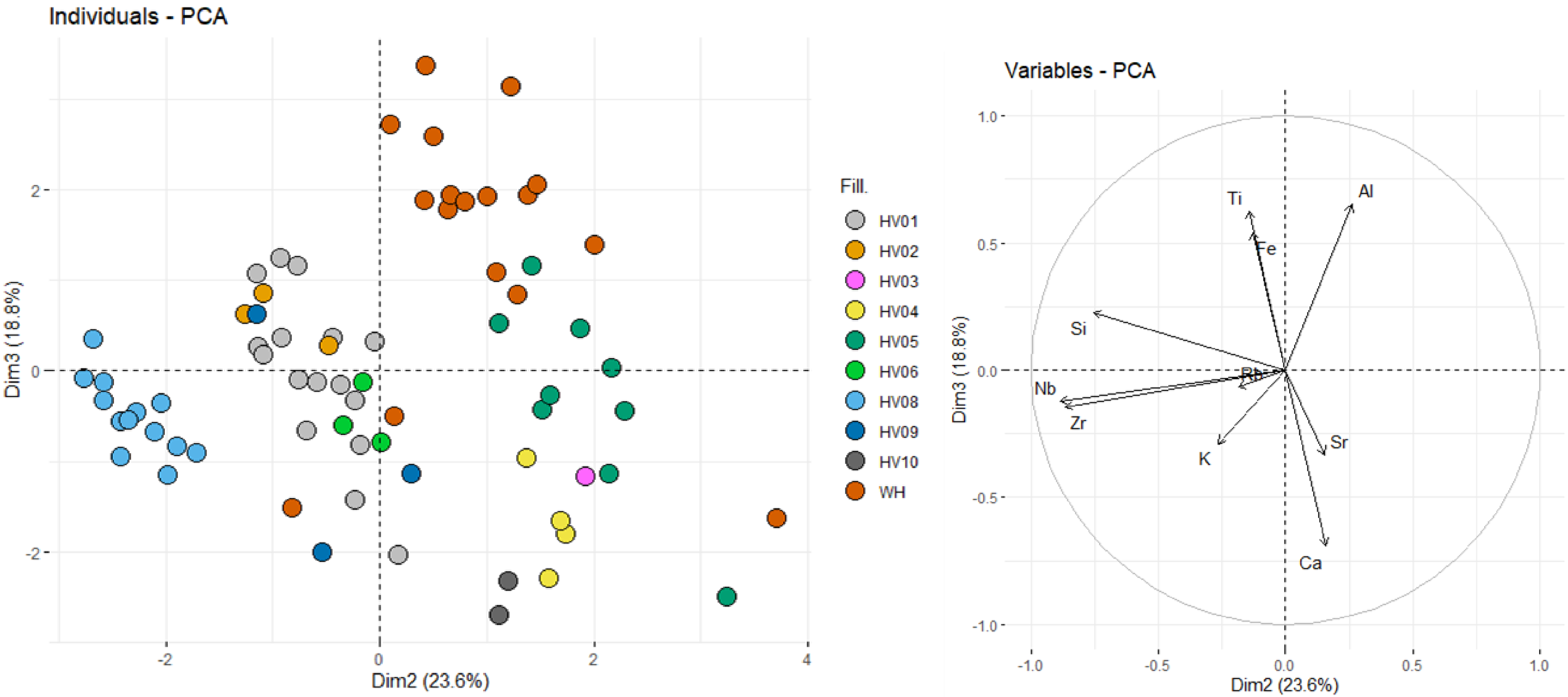


**Figure 9.34: Graph plotting principal component values two and three for hollow voussoir and Westhampnett hollow voussoir offcuts analysed from the Roman Baths, coloured by HV type. All samples from Westhampnett hollow voussoir sherds were grouped together under WH. Sherds from unidentified hollow voussoir types were omitted from the analysis.**

The third grouping, though less coherent, consists solely of hollow voussoirs and Westhampnett hollow voussoirs in coarse fabrics 01, 11, 12, 14 and 16. Though the numbers of offcuts per tile type are small, there are nevertheless several discrete sub-groupings. The two sherds of HV10 groups together, as do several sherds of HV04. Many of the Westhampnett offcuts form a group with high PC 3 values, suggesting high Ti, Al and Fe readings (figure 9.34). One Westhampnett offcut does occur alone, with high PC 2 and low PC 3 values suggestive of low Nb, Zr and Si but high Ca readings. This was OTK sherd 383, which was from an unidentified Westhampnett voussoir type. This could suggest that it is an unidentified sherd from a particularly thick hollow voussoir, or perhaps that it was made from a non-typical deposit at the same kiln site as the other Westhampnett sherds. The samples of HV05 also form something of a group, though there is some overlap with a few Westhampnett and other coarse hollow voussoir sherds.

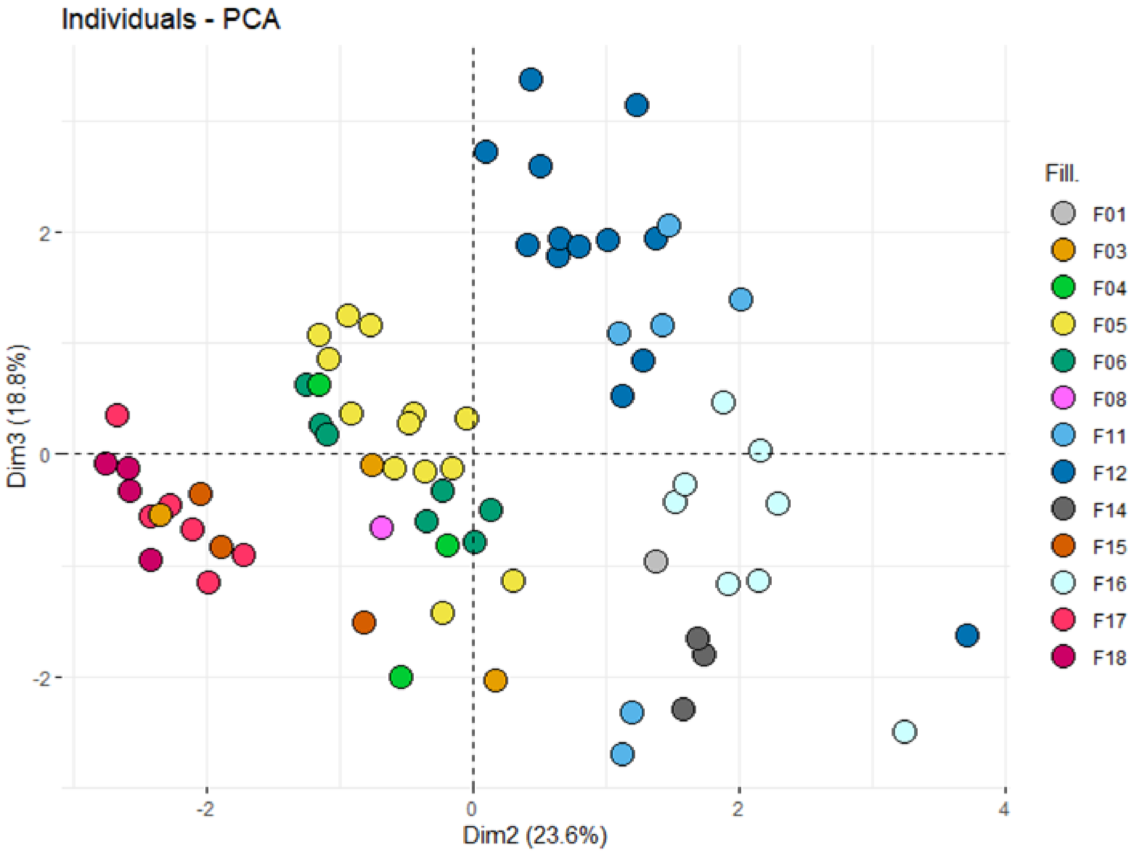


**Figure 9.35: Graph plotting values for PC 2 and 3 for hollow voussoir and Westhampnett hollow voussoir offcuts analysed from the Roman Baths, coloured by fabric group. Normal and massive (M) streaky variants have been amalgamated, e.g. F05 and F05M. See figure 9.34 for the loading plot.**

Overall, the groupings of samples from different hollow voussoir types (figure 9.35) suggests that the distinctions made between these components on the basis of different sizes (section 9.1.3) and fabrics (section 9.2.4) are likely to be meaningful. The distinct grouping of HV04 offcuts of fabric 14 away from HV01 offcuts in their range of fine fabrics further suggests that HV04 is unlikely to be a mere batch of HV01 used to roof the Period III Great Bath. Conversely, the two offcuts from HV09 sherds group well with HV01 sherds and therefore HV09 may well be a distinctive batch within HV01, as discussed in sections 9.1.3 and 9.1.6. The limited overlap between offcuts of the Westhampnett hollow voussoirs and pale HV05 hollow voussoirs may also indicate a common source for these fabrics.

### 9.3.3 Principal Component Analyses of Comparative Samples

All non-outlier samples from the Roman Baths were collated with all offcuts of comparative and stamped material sampled. Further principal component analyses were then completed on this dataset in order to investigate how compositionally similar the samples from stamped tiles or other sites were to those from the Roman Baths.

These analyses served to demonstrate that there are clear limits to the capabilities of pXRF as applied to archaeological ceramics using such a restricted range of elements. Figure 9.36 shows a number of clear overlaps between material from the Roman Baths and regional comparative materials, many of which were the result of production across a wide range of geological strata. The overlap between the samples analysed from Fishbourne Roman Palace and from the Minety kiln site are particularly problematic. This is because the samples from Fishbourne are likely to be the products of a workshop that may have been located nearby in West Sussex, for a range of sherds of relief-patterned tiles in the distinctive London-Sussex group fabrics have been identified among the Fishbourne assemblages (e.g. Betts et al. 1997: 19-20, 28). The overlap between the Fishbourne samples and the Minety material is therefore significant for two reasons. Firstly, it suggests that clay deposits of different ages in discrete regions can yield very similar compositional readings for the ten elements included here. Secondly, both Minety and the London-Sussex group workshop presented reasonable candidates for the source of at least part of the ceramic building materials from the Roman Baths, particularly the early Westhampnett hollow voussoir sherds in the case of the latter.

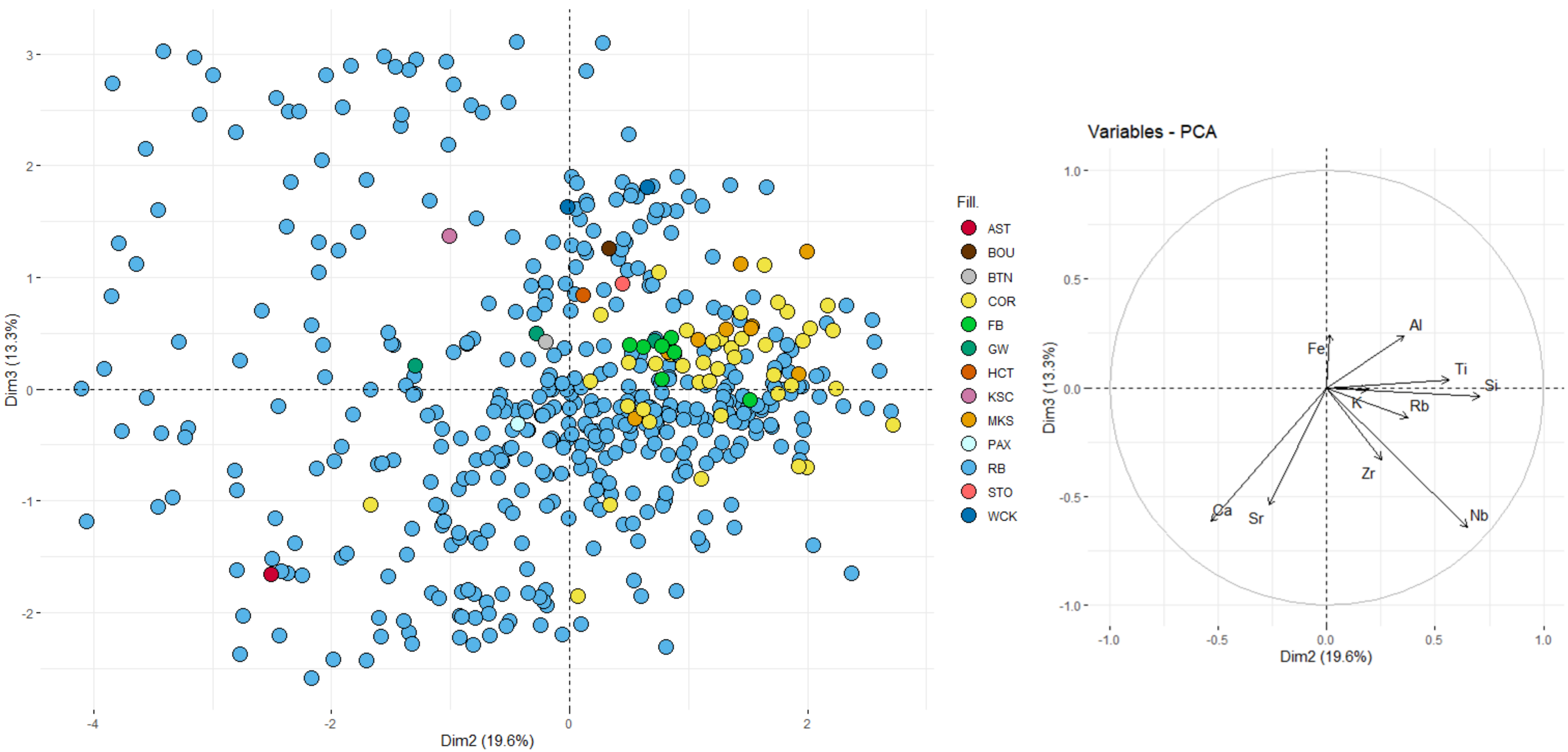


**Figure 9.36: Graph plotting values for PC 2 and 3 for stamped tile from Cirencester (COR), Roman Baths samples (RB), Hucclecote (HCT), Kingscote (KSC), Fishbourne (FB), the Minety kiln site (MK), St Oswald's kiln site in Gloucester (STO), Great Witcombe Villa (GW), the possible kiln site at Wick (WCK), Bitton (BTN), Aston Magna (AST), Paxford (PAX) and Bournemouth (BOU). Loading plot shown on right.**

The values of material from both production centres appear consistent with those for many samples of the Roman Baths, yet the range of elements selected are not enough to discriminate further. It is therefore possible that the sherds from the complex that demonstrate similar values could be from one kiln site, from the other, or from a separate workshop entirely. Despite this, it is important to emphasise that the unanimously coarse and rarely streaky Fishbourne samples are texturally very distinct from the offcuts of fine fabrics they share values with, in contrast to the Minety samples. The Fishbourne material is also compositionally distinct from texturally similar samples of F11 and F12, many of which present higher values for PC3 and lower values for PC2, indicating reduced Nb, Ti, Si, Ca, and Sr values (figure 9.36). These samples also included all but two offcuts of Westhampnett hollow voussoirs analysed. This suggests that, on balance, the London-Sussex workshop is a less likely source for the Roman Baths CBM than the Minety kiln site.

A range of other samples from Roman or post-medieval brickworks in Gloucestershire also present similar compositional values to material from the Roman Baths. A single imbrex fragment analysed from the St Oswald’s kiln site in Gloucester (e.g. Heighway and Parker 1982, STO in figure 9.36), groups closely to a range of sherds from the Roman Baths in fabrics 04, 05, 07 and 08 and with several different stamped tiles (figures 9.37), yet this kiln site appears to have exploited alluvium (e.g. BGS 2022b). A sample of brick from the post-medieval Paxford brickworks (PAX in figure 9.36), situated on the Early Jurassic Charmouth Mudstone (BGS 2022a), appears close to the origin amid a group of fine sandy fabrics from the Roman Baths. Intriguingly, a sample of post-medieval brick from the Aston Magna brickworks, which were only a few hundred metres from the Paxford brickyard and on the same deposits (BGS 2022a), instead shows significantly reduced values for both PC 2 and 3. This is a result of reduced Ti, Si and Nb, which correlate strongly with PC 2, and increased Ca and Sr, which has a negative correlation with both PC 2 and 3 (figure 9.36, right).

The close relationship of certain comparative regional samples with offcuts from the Roman Baths may suggest a diverse but regional or local origin for the CBM from the site. Nevertheless, the overlap in values with the Roman material from Fishbourne, and indeed a brick from Bournemouth (BOU in figure 9.36), indicates that samples from different regions and from formations of different geological age nevertheless present

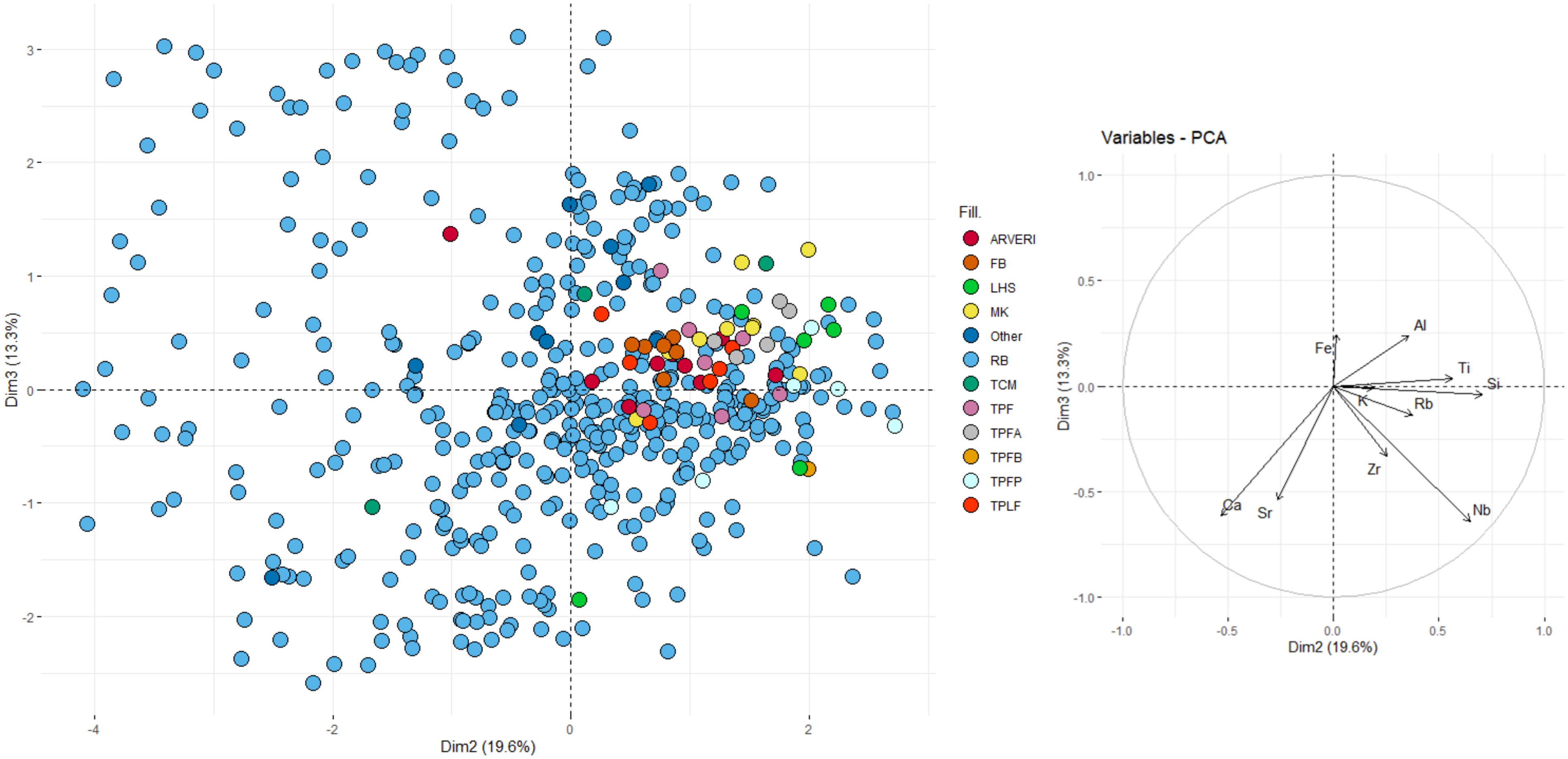


**Figure 9.37: Graph plotting the values for PC 2 and 3 for samples from the Roman Baths (RB), from all stamped tile groups, from Fishbourne Roman Palace (FB), the Minety kiln site samples (MK) and comparative regional materials. Loading plot shown to the right.**

very similar values for the ten elements included here. More secure provenance therefore requires methods employing a greater, or different, range of elements.

Despite the limitations of the range of elements selected, the close relationships between many of the ARVERI, TPLF, LHS and TPF series stamped tile samples and the Minety kiln site material (figure 9.37) appeared significant. In order to test if these relationships were still present when outlier values and fabrics were omitted, the offcuts from the ARVERI, TPLF, LHS and TPF series stamps were grouped into a single dataset with the Minety kiln site samples and sherds of fabrics from the Roman Baths that most closely matched this material texturally. Principal component analyses were rerun on this dataset, and the results plotted (figure 9.38).

Many samples of TPF, TPFA, TPFP and LHS stamped tiles still plotted closely together with each other and with samples collected from the Minety kiln site (circled in figure 9.38), though TPFP tiles perhaps show more affinity with the LHS group than with other stamp types. This suggests that these series of stamped tiles are largely consistent with having been produced at the Minety kiln site. While the limitations of these elements for understanding provenance still apply, in fact many of these tiles have previously been suggested to have a Minety origin on the basis of thin-section petrographic analyses (Darvill 1979). Moreover, TPF and LHS stamped tiles have actually been recovered from topsoil at the site (McWhirr 1984: 42), thus confirming some of the relationships demonstrated in these pXRF results.

Most samples of ARVERI and TPLF stamped tiles also plot closely together with each other (dashed ellipse in figure 9.38) and with samples from other stamped groups, particularly TPF, TPFA and LHS, in addition to the Minety kiln site samples. This is perhaps surprising, for the ARVERI and TPLF stamps have previously been treated as distinct from the TPF series in terms of quartz size distributions in thin-sections (Darvill 1979, 1982), in the suggested evolutionary sequence of Roman stamps in Britain (Warry 2017: 94-95) and on the basis of the actual distribution of finds of these stamped tiles (Darvill 1979, 1982, Darvill and McWhirr 1984, Warry 2017), though the majority of these have been excavated in Cirencester in common with the LHS and TPF series stamps

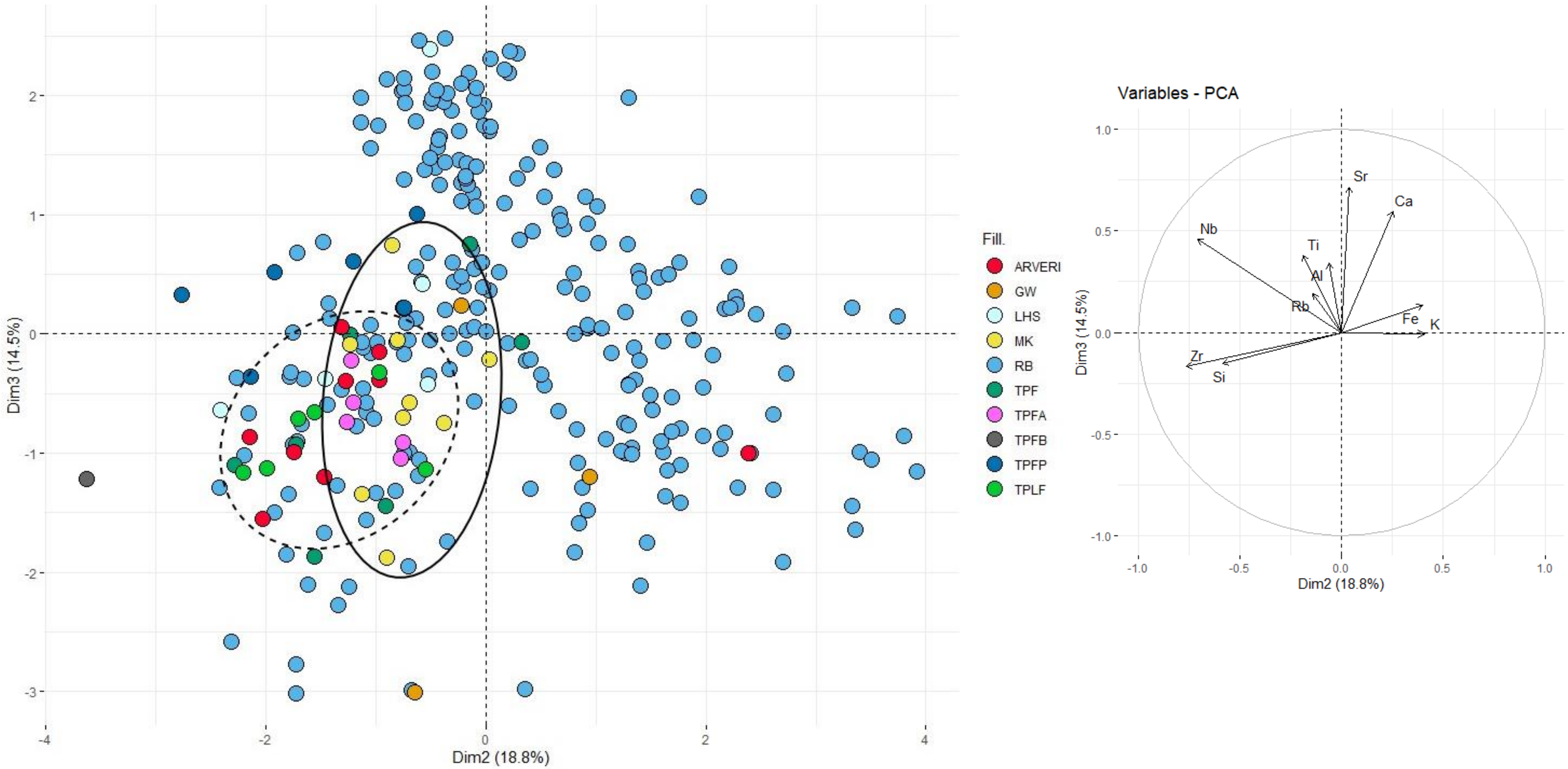


**Figure 9.38: Graph plotting values for PC 2 and 3 for offcuts of F04, 05, 06, 08 and 15 from the Roman Baths (RB), from ARVERI, TPLF, LHS, TPF, TPFA, TPFB and TPFP stamped tiles, from the Great Witcombe Roman Villa (GW) and the Minety kiln site samples (MK).**

The similar compositional values between the ARVERI and TPLF specimens and Minety samples may represent nothing more than the use of compositionally similar clays at a different kiln site entirely. Nevertheless, given the range of different stamped tiles already linked to Minety (e.g. figure 9.39) and the concentration of ARVERI and TPLF tiles in Cirencester, it seems highly likely that these stamps may only represent further workshops at the same site or nearby, though perhaps separated temporally from the other stamped tile groups as Warry (2017: 94) suggested. While no examples have yet been found of TPLF or ARVERI stamps at Minety, the site has received limited investigation (e.g. McWhirr 1984: 42, Scammell n.d.), and it may be that the areas and kilns of these other workshops merely await discovery.

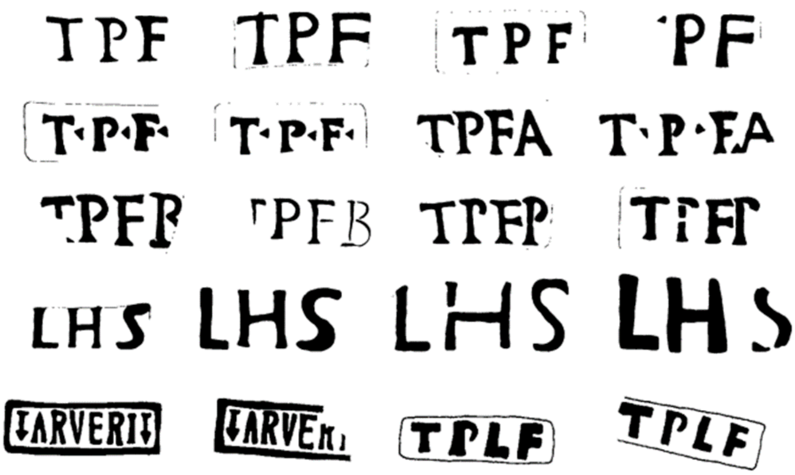


**Figure 9.39: Illustration of different stamps found on Roman brick and tile from Gloucestershire and which were analysed in this study. Not to scale. Modified from Darvill (1982: figures 2 and 5) and Darvill and McWhirr (1984: figure 5). Darvill, T. C. and McWhirr, A., 1984. Brick and Tile Production in Roman Britain: Models of Economic Organisation. © Bristol and Gloucestershire Archaeological Society and Informa UK Ltd. Reproduced with permission of Informa UK Ltd. through PLSclear.**

There is also considerable overlap between many samples from the Roman Baths and those of stamped tiles and Minety kiln site samples (figure 9.38), suggesting that many sherds from the Roman Baths are consistent with production at that site. Further evidence for the production of CBM from the Roman Baths at Minety is presented in section 10.2. Nevertheless, the lack of stamped tile finds from the Roman Baths or the wider settlement does suggest that supply to the complex was distinct from the typical production of the stamping workshops, whether chronologically or in practice.

# 10 Discussion

This chapter will consider and evaluate the results of the novel analyses of the ceramic building materials from the Roman Baths. The implications of the range of components and typical sherd weights and dimensions present in each assemblage are initially considered to understand the histories of these materials. The evidence from different hollow voussoir types is then used to suggest and reconstruct possible source structures, and in the case of the Spring Reservoir Enclosure to offer a new date for its construction. Different phases of supply to the Roman Baths site are then considered. The fabrics and components identified among the Roman Baths assemblages are then equated with those from sites in the rest of the settlement, in order to create a local understanding of the provision of ceramic building materials to the Roman town. This research is then integrated with previous analyses of bricks and tiles from the wider region, revealing the importance of the Minety kiln site to supply of sites and settlements in northeast Somerset, Gloucestershire, northwest Wiltshire and even Hampshire. The evidence for the development, organisation, and phasing of different workshops at the Minety kiln site is then considered, in order to better understand how demand in the study area was met. Finally, this chapter concludes with an investigation of the different factors that may have contributed to the emergence and prevalence of centralised production and medium or long-distance transport of ceramic building materials in the region during the Roman period.

## 10.1 The Nature of the Assemblages

Each assemblage from the Roman Baths included a distinctive range of ceramic building material components, fabrics and sherd weights and sizes, indicating discrete histories of supply, use and post-depositional alteration.

### 10.1.1 The Temple Precinct and East Baths Assemblages

Sherds from the Temple Precinct and East Baths material presented similar mean sherd weights and dimensions (tables 9.1-2), suggesting closely comparable fragmentation and movement. This is perhaps surprising, for while the contexts the East Baths materials were recovered from were clearly reworked (Davenport 2011a: 11), this assemblage was relatively cohesive and dominated by bricks and combed tiles (table 9.4), often in distinctive fabrics 17 and 18 (table 9.17). It also included 55 examples of hollow voussoir type HV08 (section 9.1.3), but only a single sherd from another type, which was a base from a Westhampnett hollow voussoir (OTK 557). This suggests little movement or intermingling with CBM from other areas of the site. In contrast, the Temple Precinct assemblage is more likely to contain material from a range of structures, for these finds were excavated from an open area originally surrounded by multiple different buildings (Cunliffe and Davenport 1985). Moreover, significant post-Roman activity has been identified in the Precinct (Cunliffe and Davenport 1985), which would presumably have facilitated the movement, scattering and intermixing of building materials. The relatively high proportion of tegulae and imbrices in the Temple Precinct material, approximately a third of all sherds, also suggests that a significant part of this assemblage is not from the many barrel-vaulted structures at the complex, which show no evidence for having additional tiled roofs. While these may have come from nearby buildings with pitched roofs, it is also possible that some of these sherds may have come from structures in other parts of Roman Bath.

The similar average sherd weights and dimensions recorded for the East Baths and Temple Precinct assemblages may be significant. If not simply indicating a typical threshold at which these ceramic building materials fragment to, these data may suggest that the material in the Temple Precinct was less altered and disturbed than might be expected. This is supported by the significant presence of combed tile, brick, and hollow sherds in this assemblage (table 9.4). All but one identifiable hollow voussoir sherd from the Temple Precinct was from type HV02, from the Spring Reservoir Enclosure roof. Many of the brick fragments from this assemblage occurred in the same range of fabrics as those in the Spring Reservoir vault, i.e. distinctive heterogeneous fabrics 04M, 05M, 06M and typical streaky equivalents, and fabric 12. These sherds are probably the result of part of the vault falling forwards into the Temple Precinct. Many of the tegulae and imbrices in this assemblage may therefore have originally been used in a possible tiled roof for the quadrangular porch buttress on the north side of the reservoir enclosure wall (e.g. Cunliffe and Davenport 1985: 57-58), or may have fallen from the tiled roofs of the Temple and its paired shrine buildings (Cunliffe and Davenport 1985: 33-35) or other structures close by. The generally early date suggested for many tegulae (section 9.2.6) and the early dates for fabrics present among tegula and imbrex sherds, particularly fabrics 07, 11 and 12 (sections 9.2.3, 9.2.5 and 9.2.6) would certainly fit with an origin from early structures such as the Period I Temple.

### 10.1.2 The York Street Assemblage

The York Street material proved very different to the Temple Precinct and East Baths assemblages, with larger sherd sizes and masses, and included a very different range of components. As shown in table 9.2, the mean sherd weight for the York Street material was nearly 1.5kg, and the average longest dimension of each sherd was approximately twice that of the EB or TP collections, at 256mm. This suggests very different histories of alteration and collection. The high average sherd weights and lengths may suggest good preservation, but it might instead indicate the discarding of more fragmentary material by the excavators. The presence of many contiguous sections of hollow voussoirs from the Great Bath roof (figure 10.1) and intact specimens of hollow voussoir from other structures, including HV04, HV05, HV06 and WH1, nevertheless indicate that much material from the York Street assemblage collapsed and was somewhat cushioned and perhaps sealed, but then carefully removed upon discovery. In contrast, not a single complete example of HV02 or HV08 has been recovered from either the Spring Reservoir, Temple Precinct or East Baths investigations, despite being excavated to modern standards. This suggests that much York Street material was in a better condition upon discovery than components from the other assemblages, regardless of whether many fragmentary sherds were discarded by the excavators or not.

While other assemblages were excavated in relatively modern circumstances, the origin of the York Street material is uncertain, but probably antiquarian. Through the identification of a range of hollow voussoirs in this assemblage, more precise origins can be assigned to a range of components. The substantial numbers of sherds of HV01 identified indicate that much material is the result of Major Davis's (1884) excavations of the Great Bath, and large sections of contiguous hollow voussoirs now on display are shown in photographs from after his excavations (figure 10.1), confirming this.

**Figure 10.1: Photograph of contiguous hollow voussoir sections from the Great Bath roof excavated by Davis, perhaps in storage in the York Street vaults. From Roman Baths (2020). © The Roman Baths, Bath and North East Somerset Council.**

Hollow voussoir type HV05 probably formed the roof of the Period III aisles of the Great Bath (section 10.3). Though these tiles were not explicitly mentioned by Davis, he did note finds of stone roof tiles from the exedrae areas (Davis 1884: 14), so it is probable that he was also the excavator of the examples of HV05. Four sherds of HV02 from the Spring Reservoir Enclosure were also identified among the York Street assemblage. While these could be finds retained from older excavations in the Temple Precinct, for example at the end of the 18th century (e.g. Englefield 1792, Pownall 1795), it appears just as likely that these were collected by Davis or Mann during their excavations in the Spring Reservoir (Davis 1881) or the Temple Precinct itself (Cunliffe 1969: 42-44). The origin of the other hollow voussoirs identified from the York Street assemblage is less clear. One possible origin is Davis's excavations in the West Baths (Cunliffe 1969: 133), which included the tepidarium, and where Irvine recorded a section of collapsed but preserved hollow voussoirs lying in soil above the hypocaust (figure 9.16). The preservation of ceramic building materials apparent in that section drawing is significant, as it may explain the number of intact hollow voussoir components present in the York Street assemblage, even for components not from the Great Bath. The range of other hollow voussoir forms in the York Street material but absent from other assemblages, for example HV03, HV06, HV09, HV10 and HV11, also suggests an origin in part of the site with a wide range of vaulted and heated structures. While consistent with the West Baths, these materials could also have come from the East Baths, though many structures there were destroyed during mid-18th century works (Cunliffe 1969: 132).

Much of the York Street material is consistent with being excavated by Davis and assistants. The limited recording of much of Davis's work (e.g. Cunliffe 1969: 133), means that it will sadly never be possible to be certain. Moreover, Scarth's (1864: pl. XXXVI) depiction of a single intact specimen of a Westhampnett hollow voussoir prior to the excavations of Davis (1881, 1884), Mann (1878) or Irvine (1873) demonstrate that parts of this assemblage must be from earlier investigations (section 3.4.1). Beyond the assignment of several hollow voussoir components to certain source structures (section 10.2-3), the origin of much of the York Street assemblage can therefore only be confidently stated to be antiquarian.

### 10.1.3 The Spring Reservoir Assemblage

This assemblage comprises material almost entirely from the brick ribs of the Spring Reservoir Enclosure (section 10.2), and no hollow voussoir sherds from the same structure (type HV02) appear to have been retained with these components. Despite consisting only of bricks from one structure, there is a surprising range of fabrics present. Bricks and voussoir bricks were identified in F07, 12, 05M, 04M and 01, and therefore included coarse, fine, very fine, streaky, and non-streaky fabrics. While 04M and 05M are also seen in HV02 sherds from the Temple Precinct (section 9.2.4), and are probably Minety products, F07 and F12 may be from a different production site, as these are texturally (section 9.2.7) and chemically (9.3.4) distinct from Minety samples (though see 10.5). They also were not identified among HV02 sherds from the same structure (section 9.2.4). The occurrence of brick sherds in these fabrics may suggest that several different kiln sites supplied only the bricks used in the Spring Reservoir Enclosure. It may be that several different mostly unidentified workshops at Minety alone provided these, or even that they represent different deposits exploited when digging through the vertical stratigraphic sequence of clay pits at the site. Given the reuse of moulded bricks in the Spring Reservoir (section 10.2), it might also be possible that the voussoir bricks in fabrics 12, 01 and 07 represent components of a generic size that were made by other workshops and stored until used, though perhaps unlikely. Despite the inclusion of a very limited range of components from only a single structure, the evidence from the Spring Reservoir assemblage nevertheless indicates complexity in the production and supply of Roman building materials for large monuments.

## 10.2 The Great Bath and Spring Reservoir Enclosure

The Spring Reservoir Enclosure and the vaulted roof of the Great Bath are both thought to have been constructed during Period III at the Roman Baths (Cunliffe 1969, Cunliffe and Davenport 1985). These two monumental, vaulted structures are therefore considered here together. While Cunliffe and Davenport (1985: 180-184) proposed a date in the late second or early third century for this construction, Davenport (2021: 117) has since suggested that it took place in the mid-late second century, in line with changes observed in the walled settlement during this period (Davenport 1994, 2000, 2021). Instead, evidence from the Minety kiln site suggests that the Spring Reservoir Enclosure was constructed prior to this in the late first or very early second century. The dating evidence for the Great Bath, though limited, only supports an early second-century date onwards. This evidence, and clear changes in design and implementation between the two monuments, is therefore used to argue that the Spring Reservoir Enclosure was constructed in Period II, and the Great Bath roof in Period III. These buildings therefore represent discrete phases of activity at the site.

### 10.2.1 The Spring Reservoir Enclosure Structure

The remains of the Spring Reservoir Enclosure roof came to light largely as a result of Cunliffe and Davenport's (1985) excavation of the Spring Reservoir. Parts of this vault clearly tipped forwards into the Temple Precinct, for large sections of partially preserved hollow voussoirs and fragmentary sherds were found during excavation of those areas (Cunliffe 1969, Cunliffe and Davenport 1985). The structure is considered in depth by Cunliffe and Davenport (1985: 50-51), and Lancaster (2006: 1831-1833), and no alterations to these schemes are suggested here. To summarise, the enclosure roof consisted of substantial N-S aligned voussoir brick ribs spaced at regular intervals (figure 10.2), spanning a vault 13.3m wide and 19.8m long. The E-W aligned spine of the vault consisted of two rows of voussoir bricks and joined with each of the ribs. All gaps between the ribs and spine were infilled with sections of distinctive tall, thin hollow voussoir tiles, type HV02 (section 9.1.3). The height of these tiles, around 400mm, matched the lengths of the voussoir bricks used. As these bricks were largely employed on end, this suggests that only a single thickness of hollow voussoir tiles was intended to be used across the vault. This structure was clearly never intended to be heated, so the hollow voussoir tiles must have been employed instead of solid alternatives or concrete in order to reduce the weight of the roof.

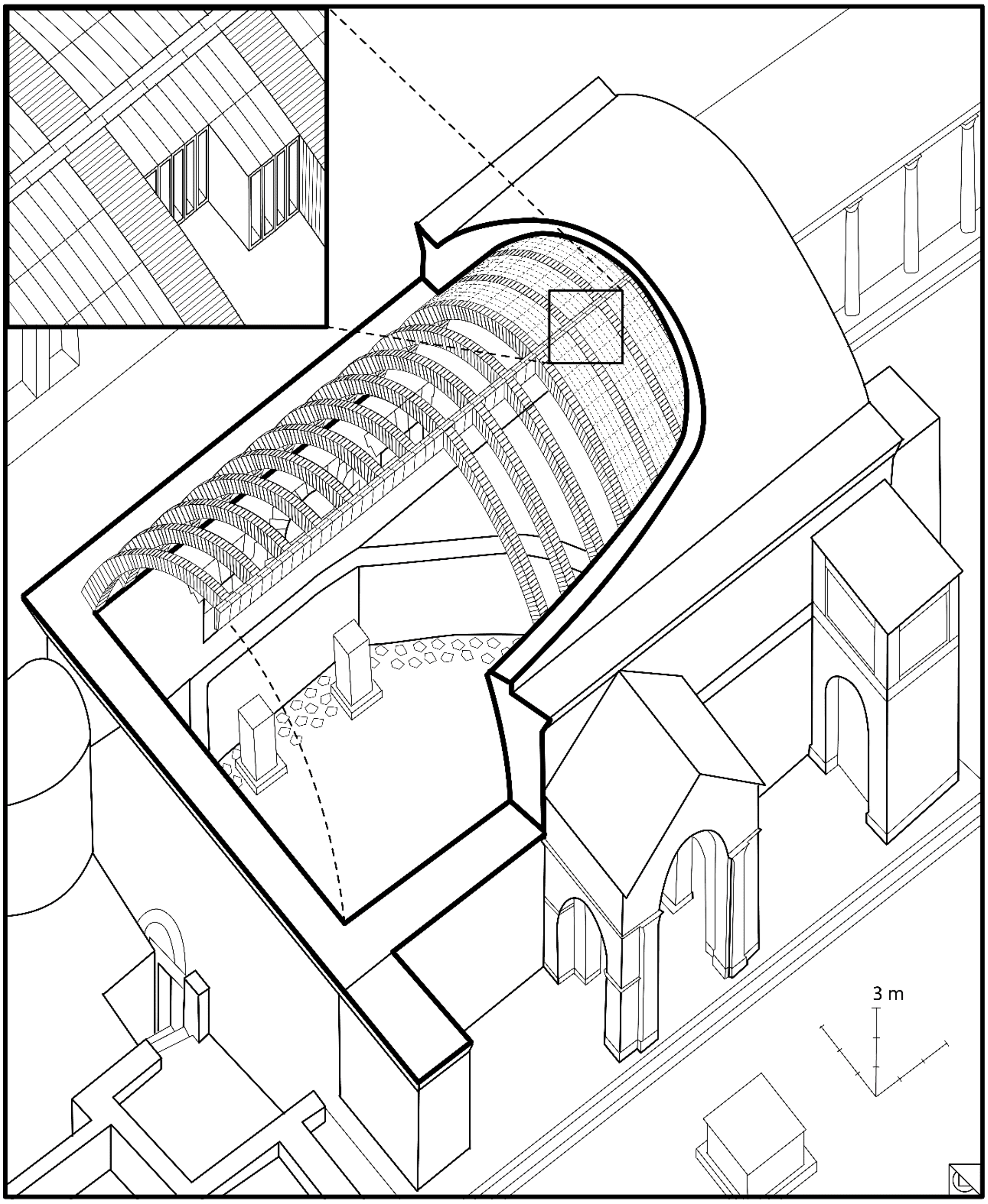


**Figure 10.2: Reconstruction of the Spring Reservoir Enclosure, showing the brick ribs and central spine of solid tiles, with infilled areas of hollow voussoirs. From Lancaster (2015: figure 98). Lancaster, L. C., 2015. Innovative Vaulting in the Architecture of the Roman Empire: 1st to 4th Centuries CE. © Cambridge University Press. Reproduced with permission of The Licensor through PLSclear.**

### 10.2.2 The Dating of the Spring Reservoir Enclosure

There is little contextual dating evidence for the construction of the Spring Reservoir Enclosure. Cunliffe and Davenport (1985: 180-184) suggested a late second- or early third-century date, on the basis that they considered it to be contemporary with the Period III reroofing of the Great Bath and adjacent areas. This phase is assumed to post-date the Hadrianic period (i.e. the first quarter of the second century), because a coin of Hadrian was found mortared into one of the Period III piers around the Lucas Bath (Taylor 1954: 14). Davenport (2021: 117) has since suggested a mid to late second-century date for all these projects, bringing them into line with a surge of construction and the reorganisation of road layouts identified in the wider walled area of Roman Bath during the same period (Davenport 1994, 2000, 2021). A late first-century or early second-century date for the Spring Reservoir Enclosure alone is proposed here. This rests on two key pieces of evidence, namely the occurrence of moulded bricks in the Spring Reservoir ribs, and the identification of HV02 tiles from the Spring Reservoir alongside dateable material at the Minety kiln site.

There appear to be few dateable examples of moulded brick finds from Roman Britain (section 9.2.6), yet a single example was recovered from a sealed pre-Hadrianic context at the Fortress Baths at Caerleon (Zienkiewicz 1985: 325). These bricks appear to be rare (Brodribb 1987: 57) and may have had a very short duration of production. It is therefore perhaps reasonable to assign a similar date to the examples used in the Spring Enclosure roof. These specific examples may have been reused or incorporated as redundant, potentially suggesting several decades between production and final use. Fabrics 05 and 05M were identified from the moulded bricks and among sherds of HV02 hollow voussoirs used in the same structure (section 9.2.4), suggesting that they are texturally consistent with production at the same workshop. The interval between production and use may therefore have been relatively short. Based on these finds alone, a late first-century to early second-century date for the Spring Reservoir Enclosure is thus implied.

A range of evidence excavated from the Minety kiln site supports such a date. Hollow voussoir tiles of the same precise dimensions as HV02 tiles from the Roman Baths, Scammell’s (n.d.: 14) type three, were found among the kiln refuse piles during the excavations at the main kiln mound at the site, with 66 examples recorded (Scammell n.d.: 14). These tiles are highly distinctive, being tall and having a very minimal taper in widths, only around 10mm over a length of 400mm, in order to span the 13.3m vault of the Spring Reservoir Enclosure. This is one of the widest barrel vaults so far known from any building in Roman Britain (Lancaster 2012: 437). The chances of these Minety tiles having been produced for any other building are therefore extremely low. These same debris piles yielded a range of other ceramic building material components, several of which are dateable. A range of examples of half-box flue tiles were excavated, Scammell's (n.d.: 14) type five, suggesting a later first- or early second-century date (section 9.2.6) for the operation of the pair of excavated kilns at Minety. Relief-patterned tiles were also identified from this mound, and several designs were consistent with impressions from the Roman Baths assemblages (section 9.1.5). Though generally dated to the late first or early second century (Lowther 1948, Black 1985, Betts et al. 1997), the exclusivity with finds of second-century stamped tiles in the same region (section 10.7.2) strongly suggests a purely first-century date. There is therefore a strong argument for the redating of the construction of the Spring Reservoir Enclosure to the late first or very early second century AD, though a first-century date within this range is more likely.

### 10.2.3 The Dating of the Great Bath Roof

Cunliffe and Davenport (1985: 180-184) and Davenport (2021: 117) conceived the construction of the Spring Reservoir Enclosure and the reroofing of the Great Bath, and adjacent areas, as taking place at the same time. Given the dating evidence presented for the Spring Reservoir Enclosure, it would therefore be logical to redate this entire phase to the late first century AD. Yet, this cannot be sustained. Firstly, a single Hadrianic coin was found in the mortar of a toppled Period III pier of the Lucas Bath (Taylor 1954: 14). Though this phasing evidence is not entirely secure, it suggests that the reroofing took place after the early second century. Secondly, there are a range of major differences in the design and implementation of the vault and its constituent components that are not consistent with construction at the same time as the Spring Enclosure. This indicates that the Great Bath reroofing comprised a distinct phase of activity, sometime after the completion of the Spring Reservoir Enclosure. The building of the Spring Reservoir Enclosure in the late first century therefore comprises a Period II of major activity at the Roman Baths.

**Figure 10.3: Photograph of contiguous hollow voussoir sections excavated by Davis lying in the Great Bath. Note the apparent absence of any brick rib sections. From Haverfield (1906: figure 28). Reproduced with permission from "A History of the County of Somerset: Volume 1", Victoria County History, London 1906, © University of London.**

### 10.2.4 Differences in the Structure of the Great Bath Roof

While the Spring Reservoir Enclosure roof extensively employed voussoir bricks in multiple ribs and in a central spine (e.g. Cunliffe and Davenport 1985, Lancaster 2006), there is no evidence for the use of any such ribs in the Great Bath beyond one at each end of the building. Davis (1884) excavated most of the Great Bath and its aisles and exedrae and retrieved the single substantial partial voussoir brick arch fragment from the west end of the Great Bath, which remains on display to the present. Many large, intact sections of CBM excavated by Davis were therefore noted (e.g. Davis 1884: 14), sometimes photographed (figures 10.1, 10.3) and have been preserved to the present in the York Street assemblage. While the east end of the Great Bath appears to have been disturbed prior to the excavations of Davis as a result of the construction of various 19th century buildings (e.g. Taylor 1954: 12), which could reasonably explain the lack of a similar eastern arch being recovered, it is highly likely that some record of any other voussoir brick ribs found in the western part or centre of the bath would exist, or even that such fragments might survive to the present. The lack of any such notes, depictions or preserved examples indicates that the Great Bath probably only had two voussoir brick ribs, one on each western and eastern face of the vault.

Another change between the Spring Reservoir Enclosure and the Great Bath roof was the central spine. While the Spring Enclosure used rows of solid voussoir bricks, in the Great Bath roof this was entirely substituted with a motley collection of recycled tegula sherds and fragments from other broken ceramic building materials, capped with three rows of imbrices above the mortar extrados at the crown of the vault (figure 10.4). Similar evidence for a more ad-hoc approach to the construction can be seen in a number of box flue tiles remaining mortared into a large, preserved section of roof from the Great Bath (figure 9.14). It appears that these were added to the extrados and cannot have served any purpose for insulation or air circulation as they are not well aligned and abut sections of solid mortar. One possible purpose is that they were added to sections near the springing of the vault to increase the vertical load acting on the walls, and thus reduce the action of lateral thrust in the vault. With the reduction in the number of heavy voussoir bricks ribs, and the substitution in the central spine, such additions may have been implemented as a result of lessons learned from the Spring Reservoir Enclosure. That structure displayed significant lateral thrust even during the Roman period, with several massive stone buttresses erected upon the north and west walls of the Spring Reservoir Enclosure after initial construction, in order to prevent lateral movement and collapse (Cunliffe and Davenport 1985: 181-184). The reduction in the number of the brick ribs, and replacement of a solid voussoir brick spine, would have acted to substantially lighten the vault of the Great Bath in comparison to the Spring Enclosure roof. It would also have allowed the incorporation of a range of now redundant roofing components, many of which may have been from a previous tiled roof suggested (Cunliffe 1969: 116) to have spanned the Great Bath.


**Figure 10.4: Photograph of a fragment of the Great Bath roof, showing hollow voussoirs abutting the central spine, which is made of broken and reused tegulae and other tiles. Photographs taken with permission from the Roman Baths, Bath and North East Somerset Council.**

### 10.2.5 Differences in the Components of the Great Bath Roof

Differences can also be observed between the hollow voussoir components used in the Great Bath roof and the Spring Reservoir Enclosure. The Spring tiles, HV02, are tall and thin, with an estimated difference of c.10mm between maximum and minimum widths (section 9.1.3). The tiles of the Great Bath, type HV01, are squatter, being 303-323mm in height, and wider. On complete examples, a difference of 20-25mm between the maximum and minimum widths was regularly observed. The Great Bath components were used in a substantial vault that spanned 10.6m north-south from pier to pier, yet the difference in recorded widths is much more pronounced than in the

Spring Reservoir Enclosure tiles. This may suggest less careful or consistent manufacture.

The significant change in dimensions between the two components, in both widths and heights, suggests it is extremely unlikely that they were produced at the same time. The sizes of hollow voussoir tiles were dependent upon the length of the span being roofed and the number of components intended to be used, and vice versa. A specific component height or quantity could thus be chosen for convenience and then the other required measurements calculated. As such, the use of tiles of substantially different heights in the Great Bath (c.310mm) and Spring Reservoir (c.400mm) represent conscious and easily facilitated choices. The latter may have been selected to line up with the solid voussoir tiles used, which had the same height on end. The shorter height of the HV01 components may instead represent the adoption of a typical convenient measure for hollow voussoir tiles, as it roughly corresponds to the length of an adult male foot and is matched by the heights of complete examples of HV03, HV04, HV07 and HV09 components (section 9.1.3). Were the two projects conducted at the same time, it seems unlikely, though not impossible, that the components used in two large vaults of similar construction would radically differ in many dimensions.

Individually, the differences in structures and components between the Spring Reservoir Enclosure and Great Bath could perhaps be ascribed to distinct practices between two or more architects and/or production sites. However, when considered together, they represent a clear separation in design and manufacture that appears more consistent with distinct episodes of construction. With the dating evidence considered, it seems clear that the Spring Reservoir Enclosure represents a substantial phase of Period II activity in the late first century or very early second century, though a first-century date is preferred. The reroofing of the Great Bath and adjacent areas are likely to have taken place in Period III, a distinct phase perhaps in the mid-late second century, following Davenport (2021: 117). An interval of perhaps 40-80 years would therefore have elapsed between projects. Given the intervening development in the production of hollow voussoir tiles, and the changes observed between the structures of the vaults, this seems reasonable. Indeed, such a length of time may have allowed for the problems of lateral thrust in the Spring Reservoir Enclosure vault to become apparent, inspiring the change in design and comparative lightening of the Great Bath vault structure.

# 10.3 Reconstructing Other Structures

In this section several hollow voussoir types identified from the site are considered, and possible source structures suggested. These reconstructions rely heavily on estimated spans derived using Lancaster's (2015: 130-131) formula, and measurements from the site plans presented in Cunliffe (1969). While there are some limitations to the uncritical application of this formula, it nevertheless represents a useful tool. For brevity, only those hollow voussoir types that present the best evidence for a source structure are considered here. These include types HV05, HV08 and WH1 (section 9.1.3).

## 10.3.1 Estimating Vault Spans

$$\text{span} = 2\left(\frac{bc}{a-b}\right)$$

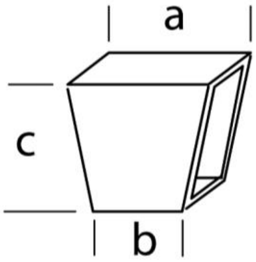


**Figure 10.5: Formula for calculating vault spans from the recorded measurements of hollow voussoir tiles. Modified from Lancaster (2015: figure 86). Lancaster, L. C., 2015. Innovative Vaulting in the Architecture of the Roman Empire: 1st to 4th Centuries CE. © Cambridge University Press. Reproduced with permission of The Licensor through PLSclear.**

Lancaster (2015: 142) has applied a formula (figure 10.5) to measurements of hollow voussoir tiles from a wide array of sites in Roman Britain in order to understand typical vaulted building spans. While the use of this formula represents a valuable tool for understanding Roman structures and buildings, there are limitations. Most are the result of contact with actual, often fragmentary, archaeological material. One issue is that it is extremely rare that sherds of hollow voussoirs present complete measurements for both minimum widths (b in figure 10.5) and maximum widths (a in figure 10.5). While it is possible to assemble composite measurements of the range of minimum and maximum widths recorded, as in section 9.1.3, it is much more challenging to understand the typical difference in widths in single components. This is problematic, as the difference in maximum and minimum widths (a-b) will substantially affect the estimated span, as is evident in figure 10.5.

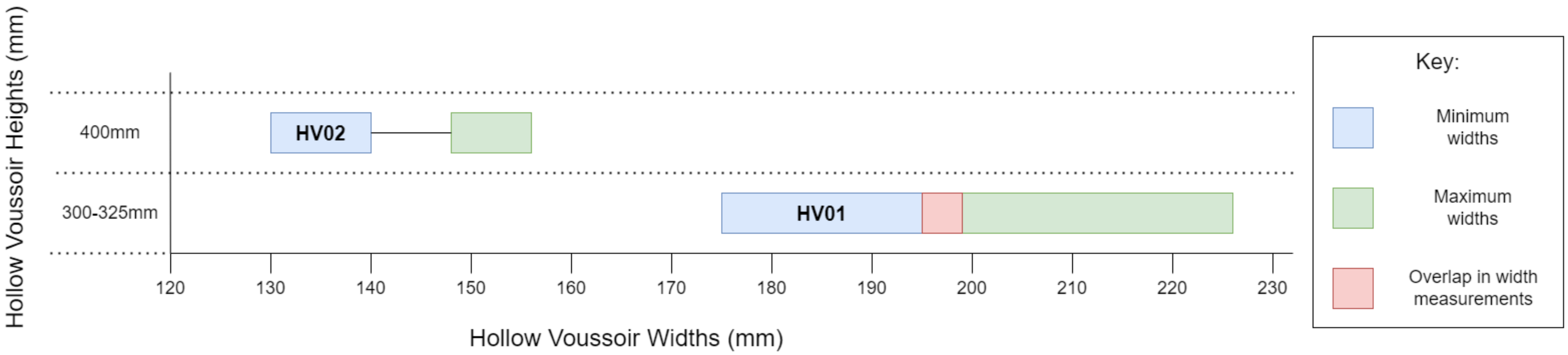


**Figure 10.6: Graph showing the heights and the range in recorded minimum and maximum widths of HV01 (68 samples) and HV02 (23 samples) hollow voussoir tiles from the Temple Precinct and York Street assemblages of the Roman Baths.**

The singular use of the formula is also fraught, as it assumes a level of perfection not evidenced by the components themselves. Measurements of HV01 tiles and HV02 tiles produced a range of minimum and maximum widths for each tile type (figure 10.6). While this variation might seem substantial, in human terms it is actually fairly small. HV02 tiles, for example, had a range in minimum widths of 10mm, and an even smaller range in maximum widths. This is remarkably consistent given that each component was 400mm long. The use of any single pair of measurements within this range in the formula could nevertheless produce very different values. To understand this variation, each minimum width value within the range of HV02 was cross-referenced with each maximum width value of HV02, then both were put into the formula (figure 10.5). For example, 130mm was paired with 148mm, then 130mm and 149mm, then 130mm with 150mm and so on. The frequency of different estimated spans was then plotted.

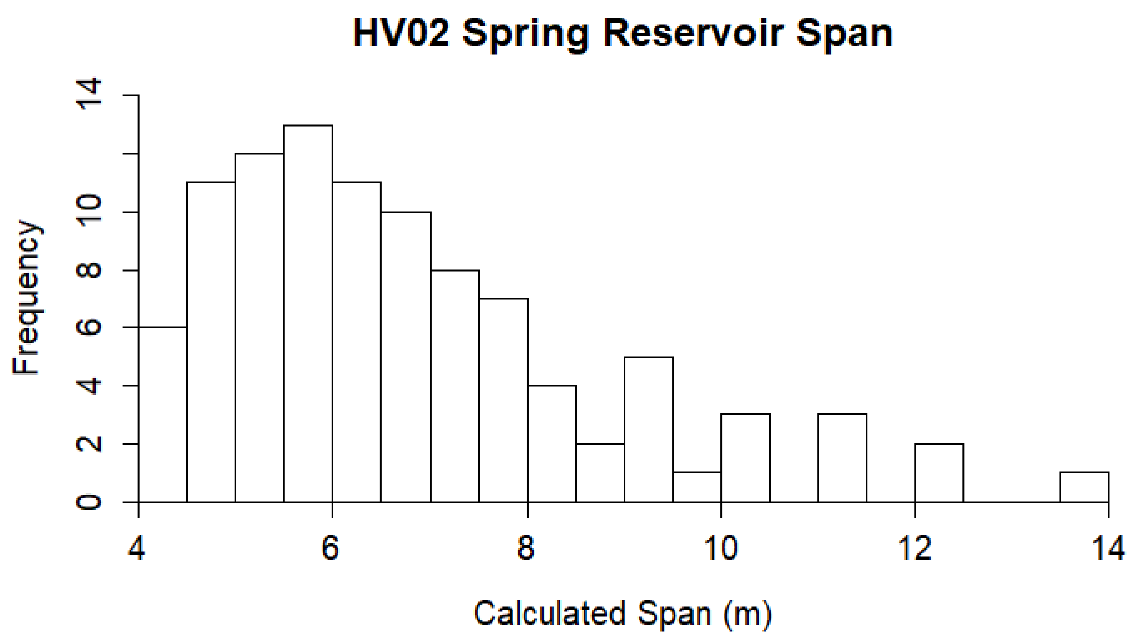


**Figure 10.7: Histogram showing the frequency of different calculated spans derived by cross-referencing every value within the range of minimum widths against every value within the range of maximum widths, and inputting the pairs into the formula in figure 10.5.**

The Spring Reservoir Enclosure had a span of 13.3m, but only a very small number of combinations achieved an estimate in this range (figure 10.7). While the vast majority of components could have had the precise difference in maximum and minimum widths necessary to achieve this span, this seems unlikely. These components were definitely used in the Spring Reservoir Enclosure, thereby suggesting a good amount of wiggle room in application, despite component sizes. Assuming someone stumbled upon a single intact component and had no knowledge of the Spring Reservoir, the application of the formula would therefore be highly likely to produce an inaccurate result, likely substantially underestimating the span of the vault. Though the formula is useful, it must clearly be applied with considerable caution.

### 10.3.2 The Source Structure of Hollow Voussoir Type 05

**Table 10.1: Measurements recorded from sherds of hollow voussoir type 05.**

| Type | Min. width (mm) | Max. width (mm) | Height (mm) | Depth (mm) | Thickness (mm) | No. of Examples |
|---|---|---|---|---|---|---|
| HV05 | 175-191 | 222-245 | 267-276 | 116-123 | 15-22 | 23 |

Hollow voussoir type 05 presents the best evidence for its original source structures. When the full range of measurements recorded from these tile types are input into the formula, a limited range of spans are calculated, with the most common between 1.75m and 2m (figure 10.8). It is clear from the distributions derived from the Spring Reservoir Enclosure tiles (figure 10.7) that the use of the formula tends to produce distributions that underestimate the actual span of the vault they came from. It therefore seems more likely that the true span was in the order of 2-3m wide, as suggested by a range of values in the upper tail of the distribution (see figure 10.8). There are few structures identified across all phases of activity in the West Baths, East Baths or around the Great Bath that present spans in the 2-3m range. Of these, the most likely candidate is the Period III aisles of the Great Bath and adjacent corridor. This hinges on several pieces of evidence.

Firstly, 21 different sherds could be identified as being of HV05 type, with two further complete examples recorded. This relatively high survival and identification rate suggests that the original structure was still present at the end of the complex and had not been demolished or replaced previously. This is consistent with what is known of the Period III Great Bath and its aisles (e.g. Cunliffe 1969: 99). The presence of HV05 tiles in only the York Street assemblage is also consistent with an origin from the aisles of the Great Bath, for this assemblage contains the many roof fragments of the Great Bath which Davis (1884) excavated. Secondly, 16 out of 23 sherds and components of type HV05 display extensive concretions up to 25mm thick, with several further sherds displaying less extensive traces. This is consistent with deposition and submersion in the waters of the Great Bath (section 9.1.6). The high proportion of sherds with these formations suggest that the original structure must have been very close to the Great Bath for so much of this material to have ended up submerged in it. The best candidate is therefore the roof of these aisles, for if these structures collapsed inwards much material would have been flung into the central bath. Even were the collapse more gradual, there would still have been plenty of opportunity for tiles to have fallen, scattered, or been pushed into the Great Bath.

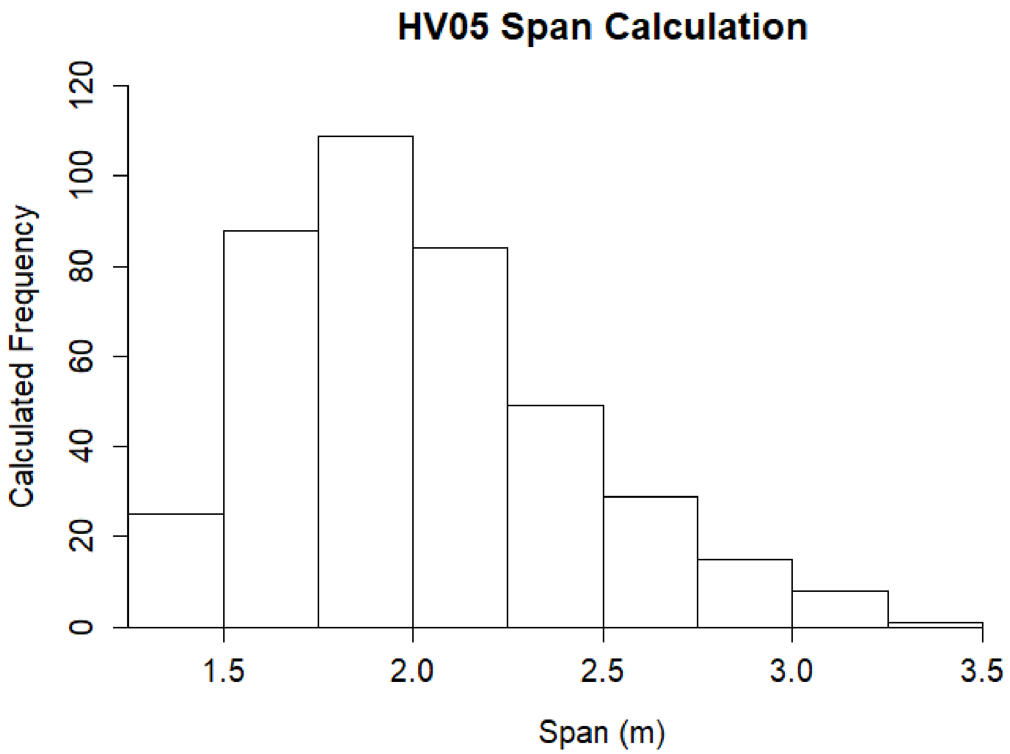


**Figure 10.8: Histogram showing the frequency of spans calculated by inputting each combination of observed maximum and minimum widths from HV05 tiles into Lancaster's (2015: 142) formula.**

Calculation of a 'perfect' hollow voussoir size for the 2.5m span of the Period III Great Bath aisles, using tools available online, yield a component size consistent with archaeological examples. For these calculations the vault was assumed to be perfectly semi-circular, i.e. the vertical height from the springing level to the centre of the intrados was equal to the radius of 1250mm (figure 10.9). A height of 270mm for each tile was chosen, as was a 5mm mortar depth between tiles, and 21 components selected.

Under these conditions the perfect component was calculated to have a maximum width of 223mm and a minimum width of 182mm, both of which fall within the range of actual observed values (table 10.1). The difference between maximum and minimum widths, 41mm, is also close to those observed on two complete components of 35mm and 46mm. Together, this evidence indicates that HV05 tiles were used to span the Period III aisles of the Great Bath.

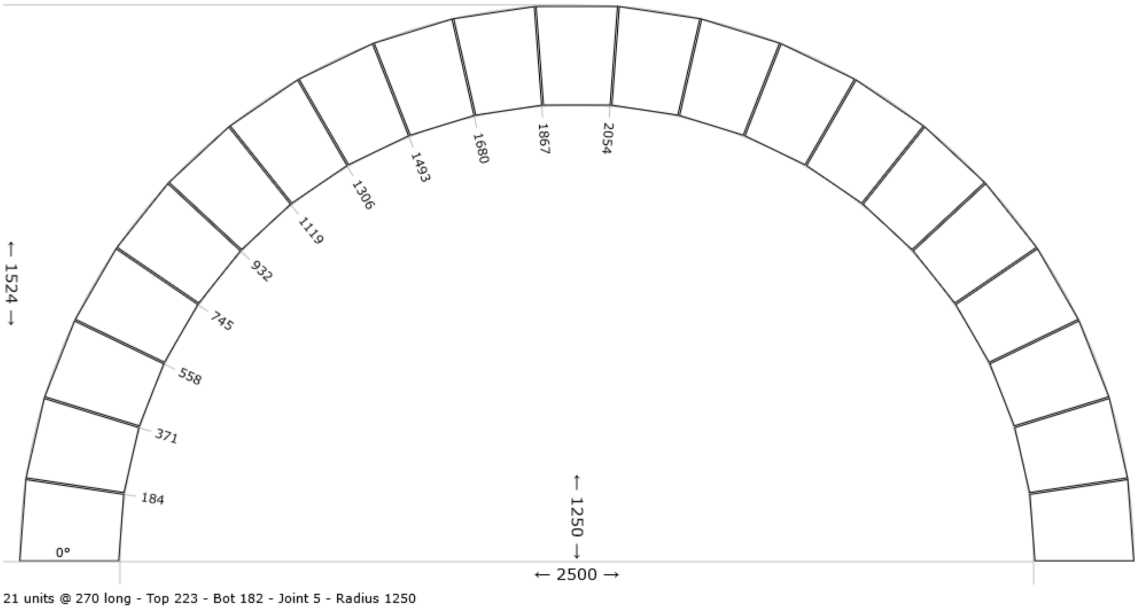


**Figure 10.9: Illustration of the 2.5m vault of the Great Bath Period III aisles, spanned by 21 tiles of HV05 size. From Block Layer (2022). © Block Layer.**

## 10.3.3 The Source Structure of Hollow Voussoir Type 08

**Table 10.2: Measurements recorded from sherds of hollow voussoir type 08.**

| Type | Min. width (mm) | Max. width (mm) | Height (mm) | Depth (mm) | Thickness (mm) | No. of Examples |
|---|---|---|---|---|---|---|
| HV08 | 85-110 | 110-136 | i251 | 115-118 | 16-24 | 55 |

Hollow voussoir type 08 presented no sherds with complete height measurements, so it was not possible to model vault spans for these components. All sherds of HV08 came from the EB95-01 excavations, which took place in rooms in the extreme southeast of the complex (figure 10.10). Sherds of HV08 were the only standard hollow voussoir type identified from these assemblages, though four sherds that probably or definitely came from Westhampnett hollow voussoirs were also found. Contexts 524 and 525 yielded a particularly large number of hollow voussoir and combed tile sherds as well as thick deposits of mortar, suggesting that these were the result of a major collapse event (Davenport 2011a: 12), probably when the vaulted roof of these rooms fell in. The material from these contexts included very few brick or voussoir brick sherds. This suggests that these roofs consisted solely of hollow voussoirs and lacked the brick ribs or spines of other structures at the complex.

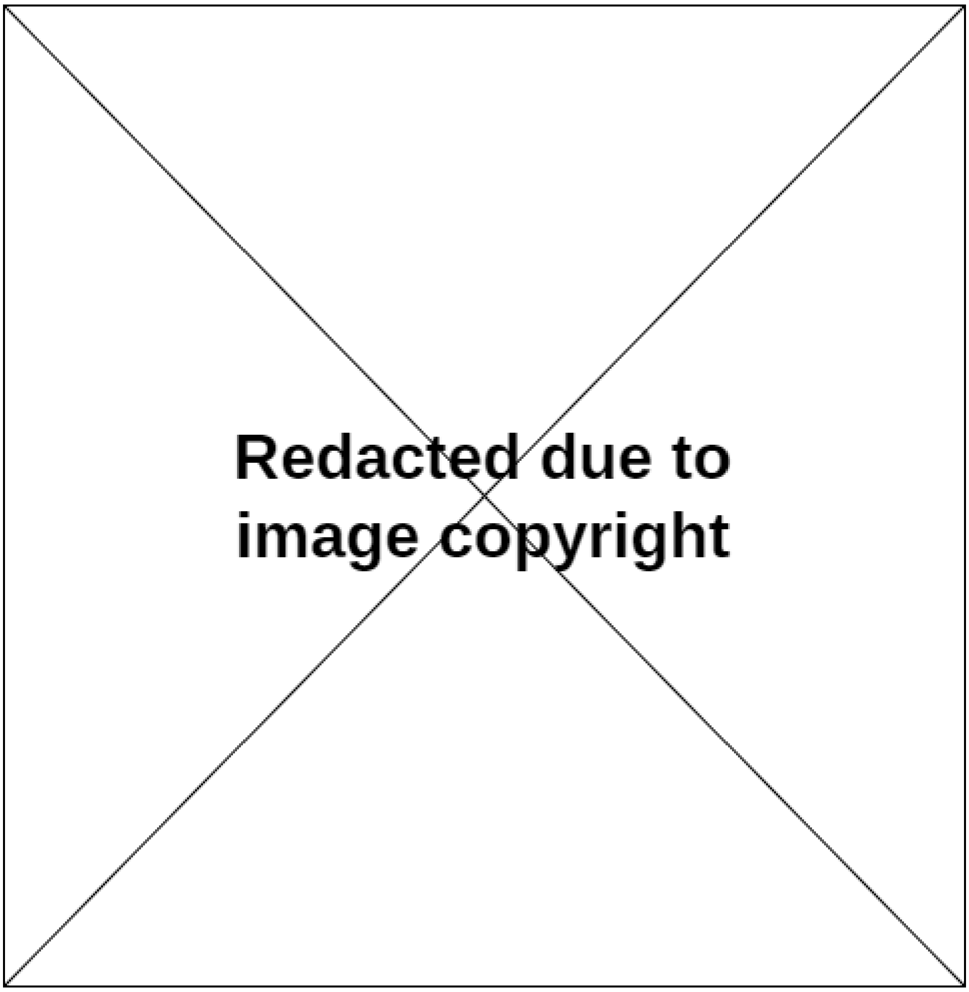


**Figure 10.10: Plan of the southeast of the East Baths in Period IV, following Davenport (2021: figure 106), indicating the approximate location of the EB95 and EB01 excavations. Modified from Cunliffe (1969: figure 47). © Society of Antiquaries of London.**

While the location and contexts of the finds of HV08 are well understood, it is not entirely clear which phase of structures they were used in. The two easternmost Period III rooms (figure 10.11) appear to have been amalgamated in Period IV, with the east-west wall between them being demolished and a hypocaust laid across the foundations to create a larger single room (Davenport 2011a: 10, see figure 10.10). While two parallel east-west barrel vaults could have covered these spaces in Period III, it seems unlikely that these could have been maintained intact with the removal of one of their supporting walls. This suggests that the HV08 tiles are from a larger single vault for the Period IV room. Significantly, HV08 occurred in several distinctive fine sandy fabrics, particularly F17, 18, 15 (section 9.2.4). This suggests that these are characteristic of supply in late phases of the East Baths, if not the wider site. The absence of F17 and F18 sherds from any other assemblage (section 9.2.1), all of which included substantial amounts of material from earlier structures such as the Period II Spring Reservoir Enclosure or Period III Great Bath, would appear to confirm this.

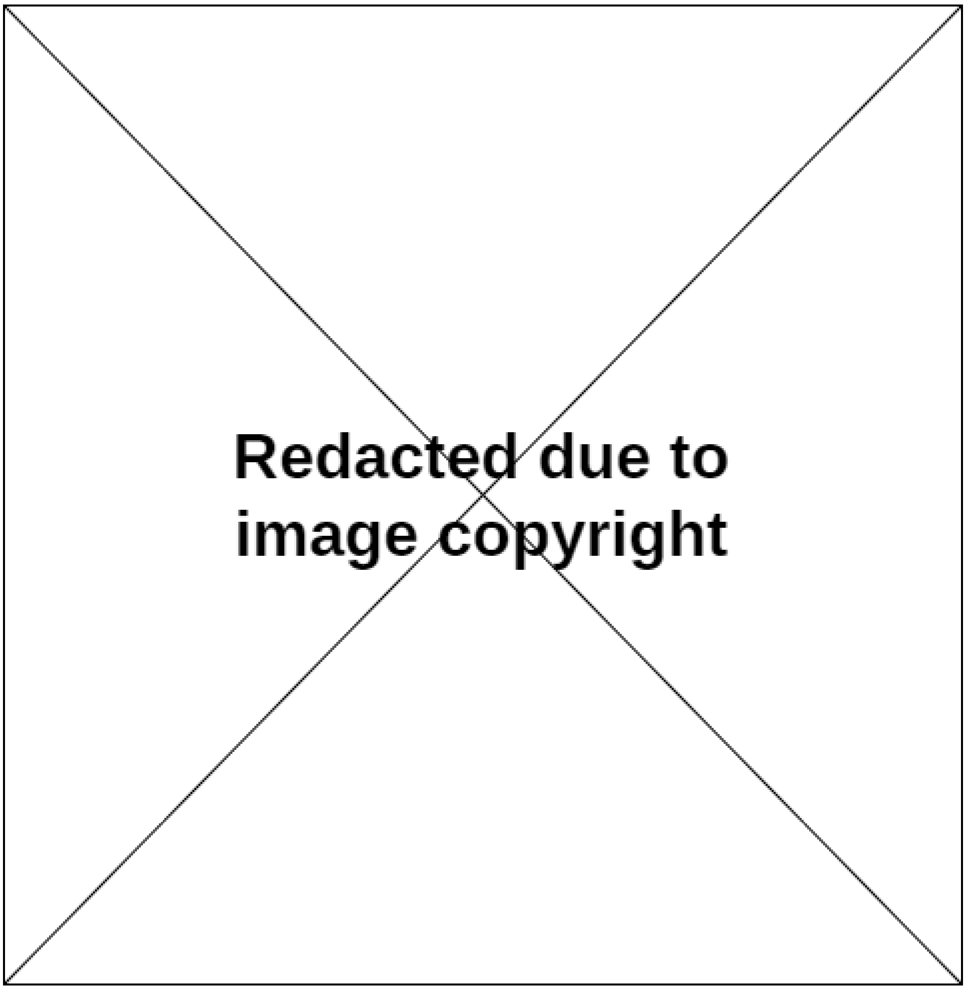


**Figure 10.11: Plan of the southeast of the East Baths in Period III. Modified from Cunliffe (1969: figure 47). © Society of Antiquaries of London.**

## 10.3.4 The Source Structure of Westhampnett Hollow Voussoir Type 1

**Table 10.3: Measurements recorded from sherds of Westhampnett hollow voussoir type 1.**

| Type | Min. width (mm) | Max. width (mm) | Height (mm) | Depth (mm) | Thickness (mm) | No. of Examples |
|---|---|---|---|---|---|---|
| WH1 | 209-210 | 251-257 | 340 | 145 | 34-37 | 4 |

Westhampnett hollow voussoir components are morphologically early (section 9.2.6), and distinct in size, thicknesses, and fabrics (sections 9.1.3, 9.2.4) from many other hollow voussoirs identified from the site. It is highly likely that these components are therefore from the earliest phases at the Roman Baths, Period I, and perhaps from some Period II structures. Many Period II changes have little dating evidence and could represent drips and drabs of activity over decades (e.g. Cunliffe 1969, 1976), rather than a single unified phase of activity. Fortunately, there were not many heated structures at the Roman Baths during these periods, and few which present dimensions consistent with those of the Westhampnett tiles.

Calculations of a possible span for WH1 components (figure 10.12) suggests that these tiles were probably used in an arch with a diameter of 3-4m. Complete maximum or minimum widths were only present on four sherds, and the range of measurements and estimations is likely to have been greater if more had survived. In spite of this, a span somewhere in the range of 3-4m represents a fairly cautious and, perhaps, realistic estimate. Conveniently, there appear to be few structures of any periods identified from the Roman Baths with spans in this range. One stands out as a likely source, namely the Period II vestibule added to the doorway just south of the 1923 Bath in the East Baths. This chamber had a north-south width of 3.8m. During the East Bath excavations, Davenport (2011a: 10) found that the walls of the building to the west abutted those of the vestibule, indicating that the vestibule itself represented a discrete early structure intended to provide access to the same floor height as the surround of the Period I Lucas Bath (Davenport 2011a: 9). While it post-dates Period I, this structure may have been added shortly afterwards, and perhaps long before other Period II changes, for example the construction of the Spring Reservoir Enclosure (section 10.2). In later periods this room had a hypocaust, and it is possible that it was similarly equipped from the beginning.

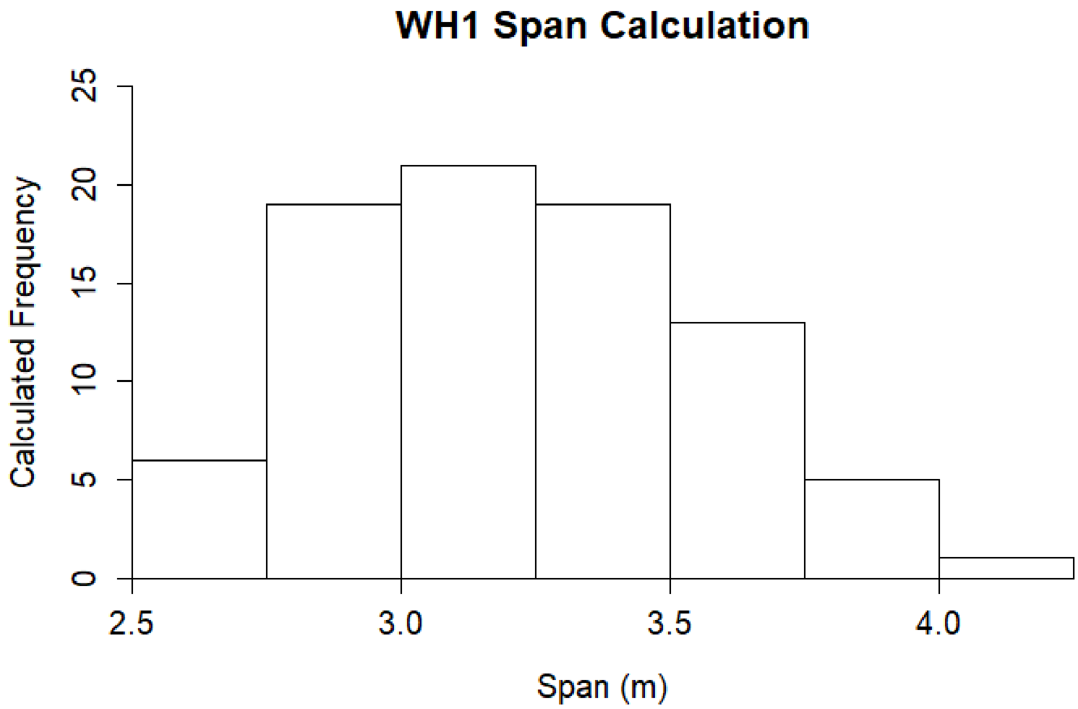


**Figure 10.12: Histogram showing the frequency of spans calculated by inputting each combination of observed maximum and minimum widths from WH1 tiles into Lancaster's (2015: 142) formula. The minimum width from actual sherds only had a range of 1mm, so a range of 11mm (204-215mm) was used to model natural variation that might be expected were more tiles available to measure.**

Modelling the vault span with a hollow voussoir height of 340mm, a 10mm mortar thickness and using 27 tiles (figure 10.13) produces a recommended component size with a maximum width of 251mm and a minimum width of 211mm. These values almost perfectly match observed measurements from WH1 tiles (table 10.3). The ideal difference in widths is 40mm, which is only 1mm greater than that of the complete WH1 tile on display at the Roman Baths. This suggests that the measurements of the WH1 tiles are consistent with an origin in the vault of the Period II vestibule of the East Baths. It must be remembered that this attribution was made on the basis of measurements from a very small number of finds, so is very tentative.

Possible supporting evidence for the use of Westhampnett voussoirs in the vestibule was found during the EB95-01 excavations, in the rooms immediately to the west. Many deposits excavated consisted of collapse and demolition layers (Davenport 2011a, b), and one sherd from a Westhampnett hollow voussoir base (OTK 557) was found in context 535 above the hypocaust destruction sequences. Three combed tile sherds (OTK 596, 947 and 948) from contexts 609 were extremely thick, c.38-43mm, and occurred in fabrics 01, 12M and 08, largely consistent with those identified in other Westhampnett hollow voussoir sherds (section 9.2.4). These must therefore represent unidentified sherds from Westhampnett hollow voussoir components. This indicates that fragments of these tiles were present among the rubble in the structure immediately adjacent to the vestibule. While these could be a few stray residual pieces, sherds of half-box flue tiles, and undiagnostic combed tile fragments consistent in fabrics and thicknesses with half-box flue tiles, were retrieved from the same and closely related contexts, i.e. 609, 612 and 614 (Davenport 2011b: 14). This suggests that these collapse and demolition deposits included material from a relatively early, and well-preserved, structure close by. It is possible that the vestibule retained most of its original vault until the end of the complex, though part may have had to be deconstructed in order to make room for the Period IV roof of the room to the southeast. The vestibule therefore presents a good candidate for the original source of the WH1 tiles, being from a very early period at the site, having a span consistent with the few complete measurements of the WH1 tiles, and having clear potential to have survived relatively unaltered until the end of the site.

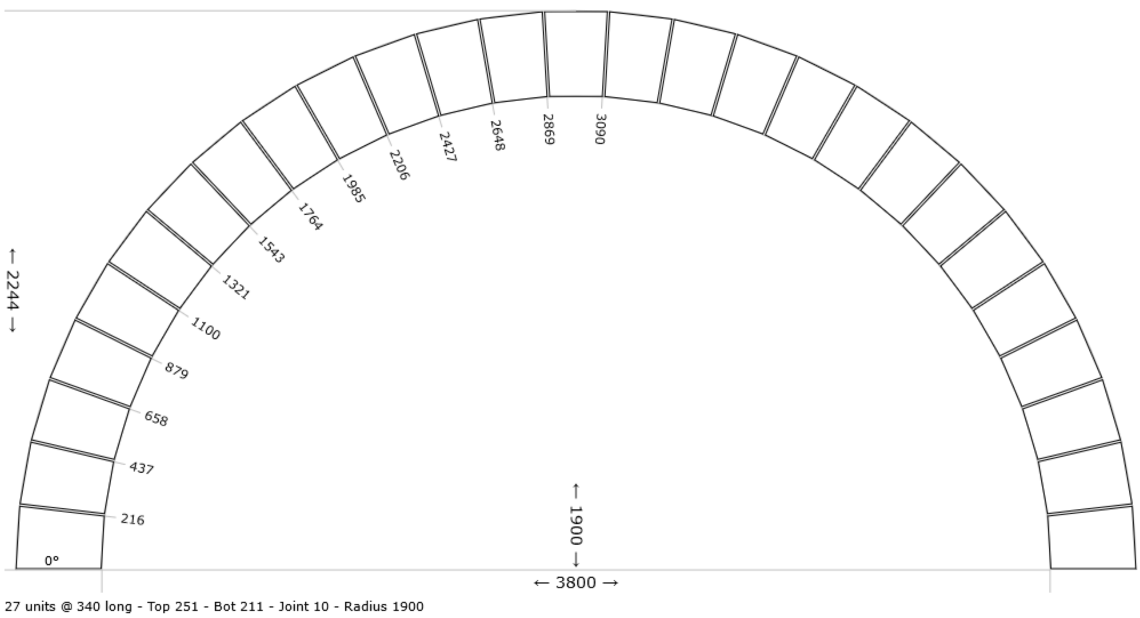


**Figure 10.13: Illustration of the 3.8m vault of the Period II vestibule in the southeast of the East Baths, spanned by 27 tiles of approximately WH1 size. From Block Layer (2022). © Block Layer.**

## 10.4 Supply to the Roman Baths

This section will investigate patterns of supply of different tile types and fabrics to the Roman Baths. While there is a range of evidence for the movement of several distinct fabrics to the site in the early phases of the complex, the sources of all of these are not yet known. What is clear is that the Minety kiln site was responsible for the supply of large quantities of material in several key phases at the Roman Baths.

### 10.4.1 Westhampnett Hollow Voussoirs

Sherds of Westhampnett hollow voussoir tiles provide some of the earliest evidence for the movement of components and fabrics to the Roman Baths. These components may have been used in Period I or very early in Period II at the site, as suggested by the correspondence in dimensions and estimated span of WH1 components and the Period II vestibule in the East Baths (section 10.3). These components occur mainly in coarse, often streaky, fabrics 12, 11 and 01 (section 9.2.4), and the location of the production site is currently unknown. Two sherds were found to occur in fabrics texturally (section 9.2.4) and chemically (section 9.3.2) consistent with production at the Minety kiln site. While this could indicate that Minety supplied a small quantity of these components, it is possible that the majority were made using an as-yet unidentified clay deposit at the site. This is supported, to some extent, by the finds of a small number of sherds of coarse fabrics from the production site itself (section 9.2.7), though chemically distinct. Coarse fabrics also occurred in components in later structures at the Roman Baths that were clearly substantially supplied by Minety. This included voussoir bricks from the Spring Reservoir Enclosure in F12 and 01 (section 10.1.3), and HV05 components used in the side aisles of the Period III Great Bath roof (section 10.3) of fabrics 16, 11 and 01 (section 9.2.4), which were chemically similar to the samples of many Westhampnett hollow voussoir sherds (section 9.3.1-2). The origin of this supply may therefore be a distinct kiln site that was reactivated during later periods or may be a further workshop at Minety.

The Westhampnett hollow voussoirs from the Roman Baths are also significant as they represent a clear link to the products of the London-Sussex group workshop (sections 2.4.2, 7.1.2). However, there are a number of differences between the Roman Baths components and those of the London-Sussex group. While the London-Sussex workshop products have a wide range of relief-patterned dies applied to them (Black 1985: 356, 360, Betts et al. 1997: 19), in addition to combing and knife scoring (e.g. Scott 1938: 20, figure 10), the Westhampnett hollow voussoirs examined from the Roman Baths were only combed, though one sherd also had knife-scoring (OTK 387). Black (1985: 356) and Lancaster (2012: 421) also noted that the examples of Westhampnett hollow voussoirs from sites in Sussex had thickened, rounded interior corners, whereas there was no evidence for these among the Roman Baths material inspected in this study. The sherds from Bath also contrasted chemically with material from Fishbourne Roman Palace (section 9.3.3), which appears to have been partially supplied by the Sussex workshop (e.g. Betts et al. 1997: 28, Black 2005: 49-50). This indicates that the products at the Roman Baths were produced locally or regionally, and were not long-distance exports from Sussex. Moreover, the typical fabrics of the Westhampnett components from Bath (F01, 11, 12) showed no evidence for deliberate additions of temper, in contrast to typical London-Sussex fabrics, which were often tempered with grog inclusions (MoLA fabric 3054, Betts 2018: 4) or cereal chaff (MoLA fabric 3059, Betts 2018: 5).

While there are clear differences in production, it nevertheless seems that the producers of the Bath tiles must have been intimately acquainted with the range of products and constructions of the London-Sussex workshop, perhaps training and working with them before setting up independently. This is especially pertinent given the antiquarian drawing (figure 7.3) and description (Scarth 1864: 95) of a large, curved tile with combing on the outside surface, which closely parallels a unique tile form produced by the London-Sussex group (e.g. Black 1985: 360, Betts 2016: 103). This antiquarian tile has recently been located, and is in the collections of the Bath Royal Literary Scientific Institute. Future research is planned to visit, record and examine the fabric of this tile to determine if it matches the distinctive fabrics seen in the Westhampnett hollow voussoirs from the Roman Baths.

Given the links between the Westhampnett hollow voussoir tiles at Bath and the products of the Sussex workshop, and the potential for their use in very early phases at the Roman Baths, there are significant parallels to evidence from the carved building stone from the site. Blagg (1979) examined the Corinthian capital, cornice and pediment from the Temple of Sulis Minerva at Bath, and identified the form and motifs as having strong parallels with first-century examples from France and Italy. In particular, he dated the stonework from the Temple of Sulis Minerva at Bath to the Neronian or early Flavian periods, and suggested that the masons responsible were probably from north-eastern Gaul (Blagg 1979: 106). This evidence has been supplemented by the research of Cousins (2016, 2020), who identified strong parallels between the gorgon head of the Temple pediment at Bath and a series of late first-century decorative roundels from similar prominent positions in Spain, France and Switzerland. These appeared to be ultimately derived from the use of a roundel as part of the Forum of Augustus in Rome (Cousins 2016: 107). The carved stonework from the Temple of Sulis Minerva at Bath therefore strongly suggests the presence of masons from other western provinces at the site at an early date, likely in the Neronian or Flavian periods.

The presence of Westhampnett hollow voussoirs at Bath, in addition to another tile form linked to the Sussex workshop, and a wide range of late first-century Continental parallels in the architectural stonework of the Temple of Sulis Minerva is highly significant. Together, this evidence indicates that skilled craftsmen for both stone carving and brick and tile production were brought to the Roman Baths from other regions and provinces for early phases of construction. This must have been necessary due to the lack of specialist expertise available locally. This indicates the significant resources, reach and social networks of those responsible for the early phases of construction at the Roman Baths, whether state organised or funded by a powerful native aristocrat (e.g. Cunliffe and Davenport 1985, Henig 1999, Cousins 2016).

### 10.4.2 Other Early Fabrics and Supplies

A range of morphologically early tiles were identified in fabric 07, including a notched wall tile, knife scored tiles, half box flue tiles and a single relief-patterned tile (section 9.2.6). These components could have come from any phases of activity from the start of the complex until the early second century (section 9.2.6). It is nevertheless tempting to see this fabric as an early supply to the site. One reason for this is that the half box flue tiles, which co-occurred with the same components in F04, may have been used together with Westhampnett hollow voussoir sherds to line the walls of the early Period II vestibule in the East Baths, as they occurred in the same demolition contexts (section 10.3). Moreover, though the fabric of these tiles could not be assessed, notched wall tiles were used at the base of the Spring Reservoir during Period I at the site in the late 60s or early 70s AD (Davenport 2000: 8). This indicates that these tiles were among the earliest material supplied to the site, though their source is not yet clear. Chemical analyses (section 9.3.2) suggest as many as two or three different sources, one of which was probably at Minety. This is indicated by the Temple Precinct relief-patterned tile, OTK 140, whose die and fabric Betts et al. (1997: 23, figure 10.11) noted as being consistent with Minety production, though not typical of the Minety products inspected in this study. Moreover, a range of voussoir bricks from the Spring Reservoir Enclosure were identified in fabric 07. This could further support a Minety origin, as this site supplied the hollow voussoirs and many voussoir bricks used in the same structure (section 10.1.3).

Fabrics 03, 05, 05M, 06 and 08 were identified from a range of components displaying early morphologies and impressions, including knife-scored tiles, moulded bricks and two sherds of possible relief-patterned tiles (section 9.1.5). These fabrics are texturally (section 9.2.7) and often chemically (section 9.3.3) consistent with typical Minety products. The two new wavy relief-patterns proposed are also closely paralleled by sherds recovered during the excavations of the main kiln mound at the site by Scammell (n.d.). This clearly indicates supply to the Roman Baths by Minety during the late first century or early second century AD.

### 10.4.3 Late Fabrics and Supply

Most of the dateable morphologies and marks recorded from the assemblages at the Roman Baths are early, yet there is also evidence of specific fabrics being used to supply the site in late periods. The presence of nail holes and a late type D1 cutaway (Warry 2005, Mills 2013) among tegula and undiagnostic tile sherds of fabrics 11 and 01, which are closely related (Appendix E), suggest that these fabrics may have comprised a small late supply of tiles to the Roman Baths. The occurrence of sherds of fabrics 17, 18 and 15, and unusually quartz rich sherds of fabrics 03 and 08, among HV08 hollow voussoirs from the East Baths indicates that these fabrics were probably used in Period IV construction in the southeasternmost areas of the complex (section 10.3), perhaps in the fourth century (Davenport 2021: 130). The absence of any sherds of F17 or 18 from other assemblages, many of which were primarily composed of sherds from structures of Periods I-III, for example the Westhampnett sherds (section 10.3), the Spring Reservoir Enclosure and Great Bath roof and aisles (section 10.2-3), supports the late dating of these distinctive fabrics. While the source is not yet clear, these samples were chemically consistent with Minety products once the effects of temper had been adjusted for (section 9.3.3). However, products of completely different kiln sites were shown to present very similar compositional values. Given the textural differences observed between fabrics 17 and 18 and typical Minety products (Appendix E), it is thus equally likely that these are the result of a different kiln site entirely.

### 10.4.4 The Contribution of Minety

While the sources of many fabrics used to supply the Roman Baths are not yet understood, the importance of Minety to the supply of the site is obvious. Many sherds of brick and tile from the Roman Baths have been shown to be texturally (section 9.2.7) and chemically (section 9.3.3) consistent with samples of fired clay and fragments of CBM collected from the Minety site, particularly sherds of fabrics 03, 04, 04M, 05, 05M, 06, 06M, 08 and 15. One confirmed fragment of relief-patterned tile from the Temple Precinct (Cunliffe and Davenport 1985: 134-5) of die 53 (Betts et al. 1997: 118) matches dies excavated from Minety (Scammell n.d.: figure 10.11). Two new proposed examples of wavy relief-patterning (section 9.1.5) also have parallels in examples found at Minety (Scammell n.d.: figure 11), and occur in fabrics typical of that site's products, namely F06 and 08. Scammell's (n.d.: 14) type three tiles also match the dimensions of the distinctive tall, thin hollow voussoir tiles employed in the Spring Reservoir Enclosure vault, type HV02, almost certainly indicating an origin at that kiln site during a relatively early period (section 10.2). Though no examples of hollow voussoir tiles of the dimensions of those used in the Great Bath roof appear to have yet been identified from Minety, these sherds are texturally (section 9.2.4) and chemically (section 9.3.2) consistent with HV02 tiles, suggesting that different workshops at the same site supplied this substantial middle phase of construction. Two sherds of Westhampnett hollow voussoirs in fabrics 06 and 15 are also texturally and chemically consistent with HV01 and HV02 samples (section 9.3.2) and suggest that Minety supplied at least part of the earliest phases of activity at the Roman Baths. While somewhat distinct, many sherds of fine sandy fabrics from late phases of activity in the East Baths (section 9.3) group closely to Minety samples once the effects of temper are adjusted for (section 9.3.2). It is therefore possible that this kiln site continued to provide the Roman Baths even into the third or fourth centuries AD. There is therefore clear evidence for the periodic and substantial scale of supply to the Roman Baths by the Minety kiln site throughout much of the Roman period.

# 10.5 Supply to the Settlement of Roman Bath

This section will explore the evidence for the supply of different tile types and fabrics to the wider Roman town at Bath. Betts's (1999a, b, 2002, 2007, 2015) analyses of material from sites in the walled area and the Walcot settlement are integrated with the results from the Roman Baths. These equate well, in terms of both fabrics and dating. A range of evidence supports a slightly more diverse origin for the ceramic building materials of the wider Roman town, including fabrics likely from kiln sites in Hampshire. It is nevertheless clear that the Minety kiln site was as important to the supply of the settlement as it was to the supply of the Roman Baths.

**Table 10.4: Table showing which of Betts's (2011) Roman fabrics were recorded in different assemblages from suburban villas and sites in the walled area and Walcot settlement at Bath. P represents possible identification.**

| Site | Site Date | CBM Fabrics Present | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **1-4** | **5** | **6** | **7** | **8** | **9** | **16** | **17** | **18** | **23** |
| Lower Common Allotments | Late | Y | Y | P | Y | Y | Y | Y | | | |
| Oldfield Boys School | Late | Y | Y | | Y | | | Y | Y | | |
| Tramsheds and Beehive Yard | Early to unknown | Y | | Y | Y | | Y | Y | Y | Y | |
| Hat and Feather Yard | Early to Late | Fabric results not available | | | | | | | | | |
| New Royal Baths | Early | Y | Y | | Y | Y | Y | Y | Y | Y | P |
| Southgate | Unidentified | Y | Y | | Y | | Y | Y | Y | Y | Y |
| St Swithin's Yard | Mid to Late | Fabric results not available | | | | | | | | | |

## 10.5.1 Early Fabrics, Morphologies, and Impressions

While several of Betts's (2011) fabrics presented features that had been seen but not assigned to distinct types in this study (section 9.2.7), on the whole the fabrics from the Roman Baths and those from the wider settlement corresponded well, as did the dating evidence for a range of material. Half-box flue tiles were found at the Oldfield Boys School site (Betts 1999b: 68) and at the New Royal Baths (Betts 2007: 53), and both occurred in fabric IB16, equivalent to fabric 07 from the Roman Baths. Further possible examples were noted from the Oldfield Boys School assemblages and occurred in IB2 (Betts 1999b: 67), equivalent to F04. Betts (1999b: 68) noted that all confirmed examples from the Oldfield Boys School site were combed and 26-28mm thick, and the possible examples were 22-27mm thick on the face, though thicker on the sides or flanges. These tiles therefore match those found in the East Baths assemblages, which included sherds of fabrics 04 and 07 with comparable thicknesses (sections 9.2.3) and suggest a similar supply to the wider settlement at an early period.

Sherds of relief-patterned tiles of die 25 were also noted to occur in IB16 at the Tramsheds/Beehive Yard site (Betts 2002: 2), as were sherds of die 25 and 53 at the New Royal Baths Site (Betts 2007: 53). These correspond with the analysis of the die 53 hollow voussoir tile from the Temple Precinct (OTK 140), which was also found to be in fabric 07 (section 9.2.4). It is therefore clear that supplies of F07, and related F04, were reaching the Roman Baths and the wider settlement during the first century, maybe as early as the start of Period II at the baths (section 10.3). Given the finds of half box flue tiles and relief-patterned tiles with cross-hatched designs at Minety (Scammell n.d.: 14-15, figure 10.11), which could be from dies 25, 53 or 92, it seems likely that this site was the source of the early F07 tiles in Bath, though this fabric is not typical of production so far known there.

A number of different sherds of notched wall tiles, many with knife scoring, were recovered from sites in the wider settlement, including the New Royal Baths (Betts 2007: 52-53) and at the Tramsheds/Beehive Yard (Betts 2002: 2). These included five different fabrics, IB2, 7, 9, 17 and 18 (Betts 2007: 52). IB2 and IB3 are equivalent to F04/04M and F06/08/05/03 respectively, and thus represent typical Minety products (section 9.2.7). IB9 and IB18 are variations in F04 or F07 fabrics, but IB17 appears equivalent to sherds of F01, or the more quartz rich sherds of F14. The early supply of normal Minety fabrics to the Roman Baths was initially suggested by the results of analyses of two Westhampnett hollow voussoir sherds (sections 9.2.4, 9.3.2). The occurrence of these fabrics in notched wall tiles from the settlement, and among sherds assigned a Neronian or Flavian date from the Walcot Street site (Betts 2015: 221), therefore strongly supports a very early start date for production and supply to Bath using these characteristic Minety deposits.

### 10.5.2 Late Fabrics and Supplies

Dating evidence for later fabrics also corresponded somewhat with the results from the Roman Baths. Betts's (2011) fabric 5, for example, appears equivalent to fabrics 17 and 18 from late phases in the East Baths (section 10.3), and this was identified among assemblages from two suggested late sites, namely Lower Commons Allotments (Betts

1999a) and Oldfield Boys School (Betts 1999b). IB5 was also found at the early New Royal Baths site (Betts 2007), but this may be due to the movement of residual material in the post-Roman period. Betts (2015: 221) also suggested that supplies of roofing tiles and box flue tiles in IB23, equivalent to F11, appeared at the same time as IB5. This corresponds with the observation of tegulae and tiles in F11, and very similar F01, with nail holes and a late D1 cutaway form (section 9.2.6). These fabrics do also appear in early Westhampnett hollow voussoir tiles from the Roman Baths (section 9.2.4), and it may be that they represent the periodic reuse of certain deposits at the same kiln site, or the products of two different sites which are texturally indistinguishable.

### 10.5.3 Extra-regional Imports

Two of Bett's (2011) fabrics did not equate to material from the Roman Baths. Fabric IB6 may have been pottery, but IB8 was clearly CBM, and was distinguished by the presence of common large rounded fine-grained platelet-like inclusions. This fabric is MoLA type 3019 (Betts 2011: 1) and may have had an origin at a kiln site in Hampshire, perhaps at Braxell's Farm or Little London (Betts 2018: 5) during the early second century (Betts 2007: 52). No sherds from the Roman Baths presented any of these distinctive inclusions, suggesting that this fabric was only used at sites in the wider settlement. It was identified among assemblages at two different sites, though only two sherds from bricks were identified from Lower Common Allotments (Betts 1999a: 3), and at the New Royal Baths this fabric again only occurred in sherds of brick (Betts 2007: 52), though the quantity was not specified. The small range of components and sherds this fabric was present in therefore indicate an extremely limited supply to the settlement, which may support Betts's (2007: 52, 2018: 1) suggestion of a very brief phase of operation for that kiln site.

Different sources supplying the settlement may also be suggested by finds of relief-patterned tiles keyed with die 54 from the New Royal Baths site (Betts 2007: 54). This die has been shown to have been employed at the Neronian (i.e. AD 54-68) Little London kiln site at Silchester (Fulford and Machin 2021: 210). It is therefore possible that the examples known from Bath were transported from this site, more than 87km away. Despite the significant distance, such transport does appear consistent with the widest distributions of tiles keyed with Little London dies (figure 10.14). Unfortunately, it is not clear precisely how many of these tiles were examined by Fulford and Machin

(2021: 210) and confirmed to be Little London products. Betts (2007: 53) noted that the tiles keyed with die 54 at the New Royal Baths occurred in fabrics IB2 and IB4, the same as those of die 56 from the same site. These equate to fabrics F04/04M and F12 (section 9.2.7), and alongside the occurrence of die 56 in the same fabrics, examples of which were found at Minety by Scammell (n.d.: figure 10.11), instead point to a Minety origin. This might even suggest the movement of a tilemaker from Little London to Minety after the former ceased operation. A similar situation could have occurred elsewhere with other dies and tilemakers from Little London, especially given its brief suggested period of operation (Fulford and Machin 2021: 210-212), perhaps spanning less than two decades. While there is little evidence that Little London supplied Bath with relief-patterned tiles during the Neronian period, the examples from the New Royal Baths site would certainly benefit from re-examination and chemical analyses.

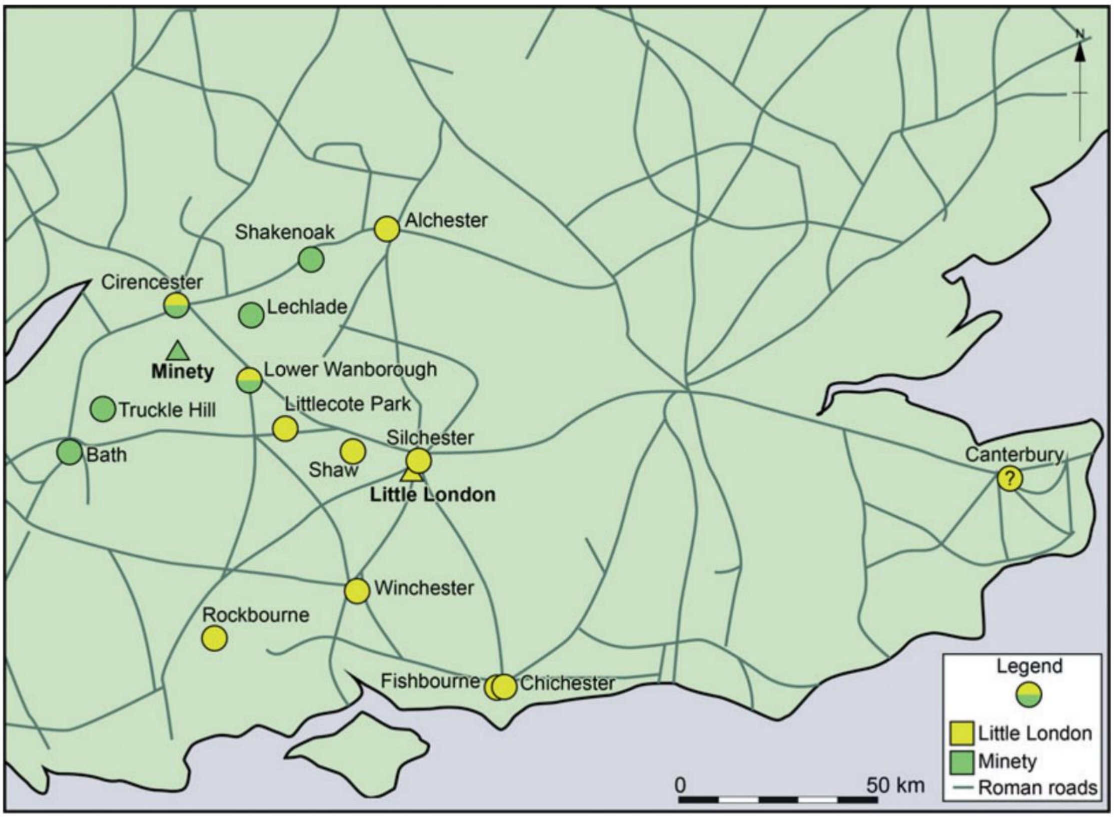


**Figure 10.14: Map showing the distribution of relief-patterned tiles with die types linked to the Little London or Minety kiln sites. From Fulford and Machin (2021: figure 2). Fulford, M. and Machin, S., 2021. Building Britannia: Pre-Flavian Private and Public Construction across Southern Britain. © Cambridge University Press. Reproduced with permission of The Licensor through PLSclear.**

### 10.5.4 Supply from Minety

While there is a small range of evidence indicating the limited import of ceramic building materials from other kiln sites to Bath, it seems likely that Minety was as important in the provision of the settlement as it was to the supply of the Roman Baths. Betts's (2011) equivalents for typical Minety fabrics, IB2, 3 and 7 (section 9.2.7), were found to occur in every single assemblage inspected from Bath, of any date (table 10.4). This was also the case with IB16, which may represent another non-typical Minety product. Furthermore, at each site fabrics IB2, 3, 7 and even 16 were identified among nearly every single major component type, including bricks, box flues and roof tiles (Betts 1999a, b, 2002, 2007, 2015). As noted above, IB2 and IB16 were identified from multiple relief-patterned tile sherds consistent with production at Minety (e.g. Betts et al. 1997: 23), though IB7 was also recorded in two relief-patterned fragments from Lower Common Allotments (Betts 1999a: 5) and the Tramshed/Beehive Yard (Betts 2002: 2) where the die type could not be identified. While the actual quantity and proportion of sherds of each of these fabrics in each assemblage is not clear, their widespread presence among many major, and lesser, component forms at each site analysed (e.g. Betts 1999a, b, 2002, 2007, 2015), nevertheless indicates that these, and by extension Minety, was highly important to the supply of the settlement. The presence of sherds of these fabrics among material from Neronian or Flavian assemblages at the Walcot Street site (Betts 2015: 221) suggests that the provision of Roman Bath by Minety began shortly after the settlement was founded. That it certainly continued through the first and second centuries is demonstrated by the roller-die finds and the dating of the Spring Reservoir Enclosure and Period III roof of the Great Bath (section 10.2). This supply could have continued even into the third and fourth centuries, particularly if sherds of F17 and F18 from the East Baths and their IB5 equivalents were manufactured at Minety, as the chemical evidence may suggest (section 9.3.2-3). Clearly, this kiln site was pivotal to the provision of Roman Bath and its most important monuments.

# 10.6 The Regional Importance of the Minety Kiln Site

There is a wide range of evidence for the production of many ceramic building materials from Roman Bath at the Minety Roman kiln site in northwest Wiltshire (section 10.4.4), which is located 9.5km south of Cirencester and 37km to the northeast of Bath. Previous research into CBM from other settlements suggest that Minety was just as important to the supply of much of Gloucestershire and adjacent areas. This included export to major settlements that are known to have had their own facilities, including Gloucester and Silchester. While Minety was pivotal to the provision of its local region, it was therefore also important in the fulfilment of extra-regional demand.

## 10.6.1 Roman Bath

The range of fabrics and components distinguished from the Roman Baths assemblages equated well with those identified from other sites in Bath (section 10.5). At the Roman Baths, a wide range of sherds from different fabrics and components were shown to be texturally (section 9.2.7) and chemically (section 9.3.3) consistent with Minety production. Significantly, this included the brick and tile used in two of the largest buildings at the complex, and indeed two of the largest vaulted structures so far known from Roman Britain (Lancaster 2012: 437), namely the Spring Reservoir Enclosure vault and the Period III roof of the Great Bath (section 10.2). In the wider settlement, the fabrics which equated best to typical Minety products (section 9.2.7) were identified from every assemblage analysed, of any date (section 10.5). This indicates that the Minety kiln site played a significant role in the supply of brick and tile to the entire settlement of Roman Bath, perhaps over an extended duration from the first to fourth centuries AD.

## 10.6.2 Cirencester

The analyses of Roman stamped tiles and unmarked CBM from Cirencester suggest that Minety was as important to the supply of this large settlement as it was to Roman Bath. The majority of finds of all private civilian stamped tile groups known from Gloucestershire and adjacent areas appear to have come from Cirencester (e.g. Darvill and McWhirr 1984: 252, *RIB* II(5): 56). Of these, stamped tiles likely produced at

Minety, namely the LHS and TPF derivatives (Darvill 1979), are by far the most common in the settlement (table 10.5). While factors of differential recovery or various stamping proportions between different tile groups may have affected these numbers, they still suggest the importance of the Minety. This is reinforced by Darvill's (1998: 351-352) analyses, who studied a complete assemblage of 2100 unmarked sherds from a single site in Cirencester, though his results may not be characteristic of all CBM assemblages from this *Civitas* centre. Nevertheless, he found that in all but one phase, 3a, the CBM assemblage was dominated by fabric types comparable to Minety products (Darvill 1998: table 31), even from early contexts. Furthermore, the fabric with the highest proportion in phase 3a was described as similar to the fabrics used in ARVERI and TPLF tiles (Darvill 1998: 352), though no stamped tiles were identified at the site. This is significant as samples of ARVERI and TPLF stamped tiles have been shown to be chemically consistent with production at Minety (section 9.3.3) and may have a source there (section 10.7.1). Darvill's (1998) report therefore suggests that Minety supplied a substantial proportion of the ceramic building materials used in Roman Cirencester, even in periods where relief-patterning or stamping were not practised.

### 10.6.3 Wanborough

Despite the presence of IVC DIGNI stamp types in assemblages at Wanborough, which are likely a result of local production nearby (Darvill 2001: 318, section 8.2.5), analysis of CBM from this site also indicates the importance of Minety imports. Darvill (2001: 317-319) analysed samples from across unmarked, stamped, and relief-patterned sherds from the settlement. Only 23 samples were included, but it was found that 70% of the CBM sampled could be attributed to a Minety origin (Darvill 2001: 318). While such a small sample is unlikely to be representative, a range of relief-patterned dies and stamps found on tiles at Minety are known from Wanborough. This includes dies 53 and 56 (Betts et al. 1997: 23, Mepham 2001: 313-316) and TPF, TPFB and LHS stamps (Wright 1970: 313, Mepham 2001: 316). While the comparative importance of Minety tiles versus local products is difficult to gauge, it is clear that the kiln site played some role in the supply of this settlement.

### 10.6.4 Other Settlements

Stamped finds suggest the occasional provision of more distant settlements, or those known to have had their own kiln sites, by Minety. One LHS stamped tile has been found at Silchester (Darvill 1979: 393), 90km from the production site. While this would suggest a very limited supply, maybe even a single batch, in fact 11% of the ceramic building materials retained from antiquarian excavations in Roman Silchester were found to have a Minety origin (Fulford and Machin 2021: 212). This is perhaps surprising given the distance traversed and the evidence for local kiln sites in earlier (Fulford et al. 2019) and later (Cram and Fulford 1979) periods. While Gloucester was provided with a municipal kiln site (Heighway and Parker 1982), it is still clear from finds of TPF and LHS tiles (e.g. Warry 2017: 89, 111) that Minety products were imported to this settlement and its surrounding area (section 8.2.5). Small numbers of finds of LHS tiles from Old Sarum, Wiltshire (Darvill 1979: 343), and Kenchester, Herefordshire (Darvill 1985: 162-164), also point to the extended reach of the Minety kiln site. Though the number of individual stamped tiles from each site are few, this demonstrates the extra-regional role that Minety fulfilled at times.

Together, this evidence indicates that the kiln site at Minety fulfilled a substantial part of the demand for the Roman Baths, for the wider settlement at Bath, for Cirencester, perhaps even Wanborough and at times provided batches for major settlements that had local facilities available, including Gloucester and Silchester. The identification of relief-patterned tiles and stamped tiles among many of these exports imply that workshops at Minety were active in the late first century and in the first half of the second century. The evidence from the Roman Baths (section 10.5.1) and from Neronian or Flavian contexts and buildings at the Walcot Street site (Betts 2015: 222) and Silchester (Fulford and Machin 2021: 212) indicate an even earlier start date. If the distinctive fabrics used in the late phases of the East Baths (sections 10.3, 10.4.3), and their equivalents from the wider settlement of Bath (section 10.5.2), are indeed the products of the Minety kiln site, then production likely continued into the third or fourth centuries.

# 10.7 Characterising and Dating Minety Production

The Minety production site probably consisted of multiple sub-units at any one time. Unless stamped or impressed, it is unlikely that the products of these may always be differentiated. Some sites may have been situated some distance away but used very similar clays and been indistinguishable. It nevertheless appears that the most well-known workshops were located in the vicinity of the main kiln site. Re-evaluation of the discrete distributions of relief-patterned and stamped tiles suggest that these can be assigned to two different periods, the former in the first century only and the latter in the second. As both occur at Minety, this indicates different episodes of production in the first and second centuries AD.

## 10.7.1 Characterising Minety Workshops

The Minety kiln site was treated as a single unified entity in section 10.6 for synthetic reasons, but this is unlikely to have ever been the case. Instead, the kiln site was probably made up of a variable number of workshops at different times (figure 10.15), most of which used very similar geological deposits. Their products may thus be indistinguishable from those of other workshops unless marked, whether separated chronologically or spatially.

It is possible that a number of workshops at Minety may have been located some distance away from the main kiln mound at the site, but still exploited the Middle-Late Jurassic clays. Such could be the case with the ARVERI and TPLF stamped tiles. Darvill (1982: 55, 57) noted that the vast majority of the ARVERI and TPLF stamped tiles were consistent in thin-section with clays taken from the area of the Querns in Cirencester, which is sited on the Forest Marble and Cornbrash Formations (BGS 2022a). These deposits contrasted with the sandier Oxford Clays used for the Minety products (e.g. Darvill 1979: 318, 328).

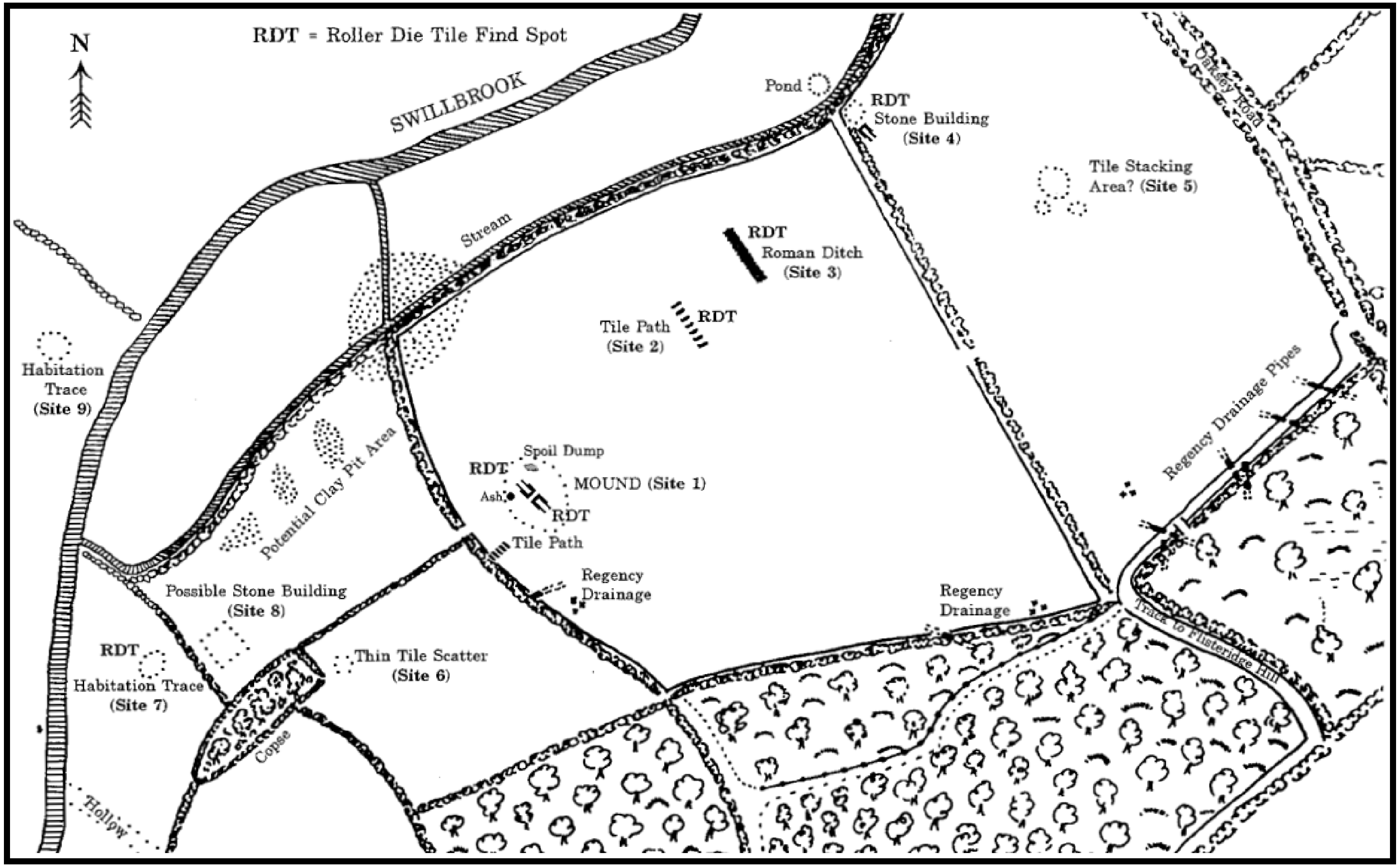


**Figure 10.15: Illustrated map of the Minety kiln site, showing kilns and surface finds identified by Scammell (n.d.). The copse in the southeast may be the remains of further claypits. From Scammell (n.d.: figure 2). Reproduced with kind permission from Wiltshire Museum.**

However, the geological mapping of the area has been refined since Darvill's (1979, 1984) studies were completed. Now the main parts of the Minety site are shown to be upon the deposits immediately below the Oxford Clays, the Kellaways Formation (BGS 2022b). This is underlain by the Cornbrash Formation, though these deposits also outcrop only a few hundred metres from the main kiln mound (figure 10.16). Significantly, they occur on the north side of the Swill Brook, in an area close to the reported location of a Roman building and many brick and tile finds (McWhirr 1984: 182b, Scammell n.d.: 23, site 9 in figure 10.15). Chemical analyses (section 9.3.3) demonstrated that the ARVERI and TPLF tiles were consistent with Minety products and clay samples and with stamped tile groups probably produced at the site. It is therefore entirely possible that ARVERI and TPLF tiles could have been manufactured at Minety or used comparable clays from the same geological deposits at another unidentified site. The finds of TPF and LHS stamped tiles in topsoil (Darvill 1979: 318, 328), and the recovery of numerous sherds of different relief-patterned tiles in the waste of the main kiln mound and as surface finds (Scammell n.d.: 15), nevertheless suggests that the most archaeologically visible workshops linked to Minety were in close proximity to each other at the site.

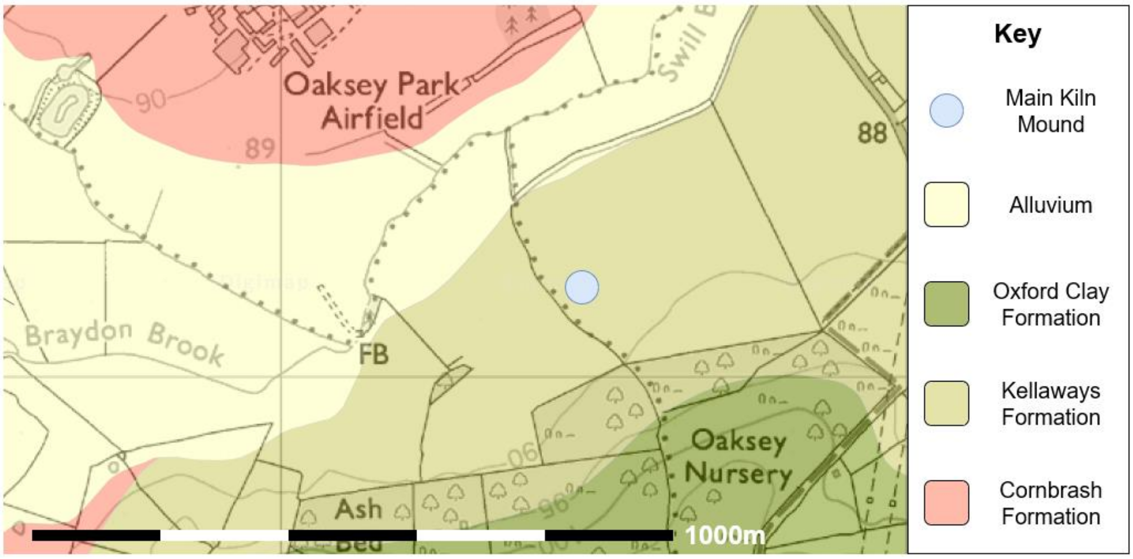


**Figure 10.16: Map showing the geology of the Minety kiln site. Modified from BGS (2022b). © BGS.**

### 10.7.2 Dating Relief-patterning Practices at Minety

There is a range of evidence that points to the operation of multiple different producers at Minety at the same time. This includes the relief-patterned and stamped tiles from the site. Relief-patterned tiles have been regionally dated to AD 80-150 on the basis of finds from a sealed context in a roadside ditch at Wanborough (Betts et al. 1997: 23). However, recent research at the Little London kiln site at Silchester has demonstrated a Neronian start date for certain dies (Fulford and Machin 2021: 210), one or two of which have been identified from Cirencester (Betts et al. 1997: 27) and Bath (Betts 2007: 54). Fulford and Machin (2021) have also argued that all relief-patterned tiles can be redated to the Neronian period or before, in direct opposition to seven decades of previous scholarship and research (e.g. Lowther 1948, Black 1985, Betts et al. 1997). In fact, the structural and contextual relationships of a hollow voussoir type from the Roman Baths demonstrates that it is highly unlikely that all relief-patterned tiles were Neronian. This evidence is presented here.

As discussed in section 10.2.2, components matching the dimensions of HV02 sherds from the Roman Baths assemblages were excavated by Scammell (n.d.) from the main kiln mound at the Minety site in association with relief-patterned sherds. This indicates that the Spring Reservoir Enclosure tiles were actually produced by a workshop that practised relief-patterning. Fulford and Machin (2021: 212) have argued that pottery excavated from Minety is Neronian in date, and thus that activity at the site can also be dated to the same period. While the forms of ring flagons excavated (e.g. Scammell n.d.: figure 14) certainly resemble Claudian or Neronian types found in the Walcot settlement at Bath (e.g. Davenport 2021: figures 13, 16), this assertion is problematic. Scammell (n.d.: 16) noted that diagnostic pottery types could not be found in association with the kilns excavated, and were instead recovered from a ditch some distance away from the primary mound at the site. Moreover, and in direct contrast to the Little London tilery (e.g. Fulford et al. 2017), no evidence of any pottery kilns were found near the excavated tile kilns. This was despite a range of other traces of ancient production being identified and investigated (e.g. Scammell n.d., McWhirr 1984: 42). While this does not rule out Neronian pottery production taking place somewhere in the vicinity, there appears to be little evidence to assign the two kilns and CBM excavated by Scammell (n.d.) to a pre-Flavian phase of activity. It is also pertinent to consider that if later activity focussed solely on tile production, then we would not necessarily expect to find abundant dateable pottery evidence from such phases anyway.

The association between HV02 tiles and relief-patterned sherds at Minety would suggest that the Spring Reservoir Enclosure at the Roman Baths could also be dated to the Neronian period, were Fulford and Machin's (2021) arguments correct. However, this simply cannot be the case. The evidence for the initial construction of the Roman Baths complex places this event no earlier than the late AD 60s (Blagg 1979: 103, Cunliffe and Davenport 1988: 359, Davenport 2021: 44-5), i.e. already in the final years of Nero's reign. A range of structural relationships indicate that the Spring Reservoir Enclosure was added to the site after the building of the Reservoir and Baths complex and disturbed the initial arrangement (Cunliffe and Davenport 1985). Prior to the construction of the Enclosure, a previously open and visible reservoir had been supplied with encircling coping blocks (e.g. Cunliffe and Davenport 1985: 42, Davenport 2021: 48). The construction of the concealing Spring Reservoir Enclosure would appear to have left very little room or need for this obstacle, and it is likely that they were deposited in the Spring at this date. Further changes that were made to accommodate the construction of the Spring Reservoir Enclosure included the Reservoir main outflow, which was reinforced and strengthened with an additional arch, likely to withstand the substantial additional weight of the Enclosure building above (Cunliffe and Davenport 1985: 50). Finally, the south-east wall of the Enclosure butted the curved wall of the north-west semi-circular exedra of the Great Bath, while the south wall was built upon the existing north wall of the West Baths (Cunliffe and Davenport 1985: 52). This proves that the Baths structures pre-dated the Spring Reservoir Enclosure, but the awkward location of these junctures must have also forced the reroofing of the exedra and the corridor immediately south of the Reservoir.

The structural evidence indicates that a wide range of changes had to be made to accommodate the Spring Reservoir Enclosure at the Roman Baths, and that it could not have been part of an original concerted, but delayed, plan. This demonstrates that there must have been some length of time between the initial construction at the site and the erection of the Enclosure building. This structure, the HV02 tiles and Minety relief-patterned sherds therefore cannot date to the Neronian period. While the exact date of this building and the necessary tile production cannot be determined, the present evidence suggests they belong to either the Flavian or Trajanic periods (see section 10.2.2).

### 10.7.3 Contrasting Minety Relief-patterned and Stamped Tile Distributions

Given that the evidence from the Roman Baths strongly argues against a Neronian date for all relief-patterned tile, should we automatically resort to previous chronological schemes? Fulford and Machin (2021) did raise a number of key, valid challenges in the current study of this CBM, particularly that contextual dating evidence (e.g. Betts et al. 1997) frequently dates the occurrence of *residual* brick and tile. One result has been the inaccurate assignment of the start of these practices to the AD 80s (e.g. Lowther 1948: 10, Black 1985: 356), whereas the finds from Little London (Fulford et al. 2017) demonstrate that these were in use more than a decade before. As such, the current mid second-century end date assigned to this practice (e.g. Black 1985: 366) also has the potential to be inaccurate. The end date of relief-patterned tile production in the Gloucestershire region, and at Minety, is therefore assessed here through the novel integration with stamped tile distributions.

Rectangular civilian stamps on tiles appear to date largely to the first half of the second century in the area (Warry 2005: 195), derived from the start dates deduced for Legionary stamping in York (RIB II(4): 125, see section 2.1.4) and Caerleon (Boon 1984: 15-16) and through the estimated duration of stamping obtained through calculation of municipal magistrates' dies from Gloucester (Warry 2017: 82). The close similarity in forms and conventions observed between many military, civil and municipal stamp dies used (e.g. Warry 2017: 94-95) supports a single relatively brief but intensive phase of stamping in the area, though military stamping certainly continued into the third century (*RIB* II(4): 125). No tiles appear to have been found that display the impressions of both a roller-die and a stamp (as opposed to a roller-die that incorporates letters). Moreover, examination of the distribution of finds of stamped tiles and relief-patterned tiles in the region show few sites which yielded both (figure 10.17).

The few sites which yielded stamped and relief-patterned finds are Minety, Cirencester, Wanborough and the villa and bathhouse site at Truckle Hill, just east of Nettleton Shrub. The Minety finds show no clear relationship, as both stamped tiles were unstratified (Darvill 1979: 318, 328). Cirencester was substantially developed in the first and second centuries (Faulkner 1998: 377-378) and appears to have represented the main centre of regional demand for ceramic building materials (Darvill and McWhirr 1984: 252). The finds of both relief-patterned tiles and stamped tiles at the settlement are therefore not surprising. Importantly, these finds are residual (e.g. Betts et al. 1997: 98, 109, 118, 126, 135) or not found in the same contexts as stamped tiles (e.g. Darvill 1986: 127-129, Viner and Stone 1986: 130) and thus demonstrate no conclusive evidence for contemporaneity.

The settlement at Wanborough similarly appears to have developed throughout the early Roman period (Anderson et al. 2001). It does not seem (e.g. Mepham 2001: 313-316) that any stamped and relief-patterned tiles have yet been found in the same contexts here, so this site provides no conclusive evidence for coeval production. The relief-patterned tile from Truckle Hill, near Nettleton Shrub, was perhaps collected by Scrope (Betts et al. 1997: 118) during antiquarian excavations of the villa (e.g. Scrope 1862). The two LHS tiles were retrieved from the recent excavation of the bathhouse (Smith 2009: 141), which was a distinct structure about 100m to the north (Andrews 2013: 107). These tiles therefore provide no evidence for contemporaneity. The range of relief-patterned tile finds and complete lack of any stamped CBM recovered from Bath (section 8.2) are highly significant, for the settlement appears to have had little development between the late first century and mid to late second century (Davenport 1994: 10, 2021: 83), i.e. during the main period of stamping. Furthermore, stamped tiles were clearly moving to sites near the bounds of Roman Bath's hinterland (figure 10.17), so this is unlikely to have been due to of difference in practice and supply alone.

While the present evidence cannot definitively prove that stamp and roller die use were *not* contemporary, it is consistent with each practice occurring in a discrete period. It is therefore likely that relief-patterning in the area was mostly a first-century practice, pre-dating the widespread adoption of stamping in the early second century AD. While this would appear to reiterate the Neronian dating arguments of Fulford and Machin (2021), the example of the hollow voussoirs from the Spring Reservoir Enclosure (section 10.7.2) demonstrate that not all such tiles could have been pre-Flavian. A broad Neronian to early Trajanic date for relief-patterned tiles is therefore suggested.

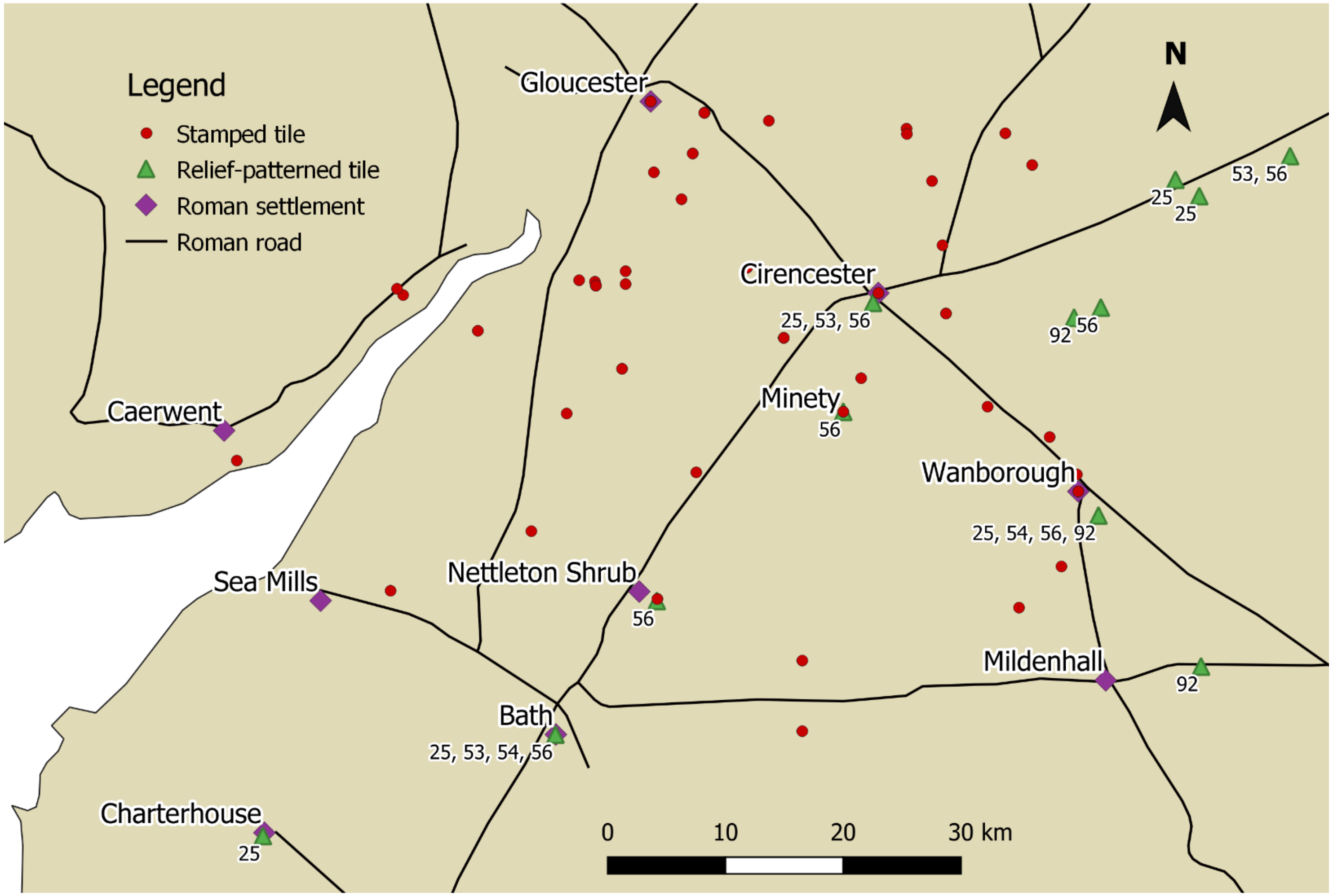


**Figure 10.17: Map of the region, Roman roads and settlements, showing finds of stamped or relief-patterned tiles of dies linked to production at Minety (e.g. Betts et al. 1997: 27) or otherwise found in Bath. Die numbers are listed next to findspots.**

### 10.7.4 Phases of Minety Production

Returning to Minety, the relief-patterned tiles found by Scammell (n.d.) are therefore likely to represent a discrete phase of activity in the first century, with the stamping workshops indicating second-century production. Scammell (n.d.: 15) noted that fragments of die 56 were found with a fragment of tile with wavy relief-patterning in the same debris pile to the north of the northern kiln's stoke hole, and a cross-hatched example, perhaps from dies 25, 53 or 92 (e.g. Betts et al. 1997), was among debris abutting the stone wall of the southern kiln (Scammell n.d.: 15), which mistook for a stone building. Other sherds of relief-patterned tiles appear to have been found dispersed across the site (figure 10.15). The finds of three different types of relief-patterned tiles among the kiln waste of the main kiln mound strongly suggests that these were contemporary, and that the tilemakers using the different dies employed the two kilns excavated by Scammell (n.d.). It is possible that a range of different die designs were used by a single workshop, but it appears more likely that each represents the products of a different tilemaker or a different foreman responsible for a group of workers (section 2.1.4). These may have been used to mark a certain proportion of tiles to quantify and record output for determining wages, as was the practice with some historic masons' marks on stone (e.g. Alexander 2007). Regardless, it seems highly likely that the close occurrence of different relief-patterns indicate the contemporaneity of at least two or more producers at Minety in the first century AD.

The two TPF and LHS stamps found in topsoil at the site (Darvill 1979: 318, 328) have no contextual evidence for contemporaneity. Tiles with both stamps co-occurred with each other, and with TPFA, TPFP, ARVERI and TPLF stamps, in residual contexts at the Beeches Road site in Cirencester (Darvill 1986: 127), suggesting that they may have been employed together in the same structures at the same time. The range and development of LHS and TPF stamp impressions is also extremely similar (Warry 2017: 94-95), and consistent with contemporaneity. A wide range of TPF variant stamps existed and have also been found in Cirencester, for example TPFA, TPFB, TPFC and TPFP (*RIB* II(5): 74-77). Though no examples are yet known from Minety, many are closely related to TPF tiles texturally (section 9.2.7, Darvill 1979) and chemically (section 9.3.3). It is therefore highly likely that these stamps represent the existence of further contemporary TPF-controlled workshops at Minety during the first half of the second century.

## 10.8 Of Minety and Men

There is a range of evidence suggesting that multiple different workshops or producers existed at the same time at the Minety kiln site, in both the first and second centuries. The range of stamps and impressions found (Darvill and McWhirr 1984: 252, Betts et al. 1997: 27) suggests that Cirencester was the main regional centre of demand throughout the early Roman period at least, and thus the main target market for any producers at Minety. There are significant questions over whether Minety was municipal or commercial, and these have potentially significant implications for our understanding of the territorial and administrative relationships between Cirencester and Bath. This evidence is therefore fully evaluated.

### 10.8.1 Beginnings

The origins of the Minety kiln site are not well understood. The kiln site appears to have supplied pre- or early Flavian military contexts in Cirencester (Darvill 1998: 351) and Neronian and Flavian contexts in Bath (Betts 2015: 221) and Silchester (Fulford and Machin 2021: 212). It is interesting that the Walcot settlement has yielded a range of ceramic and metalwork evidence for early military occupation (Davenport 2000: 17). The kiln site may therefore have started as a military facility providing for these developing settlements. However, this may be contradicted by two sherds of Westhampnett hollow voussoirs found at the Roman Baths that are texturally (sections 9.2.4, 9.2.7) and chemically (section 9.3.2) consistent with Minety products. Though the dating of these components is not completely understood, by analogy with early sites in Sussex (section 9.2.6) an origin in Period I, or a very early stage in Period II (section 10.3) seems likely. These components represent a purely civilian innovation from West Sussex (Lancaster 2012), and if indeed from the late AD 60s or 70s may instead suggest a civilian origin to Minety.

### 10.8.2 Technical and Geographical Factors

While the possible origins of the kiln site have been considered, this does not explain how it came to prominence. One contributing factor must have been the high quality of the products. Many sherds of typical Minety fabrics from the Roman Baths, including F04, 05, 06, 08 and 15, are well-fired, sometimes to the point of semi-vitrification. They remain robust and hard even to the present, after more than 1500 years of immersion in rubble, soil, and even periodic flooding of the complex (e.g. Cunliffe 1969, 1976). This suggests the selection of generally high-quality raw materials, but also considerable skill in the control and maintenance of firing conditions.

The positioning of Minety must also have contributed to its success. While the kiln site is less than 10km from Cirencester, it is considerably further than the distance of the Neronian Little London kiln site to Silchester, 2.8km, or that of early kilns to the settlement at Londinium, which were inside the bounds of the late Roman walls (Betts 2017: 369). It therefore appears that the kiln site was sited with the intention to provide for other emerging regional settlements as well, though factors of land ownership and rights, suitable clay, water access and woodland for fuel may all have been important factors in this decision. The location of Minety is also strategically situated between two important Roman roads, the Fosse Way and Ermine Street. The Fosse Way was closer to the site, approximately 5.3km to the west, and granted access to the southwest and northeast, particularly to Cirencester and Bath. Ermine Street was about 9.6km to the east and allowed access to Wanborough and Silchester in the southeast, and Gloucester in the northeast. The proximity of these roads clearly facilitated the transport of large quantities of components to near and distant sites.

### 10.8.3 Evaluating Commercial and Municipal Production

Given the wide range of connections established between the Minety kiln site and Bath, it is important to assess and determine the nature of the operation of the site. This is necessary because Minety has been suggested to have comprised a municipal kiln site for the supply of Roman Cirencester (Warry 2017: 95). If this theory were accepted, it would therefore have significant implications for understanding not just the supply of building materials, but the direct relationship and obligations between the *Civitas* of the *Dobunni*, centred on Cirencester, and the settlement at Bath.

Warry (2017: 95) has suggested that the TPF series of stamps were the result of municipal production for Cirencester and its hinterland, interpreting the stamp as an abbreviation for *Tegularia Publica Fecerunt,* i.e. product of the public tile works (Warry 2017: 95). There is a range of evidence that may support this. The letters TPF have been noted as part of a single relief-patterned impression, die 63 (Betts et al. 1997:

123), found outside the study area. This might suggest that these letters indicate a phrase intrinsically linked to the manufacture of ceramic building materials, rather than representing a specific *tria nomina*. Moreover, and as noted in section 7.2.5, many finds of TPF tile stamps and derivatives have been found either in Cirencester or within the bounds of its hinterland area (figure 7.7), c.15-20km from the settlement (Davenport 1994: 7). This compares reasonably well with the distribution of assuredly civil RPG stamps around Gloucester (figure 7.6), and may be consistent with municipal production.

Yet, there are several problems with the assertion that the TPF series of stamped tiles represents civic manufacture. While the roughly alphabetical sequence of TPF workshops, including TPF, TPFA, TPFB, TPFC, TPFP and perhaps TPLF, could suggest ordered production in response to specific civil projects, it is not similarly reflected in the municipal RPG stamped tiles of the St Oswald's kiln site in Gloucester (Heighway and Parker 1982). Moreover, no inscriptions or stamps featuring magistrates' names have yet been found in association with any of the TPF series of stamps (e.g. *RIB* II(5)), in contrast to the wide range recorded from RPG tiles (Heighway and Parker 1982, Warry 2017). These differences are in spite of otherwise close parallels in stamp designs, development and dating between the TPF series and RPG products (Warry 2017: 94-95), suggesting that the mode and organisation of manufacture was fundamentally different.

Furthermore, the find of a milestone inscribed RPCD from Kenchester, Herefordshire (Sedgeley 1975: 8), suggests that this is the legend that should be expected for municipally produced tile from this region, for this abbreviation likely stood for *Res Publica Civitatis Dobunnorum*, i.e. for the state of the *Civitas* of the *Dobunni* (*RIB* 2250), which was centred on Cirencester (Frere 1978: 233).

Looking at parallels for municipal production from further afield, finds of inscribed and stamped tile from the Iberian peninsula reveal other instances of municipal kiln sites supplying a settlement and selecting to include the name of the settlement as part of the stamp. This includes at *Conimbriga,* in the Coimbra district of central Portugal, where a brick stamped RPC has been found (Ribeiro et al. 2021: 4138). Two sherds of Roman CBM inscribed with the initials RPS have also been retrieved from the Roman settlement of *Seilium*, modern Tomar in Portugal (Fernandes and Ferreira 2002: 261).

Finds of Roman bricks stamped AFL at Tres Minas, in northern Portugal, may also indicate municipal production for the nearby Roman settlement of *Aquae Flaviae* (Triaes et al. 2002: 157).

At Séez, in Savoy in France, several tiles stamped RPA have also been found, being interpreted as the product of a municipal kiln site from the Roman settlement of *Augustorum* (Beal et al. 2019: 18), modern day Aosta in Italy, which is c.50km to the north-east. The only similar stamps to have come to light in the rest of France or Belgium are perhaps the TRPS series from the area around Bavay (e.g. Luppens and Cattelain 2014, Deru et al. 2019), on the French-Belgian border. The R and S in these stamps could be expanded to *Res Publica* in the same way as above, but given the occurrence of tiles stamped TRAVCPSB from the same region (e.g. Luppens and Cattelain 2014: 242) it seems much more likely that this is an abbreviation of a name instead. Indeed, the sheer number of apparent derivatives of the TRPS stamp, including TRPOS, TTPS, TRP, TPR, TRAUCPSB and TRPOIS (Luppens and Cattelain 2014, Deru et al. 2019) mirror the variety observed in the TPF series (e.g. *RIB* II(5)). Together this evidence, and particularly the lack of any explicit reference to Cirencester or the *Dobunni* within the TPF stamps, indicates that the TPF series is unlikely to represent municipal production for Roman Cirencester, and is probably derived from a *tria nomina.*

It is vital to understand the evidence for commercial or municipal production at Minety because of the implications for understanding the nature of supply and the relationship of the kiln site to Bath, and particularly to the Roman Baths. If, for example, we accept that the TPF-series was municipal then there is the potential that earlier phases of production at the same kiln site were also civic, even if stamping had not yet been adopted. This may have been the case at the St Oswald’s kiln site in Gloucester (Heighway and Parker 1982: 30-31). While Bath has so far not yielded any stamped Roman tiles, this could be the result of major phases of activity at the settlement taking place outside the period of stamping (see section 7.2.3). However, this is extremely unlikely given the constant small-scale demand expected of a typical Roman settlement (e.g. Darvill and McWhirr 1984: 242).

The range of evidence presented indicates that it is more likely that the TPF series represents private manufacture and commercial activity than civic production. By extension, it is possible that Minety also began as a private producer, though it must be admitted that there is nothing to rule out the site as being initially civic owned before a transition to private ownership. The understanding of Minety as a private enterprise complements the present and very limited understanding we have of the status of Roman Bath, and its relationship to *Corinium* and its territory.

Though Bath, or ancient *Aquae Sulis*, was included in the late second-century Antonine Itinerary (Rivet and Jackson 1970), we have no evidence of the exact status of the settlement and its administrative boundaries (Davenport 2000, Cunliffe 2000). Rather than falling within the area of the Dobunni tribe to the north, Ptolemy recorded that it was instead part of the territory of the Belgae (Cunliffe 2000: 127). This is surprising, and perhaps entirely unreliable (Cousins 2016: 103), as Bath is 45km from Cirencester, but more than 80km from Winchester, the apparent capital of the Belgae (Frere 1978: 68). Antiquarian finds of Provincial lead seals (*RIB* 2411.37) and inscriptions describing repair to a headquarters from the villa at Combe Down (Davenport 1994: 17-18) also complicate the picture. As does an altar from central Bath dedicated by a *centurio regionalis* (*RIB* 152), who may have been detached from his unit and made responsible for the security and administration of the local region (Cousins 2020: 95-6). These finds suggest a long-term state presence in Bath, and perhaps a formal headquarters (Davenport 1994), either at Combe Down or in the settlement proper. Whether this control extended solely to stone quarries in the area, or to the entire region of Bath (e.g. Davenport 1994), is unknowable.

An understanding of the Minety kiln site as commercial in nature does not contradict ideas about state control or involvement in the way that Bath receiving municipal supply from Cirencester might. Indeed, finds of relief-patterned tiles matching typical Minety dies among demolition rubble from an early high status building at the New Royal Baths site in Bath (Betts 2007) interpreted as a potential administration or headquarters building (Davenport et al. 2007), at Charterhouse (Betts et al. 1997: 98), and alongside Spring Reservoir Enclosure tiles at Minety (section 10.2) may suggest a range of different authorities, perhaps state, military and civilian respectively, successively engaging commercial contractors at Minety.

## 10.9 Understanding Demand, Production and Supply

The importance of the Minety site in the supply of Cirencester, Bath and other sites and settlements in the region suggest that old models used to understand the manufacture and distribution of ceramic building materials in the area (e.g. Hodder 1972, 1974, McWhirr and Viner 1978, Darvill and McWhirr 1984, McWhirr 1984) need to be revaluated. In particular, these results may suggest that itinerant production at different sites was not as routine as previously supposed. In common with Roman London and the southeast (e.g. Mills 2013, Betts 2016, 2017), major centralised production relying heavily on long-distance transport appears to characterise much Roman ceramic building material production and distribution in Gloucestershire, northeast Somerset, and northwest Wiltshire. This situation is likely a result of demand from a small, dispersed population with good arterial networks and high-quality building stone locally available.

### 10.9.1 Revaluating Itinerant Production

Itinerant production has been used to explain significant differences in the fabrics of stamped tiles with the same stamp (section 4.3.3), including LHS and TPF tiles from Hucclecote (Darvill 1979: 319, 328), a single ARVERI tile from Kingscote (Darvill 1982: 55), and TCM tiles from Cirencester and other sites (Darvill 1980: 52). There are abundant examples of such temporary production in the historic and ethnographic record (e.g. Peacock 1979, McWhirr 1984), yet these are invariably post-Roman. The ARVERI tile from Kingscote was chemically analysed as part of this study (section 9.3.3) and presented different compositional values to the other ARVERI samples analysed, indicating that this example remains consistent with temporary production at a different site. It is therefore highly likely that there were episodes of itinerant production in the region in the Roman period, with brickmakers moving from site to site, yet the importance of Minety to the supply of Bath, Cirencester and other areas suggests that this was less frequent and routine than previously indicated.

While the hiring of a brickmaker to produce CBM at the site of a villa using a temporary kiln could have benefits, cutting out transportation costs and perhaps achieving a cheaper rate per component, there were limitations. These included being subject to the quality of clays available nearby, not all of which are suitable for brickmaking (e.g. Richardson and Webb 1910, 1911, section 7.2). The components themselves may also be more likely to be fired irregularly or to lower temperatures as a result of the use of a clamp kiln, rather than a dedicated permanent structure. The digging of clay and claypits for this process would have impacted subsequent land use, and the firing of components would have required substantial fuel. Significantly, much of the area considered is rich in high-quality building stones (e.g. HE 2017a, b, c), which was widely and locally exploited at Roman sites (Williams 1971). The quantities of ceramic building materials required for many structures may thus have been modest and restricted to specific roles, for example roof tiles, hypocausts, and bathhouses, rather than providing bulk walling. For most building projects, it appears far more likely that a supply of high-quality ceramic building materials from an established kiln site close by, and accessible using well-maintained road networks, would therefore be opted for. The evidence suggests this is likely to have been the case, for stamped and relief-patterned tiles linked to a Minety origin occur at a range of known villa sites, including Hucclecote (Clifford 1955: 71), Truckle Hill (Betts et al. 1997: 118, Smith 2009: 141), Frocester Court (Price 1996: 173) and Kingscote (Darvill 1979: 339), and as solitary finds perhaps derived from similar sites (e.g. *RIB* II(5): 65, 74-77, Betts et al. 1997: 98, 120, 140). In contrast, only a small number of examples of itinerant production have been suggested in the region (Darvill 1979, 1980, 1982), and the evidence for these is sometimes ambiguous (section 4.3.3) or actively contested (e.g. Warry 2017: 92). It is therefore likely that itinerant production was practised less widely in the region than previously supposed.

### 10.9.2 Understanding Demography, Circulation and Value

Proposals for centralised production and routine long-distance transport of ceramic building materials in the region contrast with other models used to interpret these distributions (section 2.2.2). One explanation for this divergence is that previous research (e.g. Hodder 1972, McWhirr and Viner 1978, Peacock 1979, Darvill and McWhirr 1984, McWhirr 1984) drew on case studies of medieval or post-medieval societies in order to understand Roman production, yet it seems there were three fundamental differences. The first was the population size and density, the second the excellent road network, and the third the nature of the relationship between stone and ceramic building materials.

A key difference between brick and tile circulation in the Roman period and later, particularly post-Medieval, society in Britain was the population size and density. Though historic population estimates are often fraught, a figure of around 2.8 to 3 million people (Alcock 2011: 260) may be likely for the population of Roman Britain in the second century. In contrast, by the end of the 17th century the population of Britain was likely around five million (Wrigley and Schofield 1989: figure 10.3), substantially greater. Moreover, Roman settlements were also fairly small, with Cirencester having an estimated population of only 10-15,000 people in the second century (CTC 2022), despite being one of the largest settlements in Roman Britain at that time. In contrast, London alone grew from around 50,000-60,000 people in 1520 to perhaps 200,000 in 1600 (Picard 2016), though other cities were likely far smaller. This suggests that the demographic size and density during these periods were significantly different, with the post-medieval populations much greater in size and more centralised. Different patterns of production and circulation in ceramic building materials between these periods are therefore to be expected, for Roman industries had to provide for a smaller number of individuals, and perhaps demand, more widely dispersed across the landscape. Such a situation lends itself more to centralised production and a greater emphasis on transport than, say, frequent and evenly dispersed kiln sites or a total reliance upon itinerancy, but it was also facilitated by a high-quality road network.

Previous studies evaluating building material or bulk goods distributions in Britain in a range of periods have emphasised (Hodder 1974: 341, Pounds 1990: 235) the high cost of road transport in comparison to riverine or maritime movement of goods. While pertinent, this perception may be, in part, a result of the poor state of many roads in Britain from the post-Roman period until the 18th century and the introduction of turnpikes (e.g. Bogart 2005, 2017). During this interval, there appears to have been no centralised road maintenance system, often being devolved to individual parishes, and thus prone to extreme deterioration (Bogart 2017: 1-2). In contrast, many important roads in Britain were first formally defined in the Roman period, for example the Fosse Way and Ermine Street, and milestone evidence (Sedgley 1975), and indeed finds of multiple road resurfacings (e.g. Davenport 2008a: 129-133), suggests phases of regular maintenance. Many roads in Britain were therefore relatively new and well-maintained in the Roman period, but deteriorated substantially afterwards. While road transport in Roman Britain is likely to have imparted an additional expense in comparison to other means, it was nevertheless still clearly practical and economical to move large quantities of material moderate or large distances over land. This is demonstrated by the substantial movement of CBM from Minety 37km southwest to Bath, traversing the southern end of the Cotswolds, and stamped (Darvill and McWhirr 1984: 253) and unstamped (Fulford and Machin 2021: 212) tiles to Silchester, some 90km away.

The third, and final, factor that differed between the Roman period and other historic periods in the region considered was the use and value of brick and tiles, and their relationship with stone building materials. In the Roman period there is a range of evidence (section 2.3.1) to suggest that ceramic building materials were expensive and often produced for use in specific roofing, vaulting, and heating roles, many tied to bathhouses. These private baths were costly to afford and maintain (Lancaster 2012: 432) and were thus the preserve of the elite. Moreover, Gloucestershire, Somerset, and Wiltshire are all well provided with high quality building stones (HE 2011, a, b, c), many of which were exploited at Roman sites in this region (Williams 1971). For many buildings in these areas, stone would therefore have comprised the bulk structural elements and been supplemented with CBM only where necessary, for hypocausts and baths. These specialised applications can still be seen in-situ at the Roman Baths in Bath and at the Chedworth (Stoten 2005) and Great Witcombe (Holbrook 2003) Roman villas in the Cotswolds. At no time during the Roman period in this area did CBM appear to represent a cheap building resource facilitating rapid development, as seen in Bath (Harper 1989, Murless 2000) and London (Hillier 1981) in the late 19th century and early 20th centuries, for example. In the Roman period, many ceramic building materials in the region therefore represented specialised and valuable components that facilitated bathing activities and associated architecture. The construction and maintenance of private bathhouses represented, to some extent, conspicuous consumption, but it also suggests the replication and adherence to traditionally Roman, and later provincial, activities. A bathhouse made up of box flue and hollow voussoir tiles was therefore greater than the sum of its humble parts, allowing participation in, and development of, cultural practices originally brought from outside of Britain.

Together, the factors of a smaller and more dispersed population, a better maintained road network and a more specialised, high-status function intended for many Roman ceramic building materials serve to explain why centralised manufacture and routine transport became the primary mode of production and circulation for Roman Bath, Gloucestershire, and northwest Wiltshire.

# 11 Conclusion

This section will bring together the outcomes of this study, review the extent to which the research aim and objectives have been achieved, and consider the implications of these findings to the understanding of Roman ceramic building materials from Britain. The limitations of this study, the changes in scope, and the impact of COVID-19 are also highlighted. Finally, this chapter will conclude by suggesting a number of potential avenues for future research.

## 11.1 Key Outcomes

- A unified understanding of the range of components, marks and impressions present among ceramic building materials from all assemblages of the Roman Baths has been developed.

- The combination of fabric and chemical analyses, and the inclusion of regional comparative material, has allowed suggestions of provenance for several prominent fabric groups and components.

- The presence of early CBM forms of a Sussex workshop at the Roman Baths was found to parallel evidence for Continental stonemasons having worked on the Temple of Sulis Minerva in the Neronian/Flavian periods. Early building was thus found to draw on different specialists from other regions and provinces, attesting the significant resources of those responsible for the construction of the Roman Baths.

- A major outcome for the Roman Baths is that the Spring Reservoir Enclosure building has been redated to the late first or very early second century as a result of the analysis of ceramic building materials. It therefore represents a discrete phase of activity, preceding the Period III reroofing of the Great Bath by several decades.

- The importance of the Minety kiln site to the provision of the Roman Baths has been demonstrated, and it has been shown to be responsible for the supply of ceramic hollow voussoirs in two major phases at this complex in the first and second centuries. These are the construction of the Spring Reservoir Enclosure roof and the Period III re-roofing of the Great Bath and adjacent areas.

- The fabric groups from the Roman Baths have been successfully equated with those from previous analyses of sites in the wider settlement. This indicated the importance of

Minety in the supply of the entire Roman settlement at Bath, through at least the first and second centuries.

- Integration with the results of other studies in the wider region suggests that Minety was pivotal to the provision of Roman Bath and Cirencester, but may also have been important in the supply of Wanborough and Silchester, and provided some material to a number of other settlements in the region, for example Gloucester.

- These findings imply that centralised production and medium or long-distance transport of ceramic building materials were routine in this region in at least the first and second centuries. Finds of late fabrics chemically consistent with Minety products in Bath could suggest that the kiln site continued to be active into the third or fourth centuries.

## 11.2 Understanding Use, Procurement and Development

Ceramic building materials were frequently employed in specialised construction roles in the region of Bath during the Roman period, with locally available building stone fulfilling many bulk structural purposes. Bricks and tiles were integral to the creation of hypocaust structures and many barrel vaults. At the Roman Baths this included many heated structures in the East and West Baths, but huge numbers of ceramic hollow voussoir tiles were also used to roof the considerable spans of the Spring Reservoir Enclosure and Great Bath, both unheated. These building materials and components were therefore intimately entwined with the emergence, development, and demand for Roman bathhouses in the region, whether private or public.

The sourcing of much material from the Roman Baths and the settlement at Bath to production at the Minety kiln site suggests that it was highly important to the provision of the Roman town. Analyses indicate that some of the largest phases of construction at the Roman Baths were supplied by the kiln site, including the Spring Reservoir Enclosure vault and Great Bath reroofing. Finds of Minety products also appear common among assemblages from more typical domestic, industrial, or suburban villa sites at Bath. This suggests that workshops at the kiln site fulfilled all sizes of projects, from small-scale settlement demand to the materials used in two of the largest barrel-vaulted roofs yet known from Roman Britain (Lancaster 2012: 437). The procurement of ceramic building materials for construction projects in the region of Bath therefore appears to have relied heavily upon the availability of Minety products, regardless of the scale of demand.

Through their use in novel architecture, ceramic building materials made a direct contribution to the socioeconomic development of the region. Bricks and tiles were used in all phases at the Roman Baths, from notched wall tiles employed in the base of the Period I Spring Reservoir (Cunliffe and Davenport 1985: 43), to the *pilae* bricks of the latest phases of hypocausts in the East and West Baths (Cunliffe 1976: 13, Davenport 2011a: 10). The range of forms and dimensions of different components identified among the Roman Baths assemblages (section 9.1) nevertheless suggest changes in design and innovation, illustrated best by the differences observed between the Spring Reservoir Enclosure and Great Bath vaults and components (section 10.2). While people consciously employed these bricks and tiles in the creation of new buildings and architecture, the resulting structures shaped how people engaged with and experienced the site. By extension, so did the ceramic components that comprised them, for these enabled the efficient heating of floors and walls so integral to the atmosphere of a Roman *tepidarium* or *caldarium*. The use of ceramic building materials also facilitated the roofing of warm, steamy, and moist spaces likely hostile to timber roofing (Cunliffe 1969: 98). The enclosure of the Spring within a cavernous building represented a huge change in how this monument was viewed, approached and how offerings must have been made (Cunliffe and Davenport 1985, Cousins 2020), all enabled by the use of ceramic hollow voussoirs in its enormous vault. The Roman Baths and Sacred Spring formed the heart of *Aquae Sulis*, and drew a wide range of visitors from across Britain and beyond (Cunliffe 2000, Cousins 2020). Through its use in architecture and its effect on the environments and experiences of the complex, ceramic building materials therefore contributed significantly to the evolution of this monument, and thus the social and economic development of the surrounding region.

## 11.3 Contribution and Impact

At the site level, the most important contribution of this study has been the redating of the construction of the Spring Reservoir Enclosure at the Roman Baths (section 10.2). If the proposed new date is accepted, it significantly alters the understanding of the history of developmental and the chronology of the complex.

The integration of the novel analyses of material from the Roman Baths with the results of previous research in Bath (section 10.5) and other sites in Gloucestershire, Wiltshire and even Hampshire (section 10.6) has created an initial local and regional understanding of the production and circulation of Roman ceramic building materials during the first and second centuries. This may serve to provide a framework or hypothesis for future investigations of these materials in this area to test, confirm or refute.

The importance and wide distribution of the products of the Minety kiln site suggests that centralised production and medium to long distance transport were routine in the region during this period (section 10.9). This tallies with similar patterns identified in the southeast of England and from Roman London (e.g. Mills 2013, Betts 2016, 2017), and with the distribution of the first-century relief-patterned products of the Little London kiln site (Fulford and Machin 2021). These mechanisms of manufacture and circulation have now been identified in three different, but consecutive, regions of southern England. As such, the results of this study may one day contribute to a national understanding of the production and distribution of ceramic building materials in Roman Britain.

## 11.4 Limitations and Changes in Scope

This project was initially conceived to analyse both the stone and ceramic building materials from the Roman Baths together, in order to create a unified holistic understanding. Analysis of the two materials to the depth desired eventually proved beyond the capabilities of this thesis. This was in part due to the impacts of the COVID-19 pandemic, which substantially limited access to assemblages and laboratories during the critical middle phase of this study. While the ceramic building materials of the complex have therefore been divorced from the building stone in this research, it is hoped that enough attention has been paid to the relationship between stone and bricks and tiles to adequately contextualise the use and value of these materials.

While originally intended to be part of this research, thin-section petrographic analysis was not completed on any samples of ceramic building materials from the Roman Baths. This was in large part because the combination of the results from the fabric analyses of fresh breaks and the pXRF analyses were found to be sufficient to fulfil many of the objectives of this project. The lack of highly precise fabric descriptions made using thin-sections means that it may be challenging for other researchers to compare their fabrics with those in this study, which is regrettable. A fabric reference collection has been collated during this research and is to be deposited with the Roman Baths Museum, so this may enable some comparison in future.

## 11.5 Recommended Further Research

The study of Roman ceramic building materials in Britain would greatly benefit from an increased integration with the study of building and roofing stone. These industries were closely related, with stone equivalents gradually supplanting the use of bricks and tiles in certain roles, for example in the introduction of roofing slates and the use of channelled hypocausts of stone (e.g. Williams 1971). The fortunes of one industry may therefore have been intimately tied to the other. Comparison of the organisation of production and the movement of stone and ceramic building materials at a regional or national level could provide significant insights into the supply and transport of bulk goods in Roman Britain. The combination of both may even allow the rise and fall of these industries to be described, and the economic impact of specific historical events, for example the Antonine plague, to be investigated.

There is substantial evidence for the manufacture of ceramic building materials and pottery at the same kiln sites (section 2.3.2), yet these two artefact types have received little integration. The study of these materials should be synthesised in order to create a more holistic understanding of the contexts of manufacture, the movement and use of these materials. The collation of these artefact types could even shed light on issues of identity, for whereas ceramic building materials were novel and adopted from the Continent (McWhirr 1984), there is a range of evidence for pottery production in the study area in the Iron Age (Peacock 1968, 1969, Morris 1994, 1995). It would therefore be valuable to determine whether the adoption and production of new Continental pottery styles provided a pathway to the manufacture of ceramic building materials, potentially facilitating novel architectural forms and the development of new cultural practices, particularly bathing.

This study has examined the present understanding of the Minety kiln site (sections 8.2, 10.7-8), but it is remarkable how little physical investigation the site has received (e.g. McWhirr 1984: 182). There is clear potential for a revaluation of the products excavated by Scammell (n.d.), as well as new geophysical survey and excavation at the site to determine the presence of further kilns. This might yield distinctive component forms and impressions that could confirm assertions made in this study, for example finds of hollow voussoirs produced for the Great Bath roof (section 9.1.3), or further stamped tiles (section 10.7.1). If dating of kilns were undertaken, it could also shed light on the chronology of specific brick and tile forms and marks found in association, and could confirm or disprove the dating proposed for the Spring Reservoir Enclosure (section 10.2). A new survey of Minety could therefore yield valuable results at a range of scales, and represents a priority for future research into Roman ceramic building materials in the study area.

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# Appendix A: Foster's Fabric Scheme for the Temple Precinct Assemblage

From Foster (1985: microfiche C4-5) in Cunliffe and Davenport (1985).

Fabric 1:

Numerous medium-large quartz inclusions sub-rounded, well-sorted throughout, 'sandy' appearance; surface – generally rough; colour – predominantly Munsell 2.5 YR 5/8 (red); hardness – 4; function – predominantly tegulae. (Note: well-fired; no reduced cores).

Fabric 2:

Moderate-numerous medium sub-rounded quartz inclusions well-sorted throughout, 'sandy' appearance but 'finer' than fabric 1; surface – generally smooth on convex curve, rough on concave (for imbrices); colour – Munsell 2.5 YR 5/8 (red), occasional reduced core; function – predominantly imbrices; hardness – 4.

Fabric 3:

Dense, compact with a few quartz inclusions; surface – generally smooth; colour – Munsell 5 YR 7/6 (reddish yellow); hardness – 4 function – unknown.

Fabric 4:

Dense, compact. Moderate red inclusions; surface – smooth; colour – Munsell 2.5 YR 4/8 (red), 7.5 YR 5/6 (strong brown); hardness - 4

Fabric 5:

Dense, moderate white inclusions, occasional elongated voids; surface – smooth (convex), rough (concave) – imbrices; colour – 5 YR 5/8 (yellowish red); hardness – 4; function – imbrices (2).

Fabric 6:

Dense, compact, frequent-numerous voids (round and elongated); surface – smooth; colour – Munsell 2.5 YR N5 (grey), 2.5 YR 5/8 (red), 5 YR 6/6 (reddish yellow); function – tegula, imbrices; hardness – 4. (Note: similar to No.2?).

Fabric 7:

Compact, flow lines clearly visible; occasional red inclusions varying in size small-large, ill-sorted; small circular voids (up to 5 per 20x lens field); surface – smooth; colour – 2.5 YR 5/8 (red); function – box tiles, brick; hardness – 4.

Fabric 8:

Rough, flow lines clearly visible, elongated voids, numerous medium quartz; surface – smooth; colour – 2.5 YR 5/8 (red); function – box tiles, brick. hardness - 4.

Fabric 9:

Firm, compact, numerous small-medium sub-rounded quartz inclusions; sparse sub-angular red inclusions, small circular voids; surface – smooth; colour – 2.5 YR 5/8 (red), 2.5 YR N5 (grey); function – box tile, brick; hardness – 4.

Fabric 10:

Moderate quartz small-medium, moderate dark inclusions, occasional elongated voids, compact; surface – smooth; colour – 2.5 YR 5/9 (red); function – box tile; hardness – 4.

Fabric 11:

Compact, numerous small quartz, moderate white inclusions; surface – smooth; colour – 2.5 YR 5/8 (red); function – box tile; hardness – 4.

# Appendix B: Betts's Fabric Scheme for Sites in Roman Bath

From Betts (1999a, 1999b, 2011, 2018).

Fabric 1: Common very small white calcium carbonate grains (up to 0.5mm), with occasional red iron oxide (up to 1mm).

Fabric 2: Common iron oxide inclusions (up to 2mm) with occasional silty bands. Little visible quartz. Silty bands more prominent in certain bricks and box-flue tiles.

Fabric 3: Fine sandy fabric with frequent very small quartz (up to 0.2mm) with occasional thin silty bands and iron oxide inclusions (up to 1mm).

Fabric 4: Fairly coarse sandy fabric with frequent quartz (up to 0.4mm) and common red iron oxide inclusions (up to 2mm) and cream silty bands. Probably a sandy version of fabric 2.

Fabric 5: Frequent small black iron oxide inclusions (up to 0.3mm) and fairly common quartz in many tiles (up to 1mm).

Fabric 6: White and pink coloured clay with common very small quartz (up to 0.1mm) with occasional much larger grains (up to 0.8mm). Scatter of red iron oxide (up to 0.8mm).
[May be pottery rather than CBM.]

Fabric 7: Fine fairly sandy fabric with common quartz (up to 0.2mm) with a scatter of red iron oxide (up to 2mm) and cream silty bands.
[Possibly a sandy version of fabric 2]

Fabric 8: Fairly frequent quartz (up to 0.3mm) with prominent cream and grey coloured silty inclusions (up to 15mm long) and common red iron oxide inclusions (up to 2mm).

[This is MOLA fabric type 3019, which is believed to come from the Hampshire area in the early second century. In London most tiles in this fabric are brick, as are the examples from Bath (Betts 1999a, Betts 2007).]

Fabric 9: Clay matrix, with very fine white and black mottling. Occasional red and black iron oxide (up to 1mm). Large voids in the clay matrix (up to 5mm). Some are filled with white calcium carbonate.

Fabric 16: Fine micaceous clay. Certain tiles have red iron oxide inclusions (up to 2mm) and silty bands. Normally fine moulding sand present (up to 0.2mm).

Fabric 17: Fairly sandy, with varying amounts of quartz (up to 0.5mm). Occasional calcium carbonate and iron oxide inclusions in certain tiles (up to 1mm).
[MoLA Fabric 3006]

Fabric 18: A finer version of existing fabric type 17, with little or no quartz.
[MoLA Fabric 2452]

Fabric 23: Sandy fabric, common quartz grains (up to 0.7mm), with occasional iron oxide and calcium carbonate (up to 0.7mm).
[MoLA Fabric 3004]

# Appendix C: Results of Ceramic Building Material Pilot Recording

**Table C.1: Table summarising the findings of the ceramic building material pilot analysis.**

| Pilot Recording Results Summary | |
|---|---|
| Number of sherds analysed: | 130 |
| Average sherd weight: | 319g |
| Median sherd weight: | 176g |
| Range of tile types identified: | Tegulae, imbrices, hollow voussoirs, bricks, box flue tile |
| Range of fabric groups identified: | F01-F10. F02, F09 and F10 not continued into full recording. |
| Range of marks, impressions and other features identified: | Combing, relief-patterned tile, finger marks and thumbprints, knife mark, mortar, concretions |
| Comb teeth numbers: | Ranged from 3-17, divided fairly equally between 6-9 and 12-17 |
| Comb widths: | 20-58mm wide |

**Table C.2: Table showing the high and low estimated sherd counts for the RB82 and East Baths assemblages, calculated using the median and average sherd weights respectively from the pilot recording, listed in table C.1. The York Street and Spring Reservoir sherds had been catalogued or were counted, not weighed.**

| Assemblage | Mass (kg) | High sherd count estimate | Low sherd count estimate |
|---|---|---|---|
| RB82 | 131 | 747 | 411 |
| EB01, 95 & 99 | 338 | 1925 | 1059 |
| York Street | N/A | 720 | 720 |
| Spring Reservoir | N/A | 77 | 77 |

# Appendix D: Recording of Ceramic Building Materials

**Table D.1: Table showing the range of data, features, marks and impressions recorded for each sherd analysed from the Roman Baths during the full CBM analysis.**

| | | | |
|---|---|---|---|
| Collections Data | Sherd number | e.g. 1099 | Unique code assigned to each sherd analysed |
| | Accession number | BATRM year.aaa.bb.c.d | Roman Baths record number listing year, trench number (aaa), find type (bb) and context number (c.d.) equivalents in their database |
| | Site code | e.g. EB01 | Site code for excavation |
| | Trench number | | Trench the sherd was excavated from |
| | Context number | | Context sherd excavated from |
| | Box number | e.g. EB01 TILE | Storage box number or label |
| | Bag/Label | e.g. EB01 INT | Bag number or name that sherd was in, or individual label number (where present) if from the catalogued York Street assemblage |
| | Provenance risk | 1-6 | Assessment of how well provenanced that sherd and/or context is to an area of the Roman Baths, and the likelihood of its in-situ preservation |
| | | 1 | Recorded during modern excavation: Sherd in-situ or lay where it fell and very unlikely to have been subsequently moved (e.g. CBM collapsed into the spring) |
| | | 2 | Modern excavation: Sherd likely lay where it fell, although some possibility of being dumped or scattered from another structure (e.g. temple precinct CBM) |
| | | 3 | Modern excavation: Sherd likely to have been redeposited from another structure (e.g. rubble being reused as hardcore, like in New Royal Baths excavations) |
| | | 4 | Pre-modern excavation: Confidently linked to an antiquarian excavated area |
| | | 5 | Pre-modern excavation: Only speculative provenance for this material, but likely to be from the Roman Baths |

| | | | |
|---|---|---|---|
| | | 6 | Pre-modern excavation: No provenance, and material may be from anywhere in Roman Baths or adjacent sites |
| Physical data | Mass (g) | | Weight of sherd |
| | Dimension (mm) | | Largest dimension of sherd |
| | Thickness (mm) | | Taken at a representative or middle point of sherd thickness |
| | Width (mm) | | Only taken for non-hollow voussoir components if a complete width is present. For hollow voussoirs, record complete width of face at one or two different points, if possible, even if not the maximum or minimum width (i.e. joint with base or top). If incomplete, record with 'i' in front of measurement, e.g. i151 |
| | Height (mm) | | Record if complete, or if partial but substantial for hollow voussoirs, using 'i' in front of measurement if so, e.g. i213 |
| | Depth (mm) | | Record if complete, or if partial but substantial for hollow voussoirs, using 'i' in front of measurement if so, e.g. i124 |
| | Diagnostic artefact features | e.g. corner, edge, flange, combing on adjacent surfaces etc. | Summarise diagnostic or significant features of sherd that have been used to identify artefact type |
| | Tile type | e.g. Imbrex, Tegula, Box flue etc. | Acceptable tile types are: Unidentified, Combed tile, Flat tile, Wall tile, Hollow voussoir, Westhampnett hollow voussoir, Half-box flue, Box flue, Tegula, Imbrex, Curved Tegula, Brick (when more than 30mm thick), Voussoir brick |
| | Position of sherd | e.g. top, side, corner, edge, etc. | Position of sherd in the complete component |
| | Flange type | e.g. F | Assessed using adapted Payne (2016) drawing |
| | Cutaway type | e.g. B6 | Assessed using Warry's (2005: 6) typology |
| Fabric data | Fabric Type | e.g. 04 | Fabric type according to fabric scheme used in this study (Appendix E) |
| | Special features | e.g. well-preserved microfossils | Describe significant features or thoughts not encompassed solely by fabric descriptions |
| Marks and Impressions | Knife marks | Y or N | Presence of knife marks on sherd surface; describe in other notes section if necessary |

| | | | |
|---|---|---|---|
| | Knife scoring | Y or N | Record presence of knife-scored grid on tile |
| | Comb marks | Y or N | Record presence of combing |
| | Finger marks | Y or N | Record presence of finger/thumb marks; describe in other notes section if necessary |
| | Signature mark | Y or N | Record presence of signature mark, describe number of fingers used and design in other boxes |
| | Stamp | Y or N | Record presence of stamp and letters visible |
| | Roller-die stamp | Y or N | Record presence of roller-die stamp and die type if known |
| | Design of mark | e.g. loop, cross, figure of 8 | Describe arrangement of combing, knife or finger marks or stamp design if possible |
| | Position of mark | e.g. top, side, flange etc. | Describe location of mark on sherd if it was complete component |
| | Animal print | Y or N | Presence of animal print; use other notes section to record paw/hoof print if identifiable |
| | Hobnail print | Y or N | Record presence of hobnail imprints from a boot |
| | Nail Hole | Y or N | Record presence of a nail hole |
| Other | Reuse | Y or N | Record any evidence for reuse, e.g. mortar over an ancient break |
| | Mortar | Xmm, S, T or N | Presence of mortar on sherd. Record depth in mm if very thick. S for substantial (i.e. >2mm thickness or covers 50% of sherd surface), T for traces (<2mm thickness or covers only small area of sherd). |
| | Concretions | Xmm, S, T or N | Presence of concretions on sherd. Record depth in mm if very thick. S for substantial (i.e. >2mm thickness or covers 50% of sherd surface), T for traces (<2mm thickness or covers only small area of sherd). |
| | Photographs | e.g. 01-CBM_20-08-20_0001_01 | Photograph code describes analysis session number and type, date of session, sherd or sample number then photograph number of that sherd. |
| | Other notes | | Use this to record any other thoughts or observations on the sherd or marks present |

# Appendix E: Fabric Scheme for the Roman Baths

During the pilot study and full analysis of the ceramic building materials from the Roman Baths, 18 different fabrics were identified, not counting very streaky (M) versions of certain fabrics. Fabrics 02, 09, 10 and 13 were abandoned, either because the types sherds from the pilot analysis could not be located during the full recording, or because these fabric did not appear sufficiently different to others to continue using. Descriptions for fabrics 01, 03, 04, 05, 06, 07, 08, 11, 12, 14, 15, 16, 17 and 18 are presented here. Massively streaky (M) fabrics are considered alongside their typical counterparts, e.g. 05 with 05M.

## Very Fine Fabrics

### Fabric 04

Fabric with macroscopically visible cream or white streaks, sometimes extending over large parts of sherd thickness (classified as 04M). Quartz of any size generally absent, though some sherds have common very fine quartz (c.0.15mm). Mica flecks occasional-common, and can be evenly distributed throughout the sherd body, concentrated in discrete inclusions, often in fine-grained red siltstone or iron oxide clasts as shown in figure E.1, or a mixture of both, as shown in figure E.2. Unsorted red iron oxides are occasional to common, and may be up to 6mm in length. Voids are occasional to common, and may be linear and irregular, tubular, or almost C-shaped, as shown in figure E.3.

Sherds of F04 are likely closely related to F07 (non-streaky equivalent) and F05 and F06 (fine quartz equivalents).

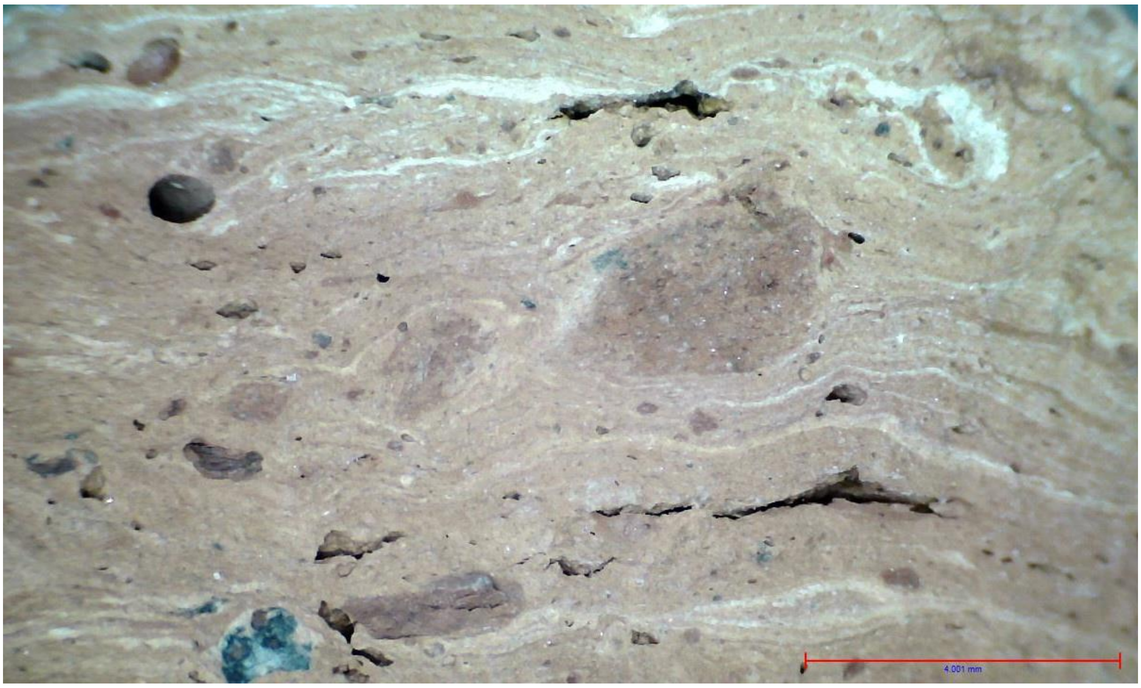

**Figure E.1: Photograph of sherd OTK 583, showing a typical example of fabric 04. Scale bar is 4mm long.**

**Figure E.2: Photograph of sherd OTK 565, showing a typical example of fabric 04. Scale bar is 4mm long.**

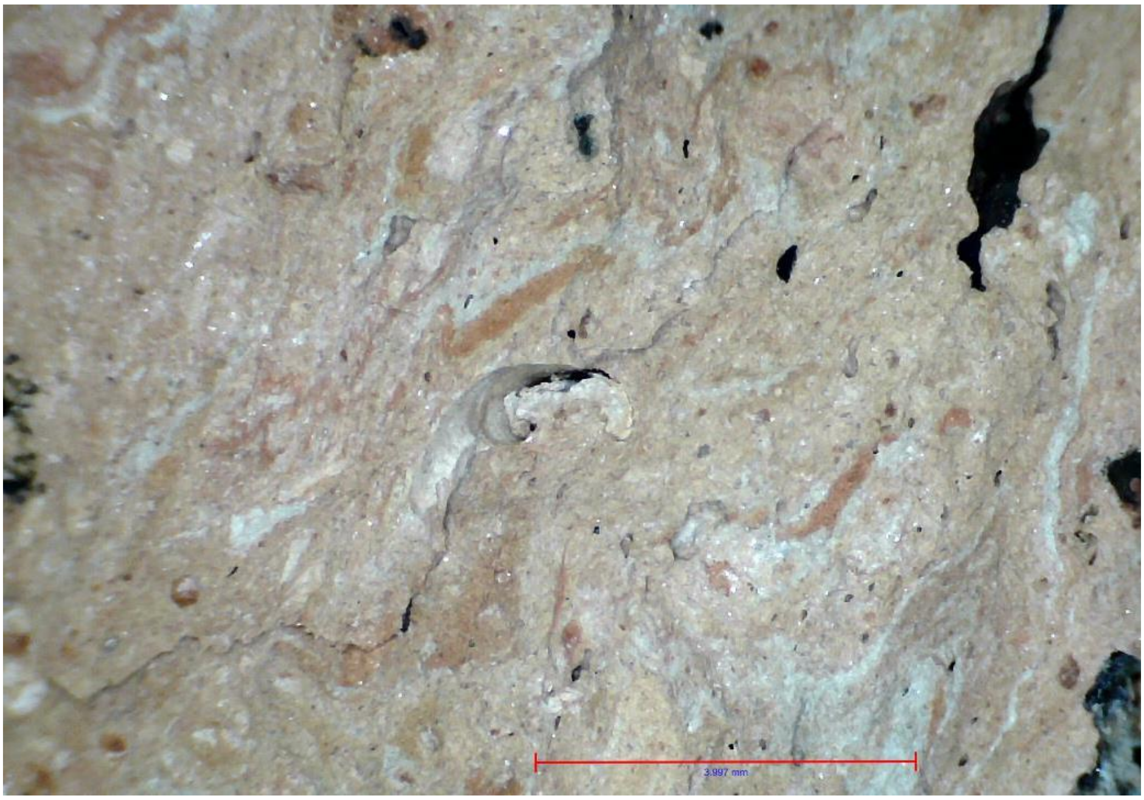


**Figure E.3: Photograph of sherd OTK 720, showing an example of fabric 04 with distinctive C-shape void. Scale bar is 4mm long.**

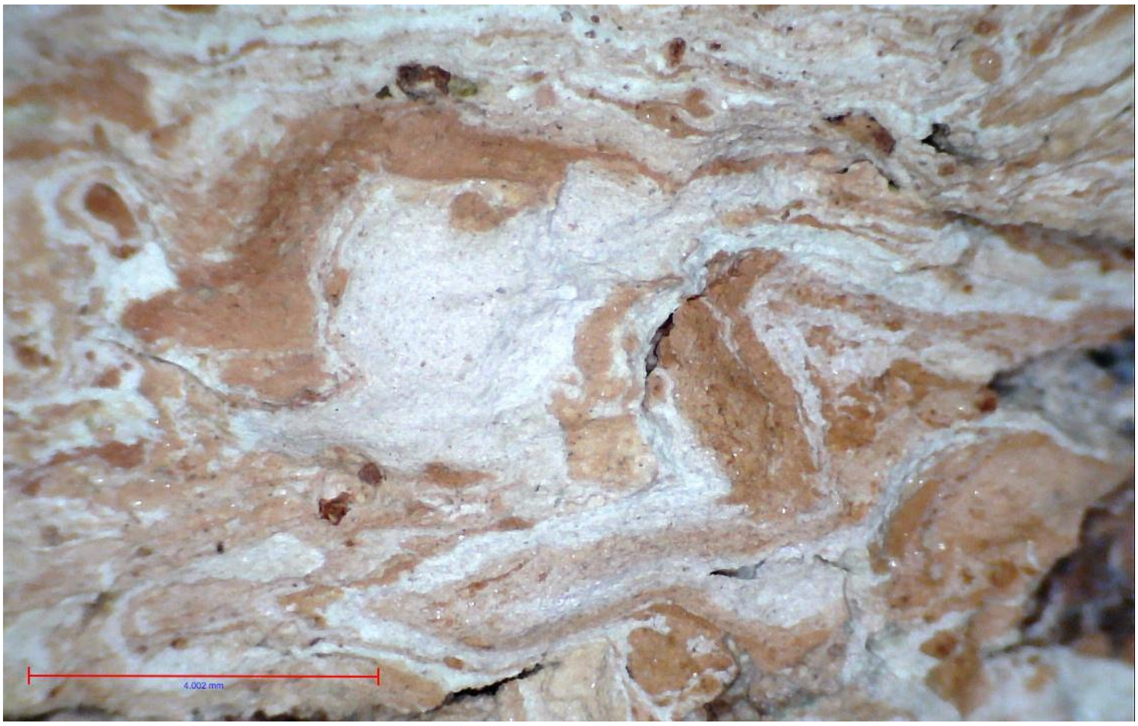


**Figure E.4: Photograph of sherd OTK 787, showing an example of massively streaky fabric 04M. Scale bar is 4mm long.**

## Fabric 07

Fabric 07 has either little quartz of any kind or occasional-common very fine quartz (c.0.15mm). Very rare large quartz (c.0.8-1mm) also present in some sherds. Mica occasional-common, and can be distributed evenly throughout the body of the sherd or concentrated in fine-grained diffuse clasts, see figure E.6, as with fabric 04. Voids occasional to common, sometimes with partial calcareous traces of shell or microfossils present, as in figure E.5. Unsorted iron oxides occasional to common, and can reach up to 5mm in size. Single, large, rounded fragments, up to 6mm in length, of what could be a white micritic limestone occur in a small number of sherds of this fabric (e.g. OTK 445).

F07 is likely closely related to F04 (streaky equivalent) and perhaps F03 (fine quartz equivalent).

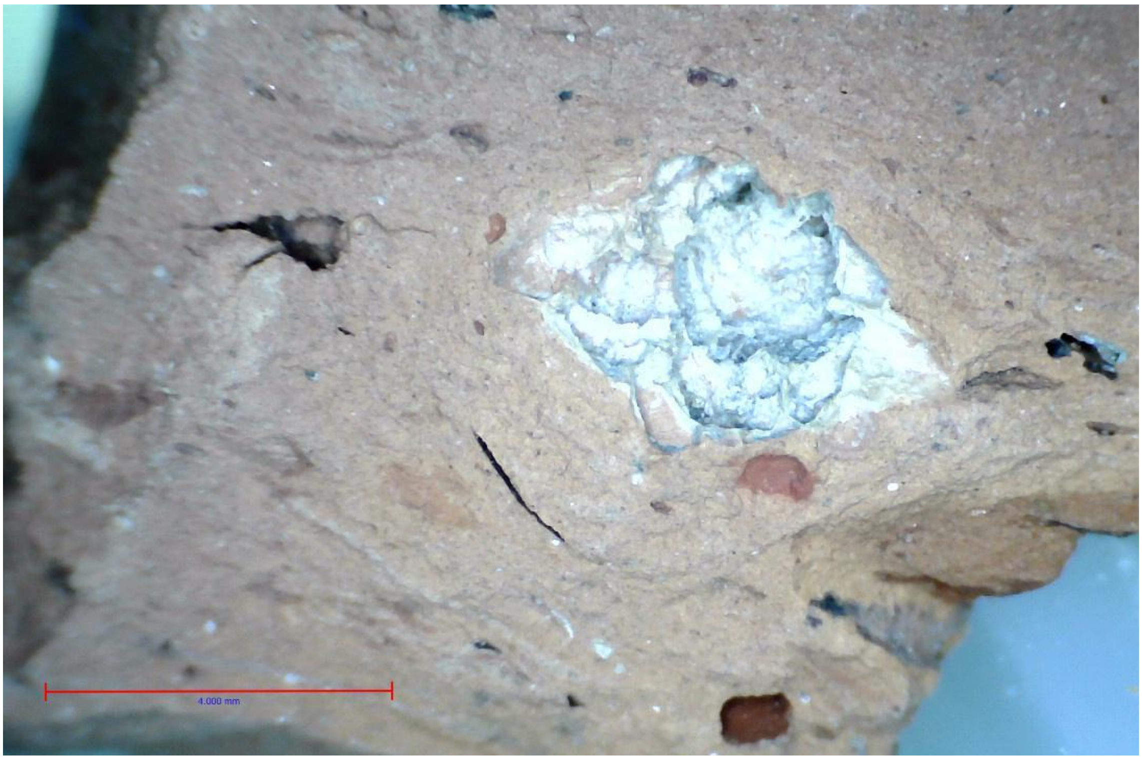

**Figure E.5: Photograph of sherd OTK 448, showing a typical example of fabric 07 with a large fossil void present. Scale bar is 4mm long.**

**Figure E.6: Photograph of sherd OTK 475, showing a typical example of fabric 07 with a fine-grained diffuse clast. Scale bar is 4mm long.**

**Figure E.7: Photograph of sherd OTK 874, showing an example of fabric 07. Scale bar is 4mm long.**

# Fine Fabrics

## Fabric 03

Fabric 03 had occasional to common generally well-sorted fine quartz (c.0.3mm), though sometimes tending to medium in size (i.e. 0.5mm). Rare large grains of quartz (0.8-1.0mm) were present in some sherds, see figure E.9. Voids occasional to common, and of various sizes and shapes. Occasional unsorted iron oxides, sometimes as large as 4mm. Mica sometimes present, but when it occurs it is not as frequent or evenly distributed as with many F04 and F07 sherds.

Perhaps related to F07 (very fine equivalent) and F05, F06 and F08 (fine equivalents).

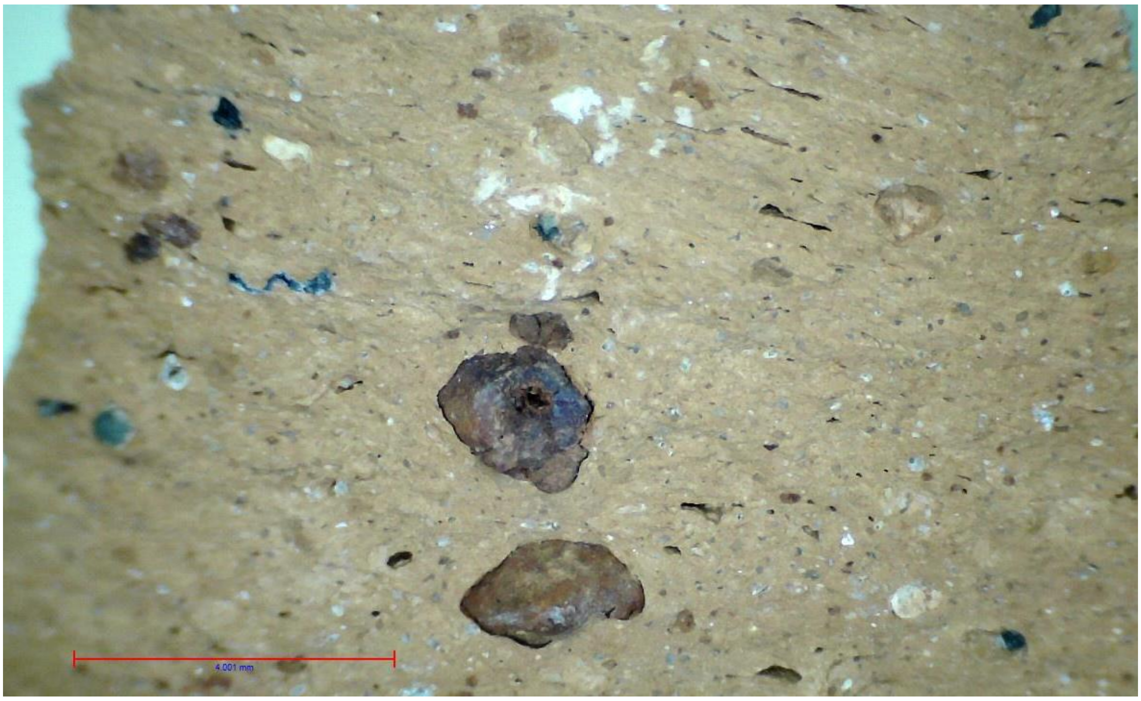

**Figure E.8: Photograph of sherd OTK 613, showing a typical example of fabric 03. Scale bar is 4mm long.**

**Figure E.9: Photograph of sherd OTK 566, showing an example of fabric 03. Scale bar is 4mm long.**

## Fabric 05

Fabric with macroscopically visible cream or white streaks, sometimes extending over large parts of sherd thickness (classified as 05M). Fine quartz (c. 0.3mm) occasional but present in discrete bands, see figures E.10 and E.11, perhaps the results of tempering or preservation of sedimentary structures. Certain sherds, particularly of F05M, may have rare medium (c.05mm) and large (c.0.8-1mm) quartz grains as well. Occasional unsorted voids and iron oxides present, though the latter is particularly common among F05M sherds, see figure E.12. Distinctive voids that occur in this fabric include roughly-hexagon shapes. Mica sometimes present, though rarely in the same concentrations as in certain F04 or F07 sherds.

Likely closely related to F04 (very fine equivalent) and F06, F08 and F15 (other fine streaky fabrics).

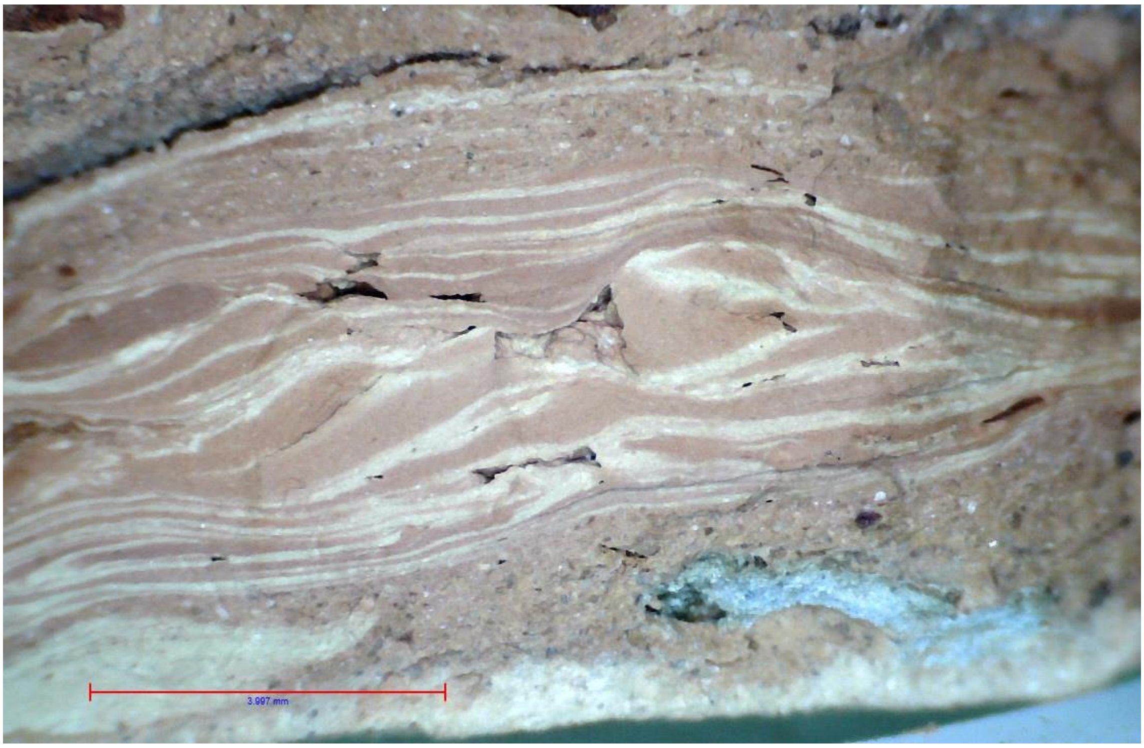

**Figure E.10: Photograph of sherd OTK 718, showing an extreme example of fabric 05. Scale bar is 4mm long.**

**Figure E.11: Photograph of sherd OTK 894, showing a typical example of fabric 05 with a band of sandy clay in the middle of the photo. Scale bar is 4mm long.**

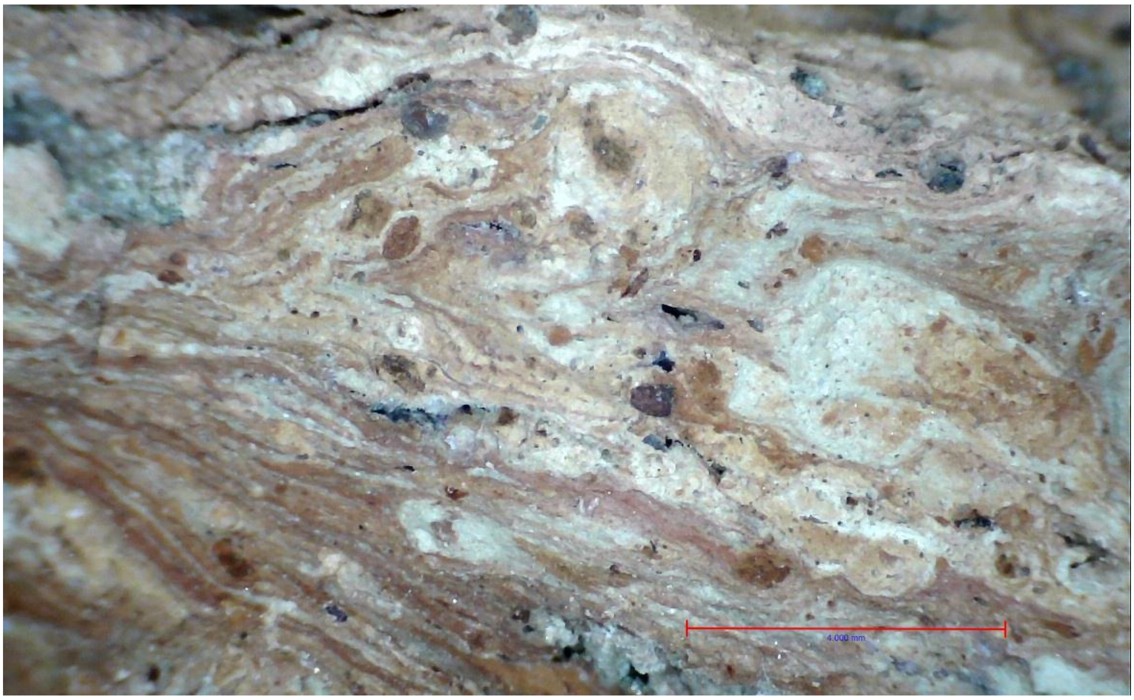

**Figure E.12: Photograph of sherd OTK 454, showing an example of fabric 05M. Scale bar is 4mm long.**

## Fabric 06

Fabric 06 has macroscopic cream or white streaks, sometimes extending over large parts of sherd thickness (classified as 06M). Fine quartz (c. 0.3mm) common and distributed evenly throughout sherd, though sometimes tending to medium (c.0.5mm) in size as well. Occasional unsorted iron oxides up to 5mm in size. Occasional unsorted voids, including rough hexagon shapes. Mica sometimes present and often distributed sparsely throughout the body of the sherd. However, distinct mica-rich siltstone inclusions do rarely occur, as observed in F04.

Likely closely related to F04 (very fine equivalent) and F05, F08, F15 (other fine streaky fabrics) and perhaps F12

**Figure E.13: Photograph of sherd OTK 790, showing a typical example of fabric 06. Scale bar is 4mm long.**

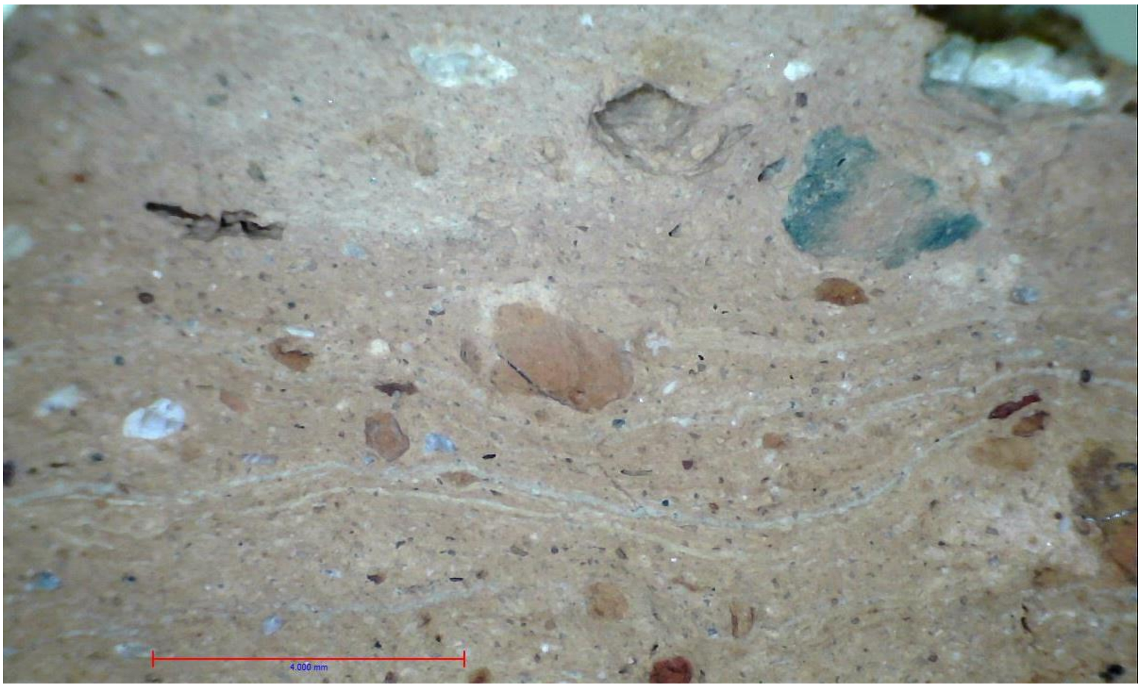

**Figure E.14: Photograph of sherd OTK 799, showing a typical example of fabric 06. Scale bar is 4mm long.**

**Figure E.15: Photograph of sherd OTK 842, showing an example of fabric 06 with a distinctive hexagon-shaped void. Scale bar is 4mm long.**

## Fabric 08

Fabric with cream or white streaks only visible under magnification. Common well-sorted fine quartz (c.0.3mm), though sometimes tending to medium in size (c.0.5mm). Occasional unsorted iron oxides, ranging up to 4mm in size. Occasional unsorted voids. Mica sometimes present.

Likely closely related to F03, F05 and F06 (fine equivalents).

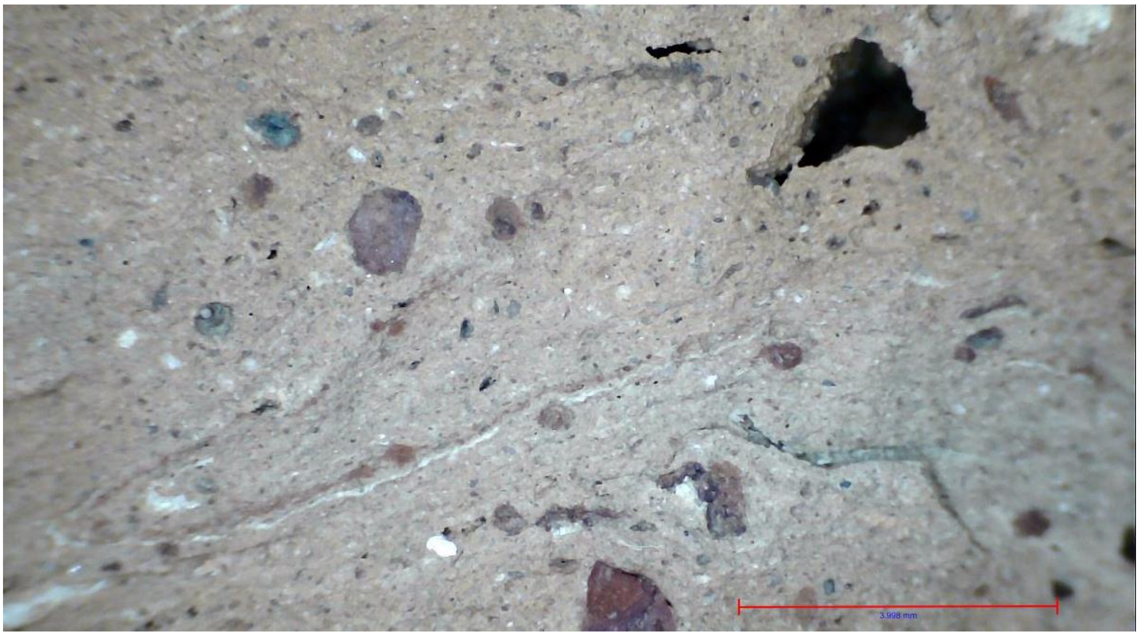

**Figure E.16: Photograph of sherd OTK 085, showing a typical example of fabric 08. Scale bar is 4mm long.**

**Figure E.17: Photograph of sherd OTK 421, showing a typical example of fabric 08. Scale bar is 4mm long.**

## Fabric 15

Fabric with macroscopic cream or white streaks, sometimes extending over large parts of sherd thickness (classified as 15M, e.g. figure E.19). Quartz common-abundant, well-sorted very fine to fine (i.e. 0.15-0.3mm) in size. Occasional unsorted iron oxides. Voids are unsorted in size but rare to occasional in frequency. Mica rarely present.

Likely closely related to F05 and F06 and perhaps to F17 and F18.

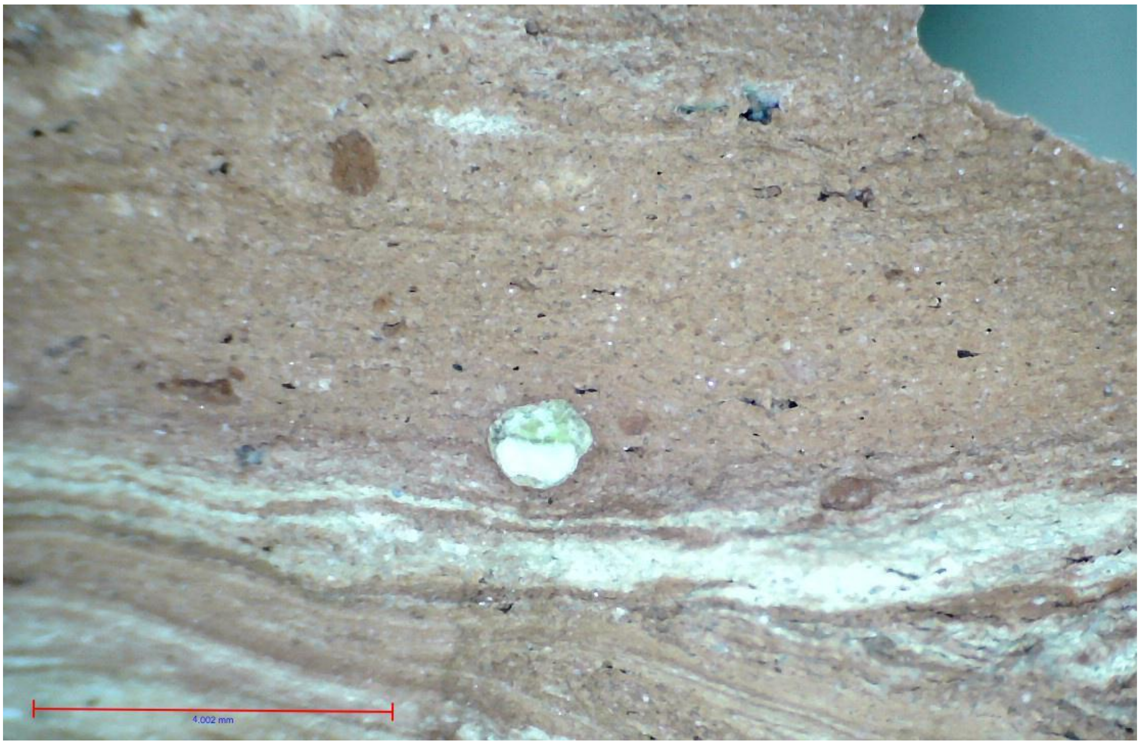


**Figure E.18: Photograph of sherd OTK 743, showing an example of fabric 15. Scale bar is 4mm long.**

**Figure E.19: Photograph of sherd OTK 721, showing an example of fabric 15. Scale bar is 4mm long.**

## Fabric 17

Fabric with typically common to abundant very fine to fine quartz (i.e. 0.15-0.3mm), though only occasional in some sherds (e.g. figure E.21). Medium (c.0.5mm) to large quartz (0.8-1mm) also rare-occasional, with most examples of this fabrics having at least a small proportion of such grains. Conspicuous well-sorted dark red or black iron oxides fine-medium (0.3-0.5mm) in size. Voids absent or rare. Mica rarely present.

Equivalent to F18 (streaky version) and perhaps related to F15 (fine) or F01 and F11 (coarse).

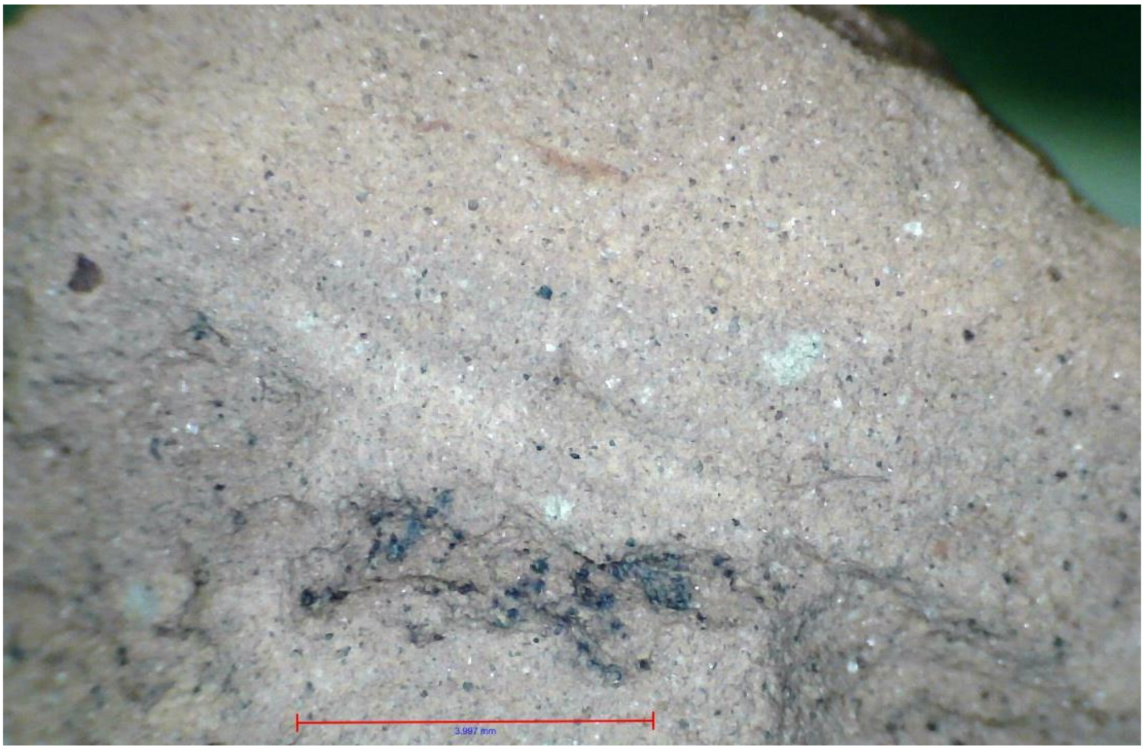

**Figure E.20: Photograph of sherd OTK 735, showing a typical example of fabric 17. Scale bar is 4mm long.**

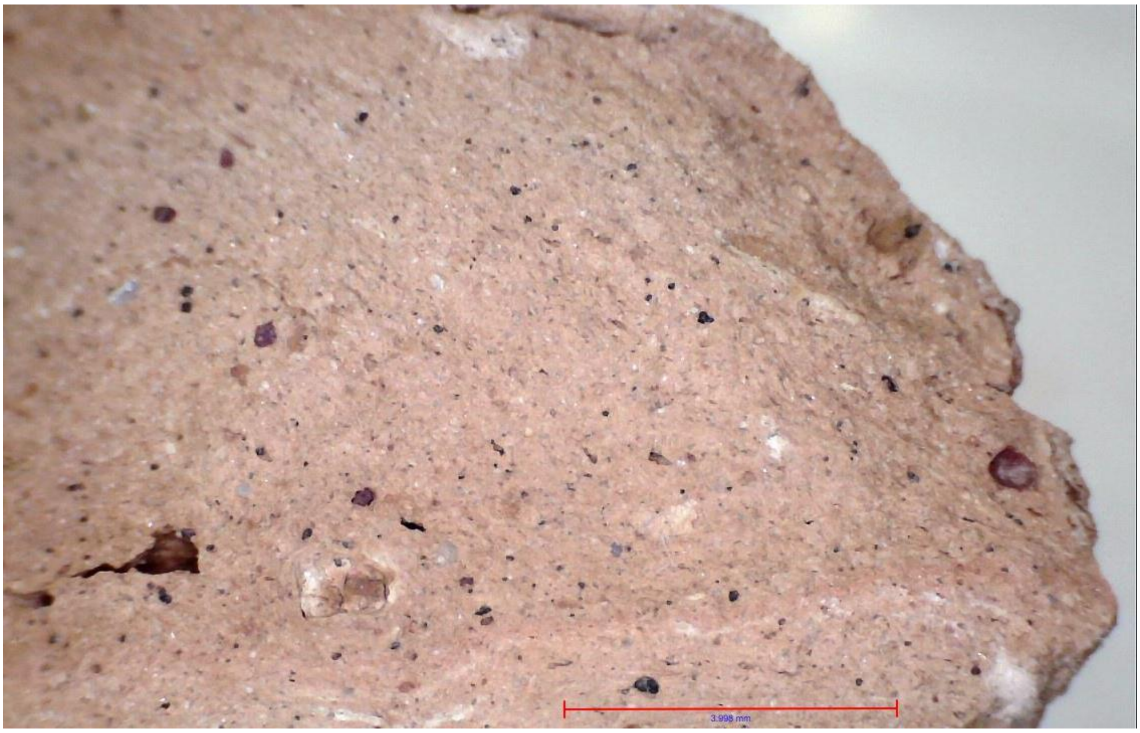

**Figure E.21: Photograph of sherd OTK 505, showing an example of fabric 17 with less quartz than many other F17 sherds. Scale bar is 4mm long.**

## Fabric 18

Fabric with occasional macroscopically visible cream or white streaks, though no examples of a massive equivalent recorded, unlike all other macroscopically streaky fabrics. Typically, common to abundant very fine to fine quartz (i.e. 0.15-0.3mm), though only occasional in some sherds. Medium (c.0.5mm) to large quartz (0.8-1mm) also rare-occasional, with most examples of this fabrics having at least a small proportion of these inclusions. Conspicuous well-sorted dark red or black iron oxides fine-medium (0.3-0.5mm) in size. Voids absent or rare. Mica rarely present.

F18 is equivalent to F17 (non-streaky version) and perhaps related to F15 (fine) or F01 and F11 (coarse).

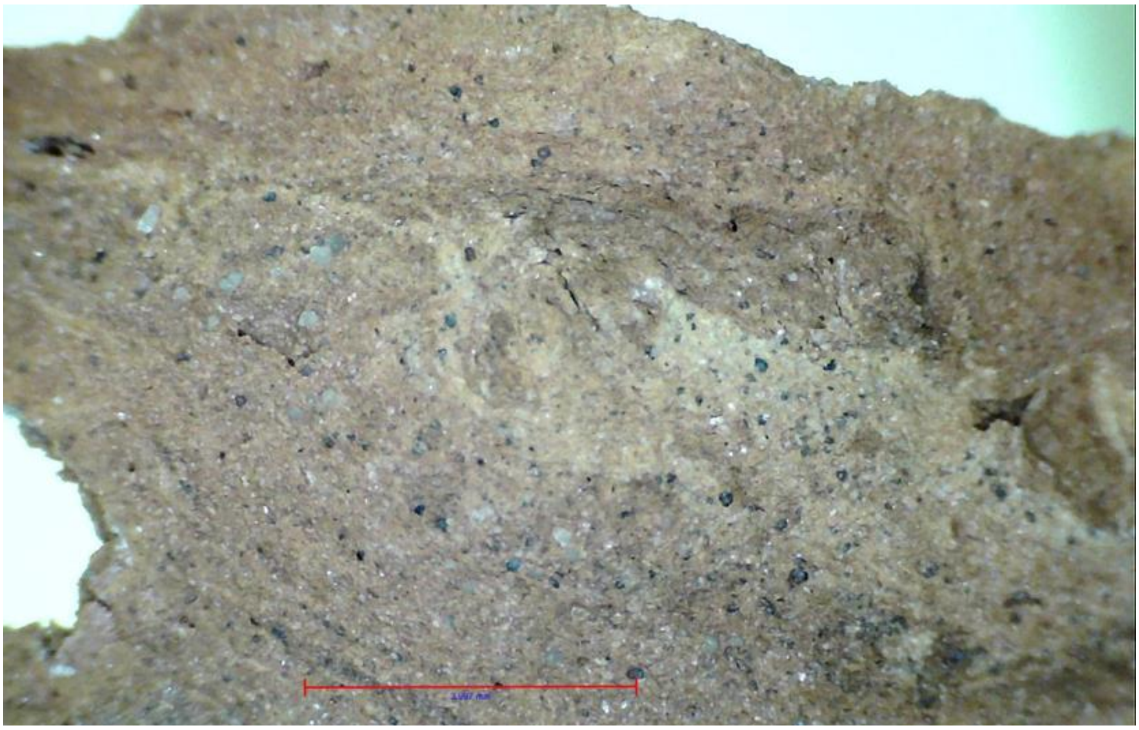

**Figure E.22: Photograph of sherd OTK 667, showing a typical example of fabric 18. Scale bar is 4mm long.**

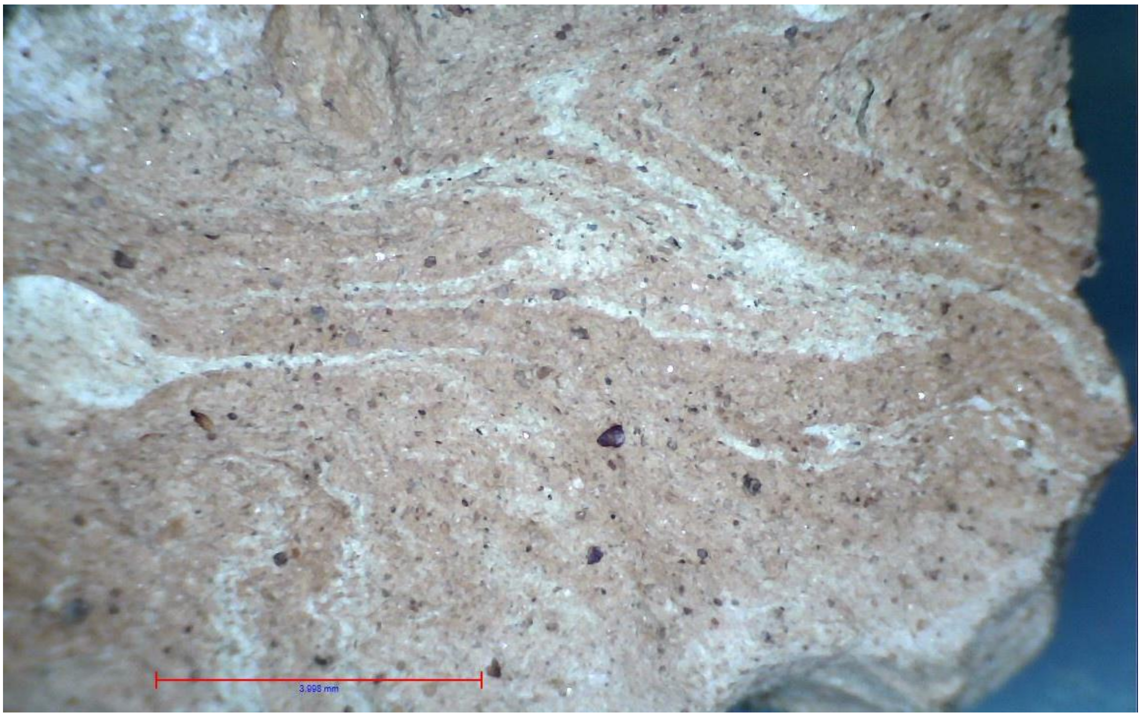


**Figure E.23: Photograph of sherd OTK 510, showing an example of fabric 18. Scale bar is 4mm long.**

# Coarse Fabrics

## Fabric 01

Fabric with common moderately-sorted quartz ranging from fine (0.3mm) to large (1mm), though medium (0.4-0.5mm) quartz predominant. Occasional poorly sorted or bimodal dark red or black iron oxides, ranging from fine to very large, even to 4mm, in size. Occasional unsorted voids, mica rarely present.

F01 is likely closely related to F11, its possible coarser equivalent, and perhaps F17 and F18 or F12.

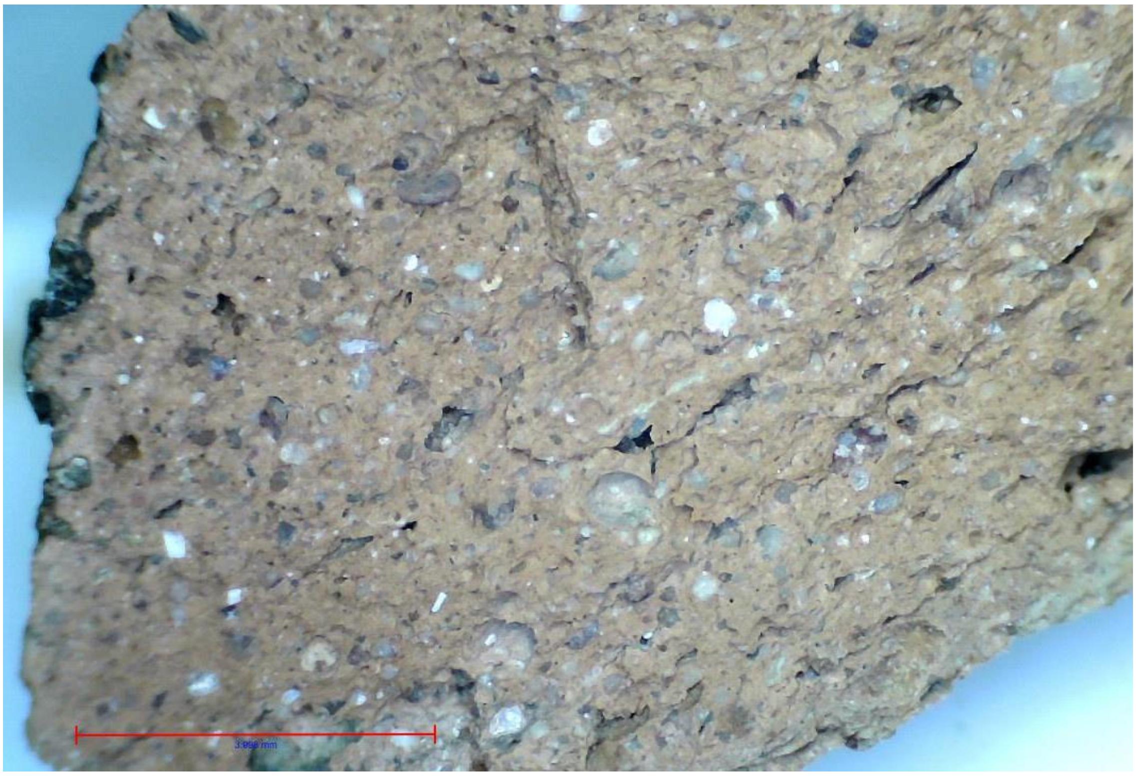

**Figure E.24: Photograph of sherd OTK 314, showing a typical example of fabric 01. Scale bar is 4mm long.**

## Fabric 11

Fabric 11 has common-abundant poorly-sorted quartz ranging from fine (0.3mm) to very large (c.1mm), though large to very large quartz is predominant. Occasional poorly sorted or bimodal dark red or black iron oxides are also present, ranging from small (c.04mm) to very large (c.1mm) in size. Mica rarely present. Voids are occasional, and include the star-profile void shown in figure E.25, and another sherd had a similar curling C shape, as shown in figure E.3 by a sherd of F05.

This fabric is likely closely related to F01 (a slightly finer equivalent) and F12 (streaky equivalent) and perhaps F17, F18 and F16. While the reddish-brown colour of the offcut in figure E.25 is typical of this fabric, a number of sherds of F11 occur in the typically pale colours of fabric 16, though lacking the macroscopic white streaks of that fabric, see figure E.26.


**Figure E.25: Photograph of sherd OTK 579, showing a typical example of fabric 11. Scale bar is 4mm long.**

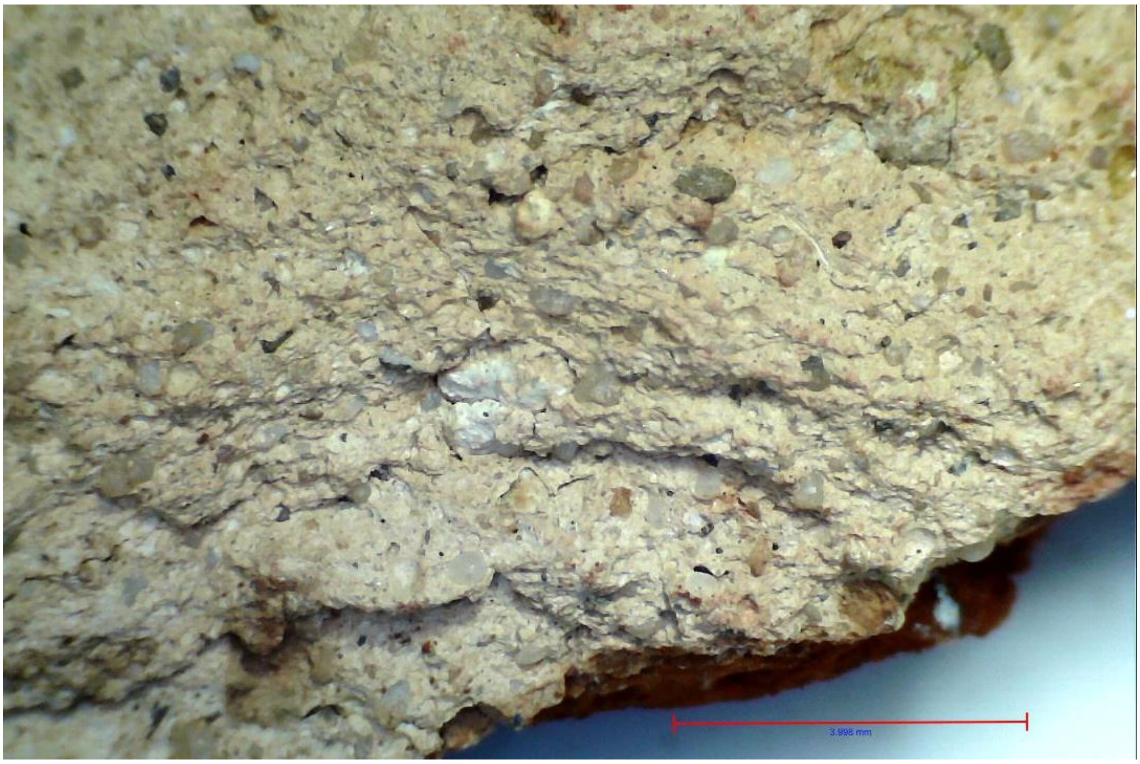


**Figure E.26: Photograph of sherd OTK 378, showing an unusual pale example of fabric 11. Scale bar is 4mm long.**

## Fabric 12

Fabric 12 has macroscopic cream or white streaks, sometimes extending over large parts of sherd thicknesses (classified as 12M). Quartz is occasional-common and poorly sorted, ranging in size from fine (0.3mm) to very large (>1mm) in size, though predominantly medium or large (i.e. 0.5-1mm). Bands of darker or more iron-rich sediment with denser quartz inclusion concentrations are visible in certain sherds, for example figure E.28, perhaps the result of tempering or the preservation of sedimentary structures. Poorly-sorted iron oxides from medium to very large (c.0.5-1mm or more) are occasional to common. Voids are occasionally present, and distinctive hexagon-shaped voids have been noted in certain sherds, in common with fabrics 05 and 06. Mica is rarely present.

F12 is likely closely related to F06 (fine version) and F01 and F11 (non-streaky equivalents) and perhaps F16

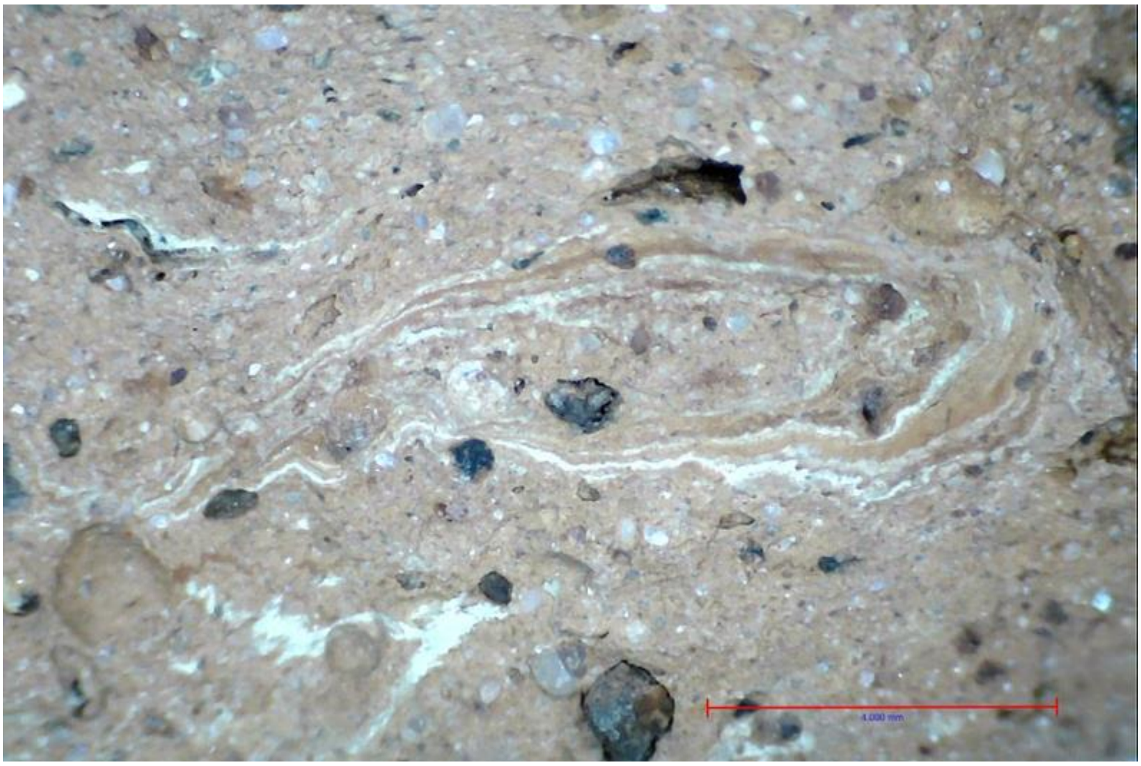

**Figure E.27: Photograph of sherd OTK 395, showing a typical example of fabric 12. Scale bar is 4mm long.**

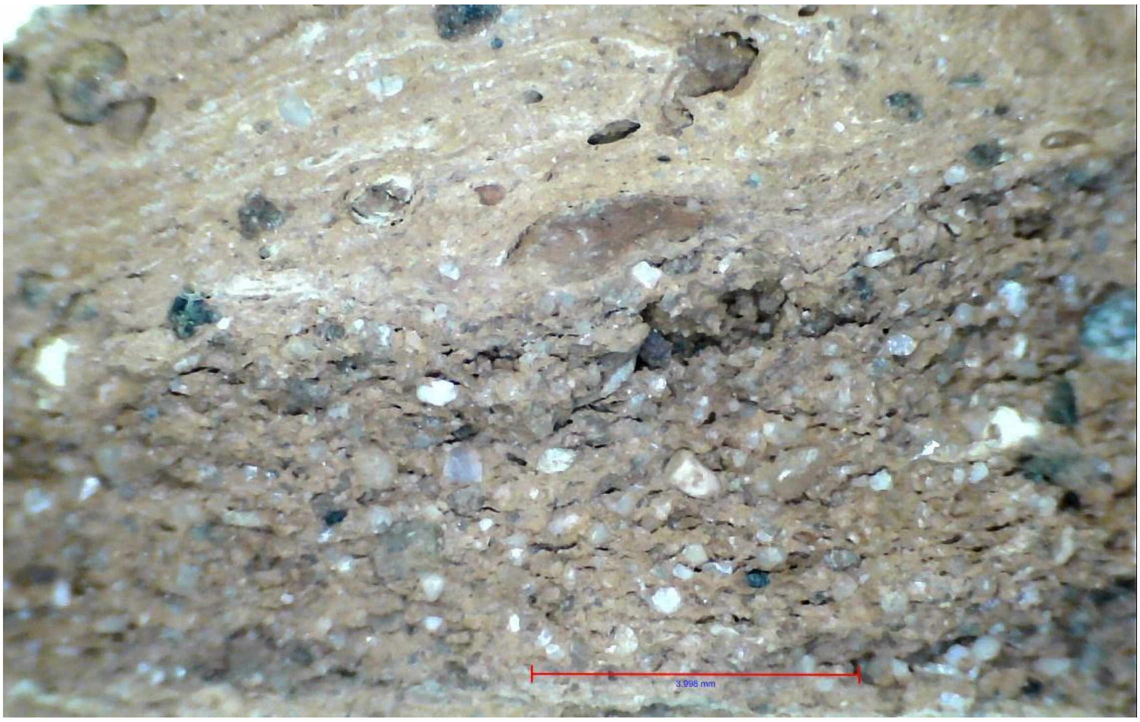

**Figure E.28: Photograph of sherd OTK 538, showing an example of fabric 12 with an intrusive band of quartz-rich clay. Scale bar is 4mm long.**

## Fabric 14

Fabric 14 has occasional poorly-sorted quartz, ranging from very fine (c.0.15mm) to large (c.1mm) in size, though the larger fraction is the most conspicuous. On some sherds, see figure E.30, these quartz fractions almost appear bimodal, with a well-sorted large component and a uniform background range of very fine material, though whether the result of natural processes or deliberate tempering is uncertain. Occasional poorly sorted or bimodal dark red or black iron oxides are also present, ranging from small (c.0.4mm) to very large in size. Occasional-common voids, often up to several millimetres long, see figure E.29. Mica is sometimes present, occasionally concentrated in discrete red-brown iron oxide or siltstone clasts also seen in fabrics 04 and 07. A small number of sherds have also included large rounded white micritic limestone fragments, as seen in fabric 07 as well.

Fabric 14 may be closely related to F07, and perhaps to F01 and F11.

**Figure E.29: Photograph of sherd OTK 772, showing a typical example of fabric 14. Scale bar is 4mm long.**

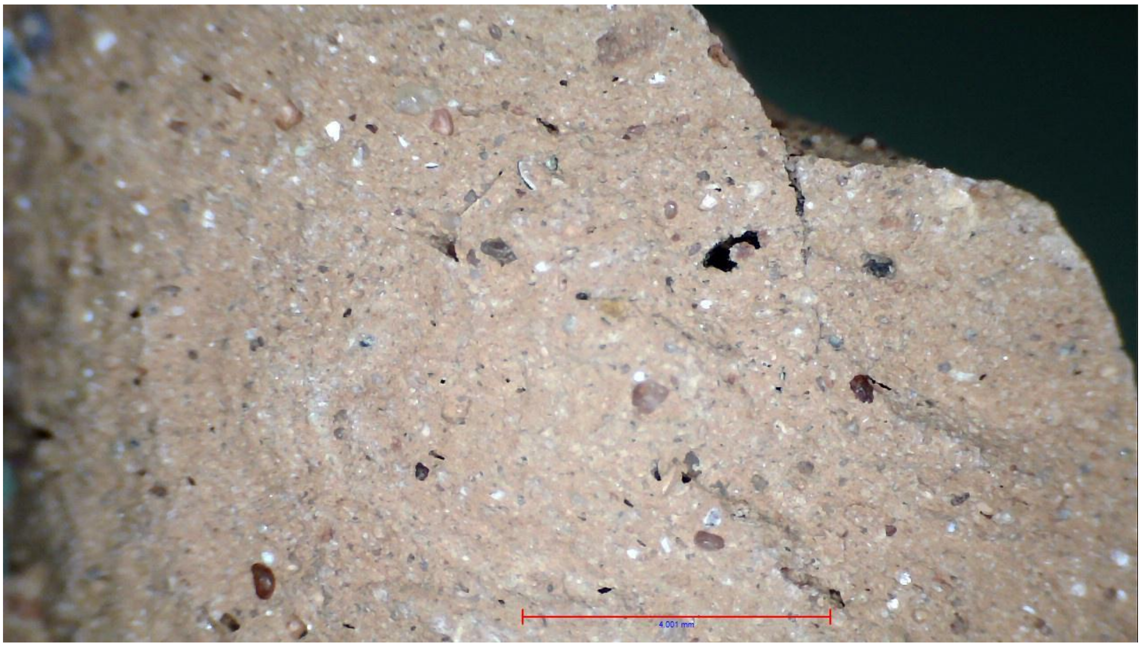

**Figure E.30: Photograph of sherd OTK 849, showing an example of fabric 14. Scale bar is 4mm long.**

## Fabric 16

This fabric was initially differentiated on the basis of its distinctive pale yellow-brown colour and occurrence in HV05 hollow voussoir tiles, suggesting a discrete production batch. However, as analysis continued it became clear that this was more likely a fluke of firing conditions, with rare sherds of other fabrics occurring in the same colour, and a small number of sherds exhibiting an oxidation gradient between the typical red or orange colours of other fabrics and that of F16. This fabric is therefore very similar to F12, though perhaps fired in non-typical conditions.

F16 has macroscopic cream or white streaks, sometimes extending over large parts of sherd thicknesses (classified as 16M). Quartz is common but poorly-sorted, ranging from fine (0.3mm) to very large (>1mm) in size, though predominantly medium or large. Unsorted dark brown or black iron oxides are occasionally present, from medium to very large (i.e. 0.5-1mm) in size. Mica is absent. Occasional large or very large voids are present, though presenting no distinctive profiles matching the other fabrics.

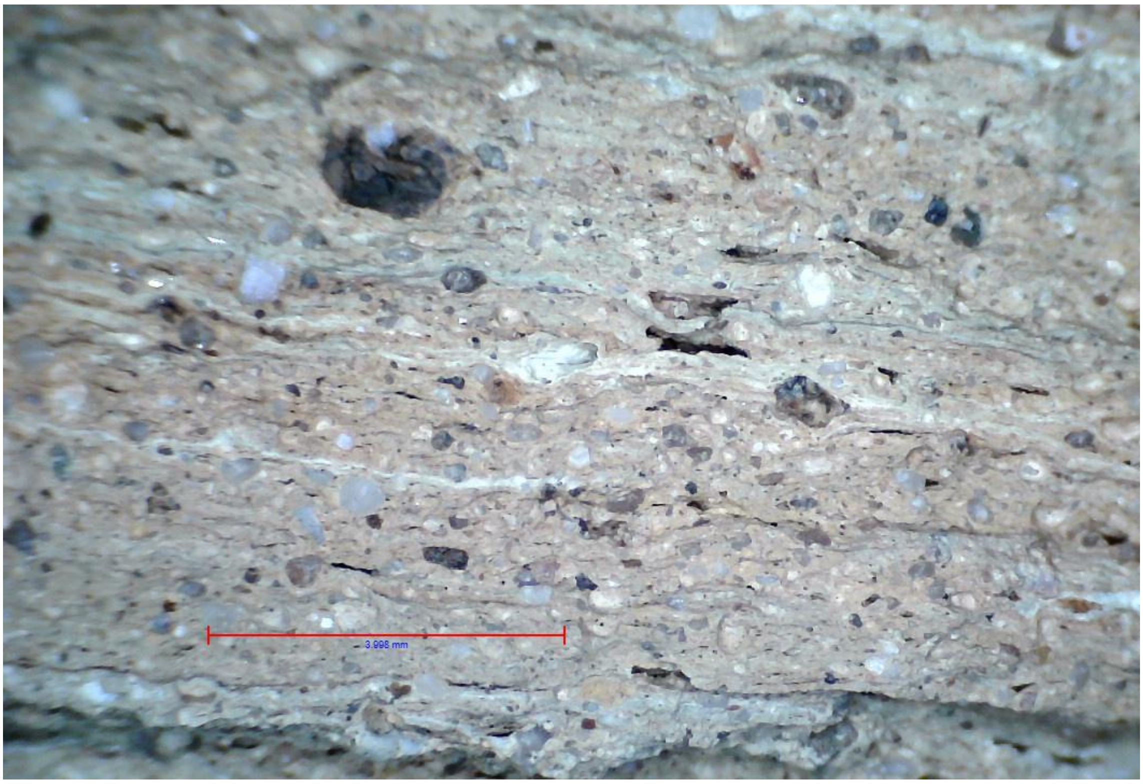

**Figure E.31: Photograph of sherd OTK 513, showing a typical example of fabric 16. Scale bar is 4mm long.**

# Appendix F: X-ray Fluorescence Sample Thickness

The minimum thickness of offcuts included in this analysis was carefully considered to ensure that all samples could be considered ‘infinitely thick’ for the purposes of X-ray absorption. This is simply the depth at which 99% of the X-ray fluorescence from the sample originates and beyond which the emissions are almost totally absorbed by the matrix (Potts et al. 1997: 32) and thus do not reach the detector. It was important that all samples analysed could be considered infinite in thickness for all elements measured as this could otherwise impact the accuracy of the results generated. In order to calculate the minimum depth of offcuts required to achieve infinite thickness the density of the ceramics was approximated using the density of silicon dioxide (following Caesaereo et al. 2008: 208), which is 2.648 g/cm3 (Haynes 2014: 4-88). The maximum depth of penetration for X-ray energies from 1-50 keV was then calculated using Potts et al.’s (1997: 31-32) rearranged equation for Beer’s law, applying mass attenuation coefficients for a SiO2 matrix provided by NIST (2004). The results for energies from 1-35 keV are plotted in figure F.1.

A range of elements analysed for in Mining (Cu/Zn) mode and consistently present above limits of detection in the CBM offcuts included in the trial analyses were then identified. These included Al, Si, K, Ca, Ti, V, Cr, Mn, Fe, Zn, Rb, Sr, Zr, Nb, Ba, Pb and Bi.  While the instrument used in this study can excite primary emissions up to 50 keV (Thermo Fisher Scientific 2021), any element with Ka emissions over this limit has to be measured solely through the less powerful La emissions (Gallhofer and Lottermoser 2018: 321), which here includes Pb and Bi. The maximum Ka or La emission energies for each of these elements was taken from Kortright and Thompson (2009: 1.9-1.13) and are shown in table F.1.

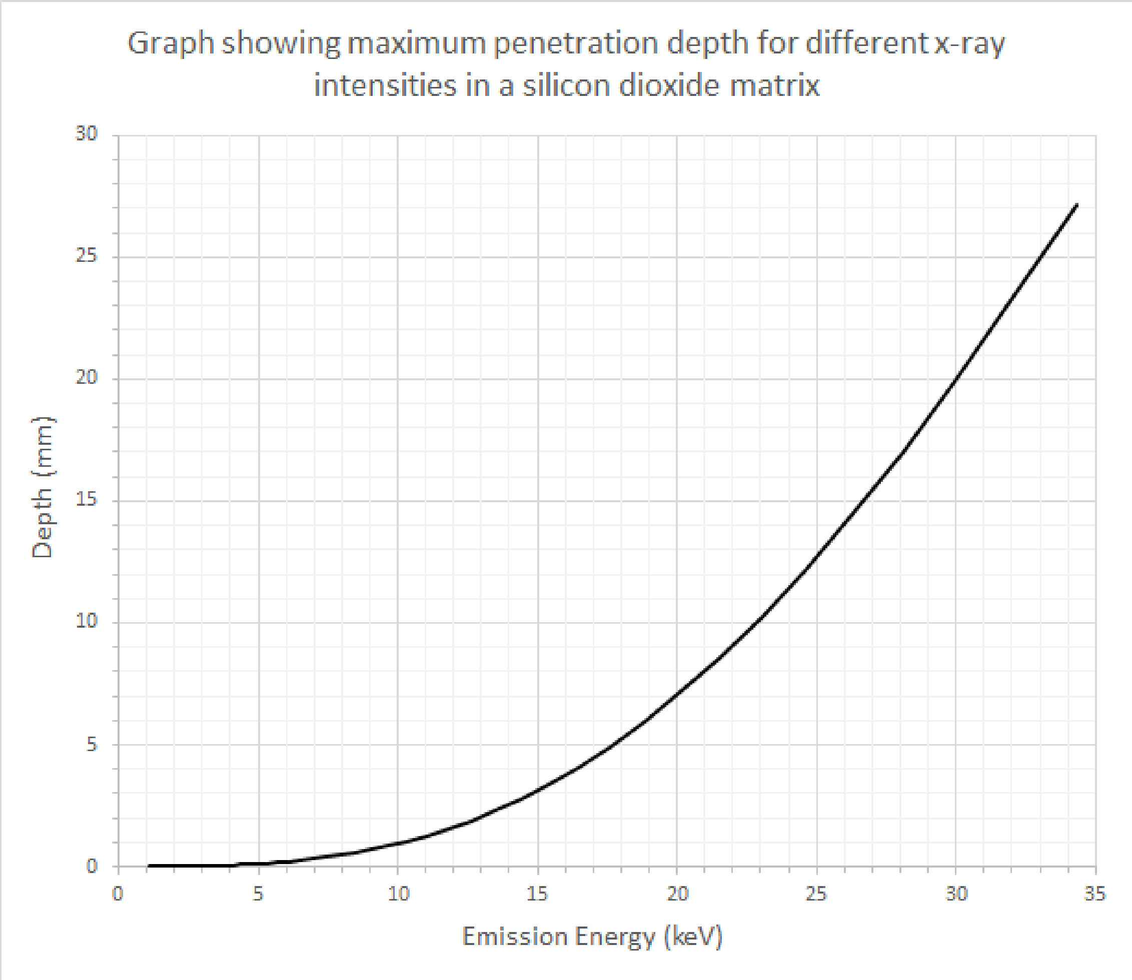


**Figure F.1: Graph showing the maximum penetration depth calculated for different X-ray emission energy intensities in a silicon dioxide matrix, used to approximate a ceramic matrix.**

By cross-referencing table F.1 with figure F.1 it is possible to estimate the maximum penetration depth of emissions for each element included in analyses. The maximum depth of all the elements considered is approximately 23mm for the 32.194 keV Ka emissions of Barium. It was not practical to restrict sample sizes to meet this thickness, so Ba measurements were therefore excluded from analysis. The next highest emission was the Ka line of Nb at 16.615 keV. This was calculated to have a penetration depth of roughly 4mm in a silicate matrix. As all other elemental emissions listed are less powerful, with consequently lower penetration depths, the minimum thickness of offcuts that could be included was therefore 4mm. A minimum thickness of 8mm was selected to ensure that infinite thickness was likely to be attained even if some sherds or fabrics had significantly lower densities than anticipated. By analysing on the inner surface of the fresh break, it also provided greater distance from exterior surface areas likely to have become depleted or enriched in certain elements as a result of post-depositional processes (e.g. Degryse and Braekmans 2014: 194), though perhaps applicable to the inner surface of the offcuts as well. While a greater minimum thickness could have been adopted for increased security of results, this was not implemented as it would have disqualified more offcuts from analysis, substantially impacting the total sample size.

**Table F.1: Table showing each element consistently present above limits of detection in the analysis of the CBM and the highest emission energy for that element under 50 keV (After Kortright and Thompson 2009: 1.9-1.13).**

| Element | Emission type | Energy (keV) |
|---|---|---|
| Al | Ka | 1.487 |
| Si | Ka | 1.740 |
| K | Ka | 3.314 |
| Ca | Ka | 3.692 |
| Ti | Ka | 4.511 |
| V | Ka | 4.952 |
| Cr | Ka | 5.415 |
| Mn | Ka | 5.899 |
| Fe | Ka | 6.404 |
| Zn | Ka | 8.639 |
| Rb | Ka | 13.395 |
| Sr | Ka | 14.165 |
| Zr | Ka | 15.775 |
| Nb | Ka | 16.615 |
| Ba | Ka | 32.194 |
| Pb | La | 10.552 |
| Bi | La | 10.839 |

# Appendix G: Determination of Beam Times and Repeat Measurements

The maximum total time of analysis per sample was set at 10 minutes in order to ensure that the pXRF analyses of over 500 samples could be completed within the timescale of this project. Three different combinations of beam times and repeat analyses that fulfilled this criterion were then trialled. This included a single long analysis of 600s, two medium repeat measurements each of 300s and three short repeat analyses each of 150s per sample (see table G.1). In order to determine the optimum method, these different measurement times were tested on the TILL-4 certified reference material and on five CBM offcuts chosen from different fabric groups.

**Table G.1: Table showing each beam time evaluated and the number of repeat measurements for each method of analysis considered.**

| Length | Analyses per sample | Main Beam (s) | Low Beam (s) | High Beam (s) | Light Beam (s) | Time per reading (s) |
|---|---|---|---|---|---|---|
| Short | 3 | 30 | 30 | 30 | 60 | 150 |
| Medium | 2 | 60 | 60 | 60 | 120 | 300 |
| Long | 1 | 120 | 120 | 120 | 240 | 600 |

The process used to compare each beam time has been adapted from Potts et al. (1997), who employed their method upon a range of geological materials to determine the extent of compositional variation within single rocks. They (Potts et al. 1997) completed multiple analyses on different non-overlapping points of a single sample to find a population mean value, a standard deviation for each element and thereby a standard deviation of the mean value for each element. From this, the smallest number of analyses required to achieve mean values within certain degrees of accuracy of the mean, for example 2%, 5%, 10% or 20%, could then be calculated using the formula in figure G.1. This method was adapted here for the analysis of single points of a standard or offcut, rather than multiple discrete locations, in order to identify which combination of repeat analyses and beam times considered can achieve the most precise results in the analyses of offcut samples.

$$n = \left( \frac{100 \cdot s}{R \cdot \bar{x}} \right)^2$$

**Figure G.1: Equation used to calculate the minimum number of analyses (n) required to achieve a mean value within R percent of the true sample mean ($\bar{x}$). After Potts et al. (1997: equation 6).**

Due to time constraints, each sample was analysed five times at each beam duration using Mining (Cu/Zn) mode, rather than ten times as practised by Potts et al. (1997: 35). Population values were then calculated for each set of five analyses at each different beam time. From these statistics, and using the formula in figure G.1, the smallest error from the mean given the number of different analyses proposed for each beam time (i.e. one, two or three) was then determined and is shown in table G.2.

**Table G.2: Smallest error from the sample mean (rounded up to 2%, 5% or 10%) predicted for a range of elements from the average of three short measurements, two medium measurements and one long measurement on the TILL-4 certified reference material and on CBM offcuts of 5 different fabrics from the Roman Baths.**

| Sample | Beam Time | Al | Si | K | Ca | Ti | Cr | Fe | Zn | Rb | Sr | Zr | Nb | Ba | Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TILL4 | Short | 2 | 2 | 2 | 2 | 2 | 10 | 2 | 5 | 2 | 2 | 2 | 5 | 2 | 5 |
| TILL4 | Medium | 2 | 2 | 2 | 2 | 2 | 5 | 2 | 5 | 2 | 2 | 2 | 5 | 2 | 2 |
| TILL4 | Long | 2 | 2 | 2 | 2 | 2 | 5 | 2 | 2 | 2 | 2 | 2 | 5 | 2 | 5 |
| OTK 514 | Short | 2 | 2 | 2 | 5 | 2 | 5 | 2 | 5 | 2 | 2 | 2 | 2 | 2 | 10 |
| OTK 514 | Medium | 2 | 2 | 2 | 2 | 2 | 5 | 2 | 5 | 2 | 2 | 2 | 5 | 2 | 5 |
| OTK 514 | Long | 2 | 2 | 2 | 2 | 2 | 5 | 2 | 5 | 2 | 2 | 2 | 2 | 5 | 5 |
| OTK 517 | Short | 2 | 2 | 2 | 2 | 2 | 10 | 2 | 5 | 2 | 2 | 2 | 5 | 2 | 5 |
| OTK 517 | Medium | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 5 | 2 | 2 | 2 | 2 | 2 | 5 |
| OTK 517 | Long | 2 | 2 | 2 | 2 | 2 | 5 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| OTK 536 | Short | 2 | 2 | 2 | 2 | 2 | 5 | 2 | 5 | 2 | 2 | 2 | 5 | 5 | 5 |
| OTK 536 | Medium | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 5 | 2 | 5 |
| OTK 536 | Long | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 5 | 2 | 2 | 2 | 2 | 2 | 5 |
| OTK 538 | Short | 2 | 2 | 2 | 2 | 2 | 5 | 2 | 5 | 2 | 2 | 2 | 5 | 2 | 10 |
| OTK 538 | Medium | 2 | 2 | 2 | 2 | 2 | 5 | 2 | 5 | 2 | 2 | 2 | 5 | 2 | 10 |
| OTK 538 | Long | 2 | 2 | 2 | 2 | 2 | 5 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 5 |
| OTK 549 | Short | 2 | 2 | 2 | 2 | 2 | 10 | 2 | 5 | 2 | 2 | 2 | 2 | 5 | 10 |
| OTK 549 | Medium | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 5 | 2 | 2 | 2 | 2 | 2 | 5 |
| OTK 549 | Long | 2 | 2 | 2 | 2 | 2 | 10 | 2 | 5 | 2 | 2 | 2 | 5 | 5 | 5 |

All three combinations of different beam times and numbers of repeat measurements are likely to produce results of closely comparable precision for both the standard and the ceramic building material offcuts analysed, as demonstrated in table G.2. This result is closely paralleled in calculations of accuracy for each set of beam times upon the TILL-4 CRM, for there is little difference in the mean values of each element calculated for each set of 5 analyses. While the duplicate medium beam time analysis perhaps performed slightly better in terms of precision than the long or short analyses for several elements from different offcuts, for example Cr in offcut OTK 549 in table G.2, the overall difference is negligible. Given these findings, the 150s beam time with three repeat measurements per sample was opted for. This was because it showed precision and accuracy equal to the other alternatives. Furthermore, the completion of three analyses per sample enabled better identification and mitigation against isolated anomalous readings that sometimes occur, which would be more challenging with only one or two longer measurements per sample.

# Appendix H: Evaluation of the Precision and Accuracy of Portable X-ray Fluorescence

Instrumental precision was assessed through regular measurement of the TILL-4 certified reference material and by calculation of the standard deviation in element readings on each CBM offcut throughout analyses. Both showed good precision for a range of major and trace elements. Measurements of the standard produced relative standard deviations of less than 2.5% for a range of elements, see table H.1, with values still less than 10% for trace elements such as Nb, V and Mn. The sets of three readings on each CBM offcut had a maximum relative standard deviation recorded across all samples being less than 15% for many elements.

**Table H.1: Table showing the mean and maximum relative standard deviations (RSD) calculated across all sets of three CBM readings and the relative standard deviation for 235 measurements of the TILL-4 certified reference material.**

| Sample | Statistic | Si | Fe | K | Zr | Ti | Al | Sr | Ca | Rb | Nb | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CBM | Mean RSD (%) | 0.35 | 0.41 | 0.76 | 0.86 | 0.86 | 1.1 | 1.4 | 1.6 | 1.6 | 4.3 | 6.3 |
| CBM | Max. RSD (%) | 6.1 | 4.9 | 6.6 | 7.8 | 4.5 | 12 | 12 | 25 | 17 | 13 | 18 |
| TILL-4 | RSD (%) | 2.0 | 0.51 | 0.88 | 2.0 | 1.5 | 4.1 | 1.6 | 2.4 | 1.4 | 6.0 | 8.4 |

Instrumental accuracy was acceptable for a range of elements. This was assessed through measurement of the TILL-4 certified reference material. A range of major and trace element measurements deviated from the certified value by less than 6% on average, including Si to Sr in table H.2. Ca values deviated from the certified value by 10% on average. Several trace elements were more inaccurate, for example Nb and Cr, in part due to low concentrations in the standard.

**Table H.2: Table showing the certified element values and the mean values of 235 measurements of the TILL-4 standard. The relative standard deviation was calculated by substituting the certified values in place of the mean values.**

| Statistic | Si | Fe | Ti | K | Al | Rb | Zr | Sr | Ca | Nb | Cr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CRM value | 303834 | 39700 | 4840 | 26980 | 76214 | 161 | 385 | 109 | 8934 | 15 | 53 |
| Mean value | 302522 | 40566 | 4645 | 25833 | 74733 | 154 | 367 | 115 | 8065 | 18 | 67 |
| RSD (%) | 2.0 | 2.2 | 4.3 | 4.3 | 4.5 | 4.6 | 5.1 | 5.4 | 10 | 20 | 29 |

The range of elements included in statistical analyses were restricted to those that consistently produced precise and relatively accurate results above the instrumental limits of detection, see tables H.1-H.3. The elements selected were therefore Si, Fe, Ti, K, Al, Rb, Zr, Sr, Ca, and Nb. While the potential for post-depositional alteration of Ca and Fe in archaeological ceramics has previously been noted (e.g. Darvill 1979: 321, Degryse and Braekmans 2014: 194), the results for these two elements were included in statistical analyses as they were precisely and accurately measured and because partially burnt-out calcareous voids and iron oxide inclusions were conspicuous features of several fabric groups. The inclusion of these two elements therefore allowed more extensive examination of relationships between microscopically-identified fabrics and chemical groupings.

**Table H.3: Table showing the proportion of readings above limits of detection for different elements in measurements of the CBM offcuts.**

| **Proportion of readings above limits of detection:** | **Elements:** |
|---|---|
| 100% | Nb, Zr, Sr, Rb, Fe, Ca, K, Al, Si, Ti, V, Cr, Ba, Zn, P, S |
| 95-99% | Pb, Mg |
| 80-90% | As |
| 40-60% | Mn, Bi |
| 20-30% | Cu, Cl |
| 1-10% | Ni |
| <1% | Mo, Au, W |

# Appendix I: Additional Tables of Results

**Table I.1: Table listing the range of dimensions and number of examples found for each hollow voussoir type identified from the Roman Baths assemblages.**

| Type | Min. width (mm) | Max. width (mm) | Height (mm) | Depth (mm) | Thickness (mm) | No. of Examples |
|---|---|---|---|---|---|---|
| HV01 | 175-199 | 195-226 | 297-323 | 110-132 | 14-23 | 68 |
| HV02 | 130-140 | 148-156 | 400 | 120-132 | 17-22 | 23 |
| HV03 | 198 | 230-237 | 318 | 172 | 23-32 | 2 |
| HV04 | 170-183 | 190-197 | 300-318 | 140 | 15-21 | 19 |
| HV05 | 175-191 | 222-245 | 265-76 | 116-123 | 15-22 | 23 |
| HV06 | 149-161 | 169-i183 | 225-238 | 126-130 | 14-20 | 16 |
| HV07 | 152 | 180 | 320 | 125 | 17-19 | 2 |
| HV08 | i82-110 | 110-136 | i251 | 115-118 | 16-24 | 55 |
| HV09 | 208-211 | 227-231 | 315 | 125-128 | 19-20 | 5 |
| HV10 | i222 | 249 | i280 | 140 | 20-21 | 3 |
| HV11 | i122 | i161 | U | U | 27 | 1 |
| HVU | - | - | - | - | 14-26 | 59 |

**Table I.2: Table listing the range of dimensions and number of examples found for each Westhampnett hollow voussoir type identified from the Roman Baths assemblages.**

| Type | Min. width (mm) | Max. width (mm) | Height (mm) | Depth (mm) | Thickness (mm) | No. of Examples |
|---|---|---|---|---|---|---|
| WH1 | 209-210 | 251-257 | 340 | 145 | 34-37 | 4 |
| WH2 | 222 | 275-288 | 362 | 137 | 36-40 | 5 |
| WH3 | 198 | 207-211 | i162 | 126-133 | 27-35 | 5 |
| WHU | - | - | - | - | 30-47 | 13 |

**Table I.3: Table listing the number of different tegula sherds found with each flange profile identified.**

| Tegula Flange Type | No. of Sherds | Thickness (mm) |
|---|---|---|
| A | 5 | 15-23 |
| B | 2 | 16-20 |
| D | 4 | 15-26 |
| F | 3 | 21-27 |
| F + V | 1 | U |
| L | 10 | 20-30 |
| P | 2 | 19 |
| Q | 5 | 17-26 |
| R | 5 | 16-25 |
| S | 11 | 21-34 |
| T | 5 | 19-24 |
| V | 8 | 20-29 |
| W | 2 | 20-24 |
| Unidentified | 13 | 20-28 |
| Total | 76 | - |

**Table I.4: Table listing the number of sherds and proportion of the total assemblage per fabric group, treating massive equivalents (M) separately.**

| Fabric | Number of sherds | Proportion of assemblages |
|---|---|---|
| 1 | 66 | 6.0 |
| 3 | 75 | 6.8 |
| 4 | 107 | 9.7 |
| 04M | 20 | 1.8 |
| 5 | 99 | 9.0 |
| 05M | 41 | 3.7 |
| 6 | 107 | 9.7 |
| 06M | 14 | 1.3 |
| 7 | 142 | 12.9 |
| 8 | 63 | 5.7 |
| 11 | 50 | 4.5 |
| 12 | 64 | 5.8 |
| 12M | 15 | 1.4 |
| 14 | 35 | 3.2 |
| 15 | 36 | 3.3 |
| 15M | 7 | 0.6 |
| 16 | 11 | 1.0 |
| 16M | 4 | 0.4 |
| 17 | 80 | 7.3 |
| 18 | 51 | 4.6 |
| U | 13 | 1.2 |
| Total | 1100 | 100.0 |